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Shot-Peening Sensitivity of Aerospace Materials

by Scott Grendahl, Daniel Snoha, and Benjamin Hardisky

ARL-TR-4095 May 2007

Army Research Laboratory
Aberdeen Proving Ground, MD 21005-5069

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REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. REPORT DATE (*DD-MM-YYYY*)	2. REPORT TYPE	3. DATES COVERED (From - To)
May 2007	Final	1 September 2005–1 April 2006

4. TITLE AND SUBTITLE	
Shot-Peening Sensitivity of Aerospace Materials	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Scott Grendahl, Daniel Snoha, and Benjamin Hardisky	589D31589U3
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
U.S. Army Research Laboratory ATTN: AMSRD-ARL-WM-MC Aberdeen Proving Ground, MD 21005-5069	ARL-TR-4095
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
U.S. Army Aviation and Missile Command Redstone Arsenal, Huntsville, AL 35898	AMCOM
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The U.S. Army Aviation and Missile Research Development and Engineering Command (AMRDEC), Aviation Engineering Division in Huntsville, AL requested that the U.S. Army Research Laboratory, Weapons and Materials Research Directorate at Aberdeen Proving Ground, MD develop and execute a program aimed at evaluating the shot-peening sensitivity of several aerospace materials. The materials represent the four most common metals utilized on U.S. Army aviation shot-peened components. The study had three main thrusts: to assess the variation in shot-peening intensity expected from various shot-peening parameters, to assess the fatigue strength yielded at prescribed shot-peening intensities, and to correlate surface roughness and x-ray diffraction residual stress analysis data to those prescribed stress intensities. Once the shot-peening parameters' effect on shot-peening intensity was characterized, specific intensities and parameters were selected over an intensity range (dictated by AMRDEC) for each material to assess the sensitivity on fatigue strength.

15. SUBJECT TERMS

aviation materials, fatigue, mechanical properties, residual stress, rotorcraft, FlashJet, rotor blade composite

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Scott Grendahl
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL	154	19b. TELEPHONE NUMBER (*Include area code*) 410-306-0819

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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1. Introduction

The U.S. Army Aviation and Missile Research Development and Engineering Command (AMRDEC), Aviation Engineering Division (AED) in Huntsville, AL requested that the U.S. Army Research Laboratory (ARL), Weapons and Materials Research Directorate at Aberdeen Proving Ground, MD develop and execute a program aimed at evaluating the shot-peening sensitivity of several aerospace materials. The materials represent the four most common metals utilized on U.S. Army aviation shot-peened components. The study had three main thrusts: to assess the variation in shot-peening intensity expected from various shot-peening parameters, to assess the fatigue strength yielded at prescribed shot-peening intensities, and to correlate surface roughness and x-ray diffraction residual stress analysis (XRD-RSA) data to those prescribed stress intensities. Once the shot-peening parameters' effect on shot-peening intensity was characterized, specific intensities and parameters were selected over an intensity range (dictated by AMRDEC) for each material to assess the sensitivity on fatigue strength.

2. Objective

Our objective is to assess the sensitivity of fatigue strength to shot-peening process parameter variation.

3. Materials

AMRDEC and ARL selected the materials utilized in this test program based upon the commonly shot-peened aviation materials and components. The materials and their characteristics are presented in table 1.

4. Experimental Procedure

4.1 Phase 1. Almen Strip Intensity Study

ARL worked jointly with AMRDEC and Metal Improvement Company (MIC) in developing a statement of work (SOW) for assessing how the fundamental shot-peening parameters affect the resultant shot-peening intensity. The SOW provided specific instruction regarding the work MIC performed, pertaining to the investigation of shot-peening parameters, and resulting

Table 1. Materials.

Material	Specification	Material Strength Supplier (ksi)	Material Strength ARL Tested (ksi)	Material Hardness
Aluminum 7075-T73	AMS-QQ-A 225/9 (*1*)	77.6 UTS 67 YS	80 UTS 71 YS	80–81 HRB
Titanium 6 Al-4V beta-STOA condition	AMS-4928Q (*2*)	153 UTS 145 YS	149 UTS 144 YS	34 HRC
4340 steel 150–170 ksi	AISI/SAE E4340 (*3*)	162 UTS 149 YS	167 KSI 154 YS	335/341 BHN
9310 steel 150–190 ksi	AMS 2759/1C (*4*)	189 UTS 155 YS	190 UTS 156 YS	38–39 surface /39 core HRC

Notes: UTS = ultimate tensile strength.
YS = yield strength.
HRB = Rockwell hardness B.
HRC = Rockwell hardness C.
BHN = Brinell hardness number.

peening intensities that were utilized on the fatigue test specimens and disks in appendices C and E. The initial phase consisted of assessing the effects of varying specific shot-peening parameters on common Almen strips. The final conditions of the SOW were agreed upon by all parties.

MIC established the peening processes that they intended to use on the fatigue and disk test specimens. For the titanium, appendices C and E required shot-peening at two different intensities. In accordance with AMS-S-13165 (*5*), the peening intensity range of 8–12A required S170 cast steel shot and 200% coverage. The second peening intensity range, 54–11N, required S70 cast steel shot and 200% coverage. AMRDEC required peening procedures that achieved nominal intensities of 10A ± 0.5A and 8N ± 0.5N for the applicable saturation curves. Upon successfully completing this requirement, MIC provided the process sheets used to achieve the nominal intensities to ARL and Research Development and Engineering Command AED for review. The peening parameters used to achieve the nominal peening intensities were varied as specified in the next paragraphs. Each parameter was changed independently, was not in combination with any other listed or unspecified peening parameter, and was performed on three Almen strips. The intent was to approximately double the standard production tolerance(s) for a given peening parameter for each of the specified incremental variations. All three Almen strips for each of the four listed parameters were peened consecutively without further modifications to the machine, including the nozzle. The peening time was held constant at the 2T time as determined by the applicable saturation curve. The intensity verification strips (AMS-S-13165, paragraph 4.2 [5]) were also peened at the 2T value prior to and after making the changes detailed next for each of the four parameters. Coverage on all Almen strips was verified via visual inspection as minimum of 100%. Slight modifications to the plan were made when a prescribed parameter level was beyond that which could be achieved or reliably controlled by MIC. Photographic representations of the experimental equipment and setup can be observed in figures 1 and 2.

Figure 1. MIC shot-peening equipment.

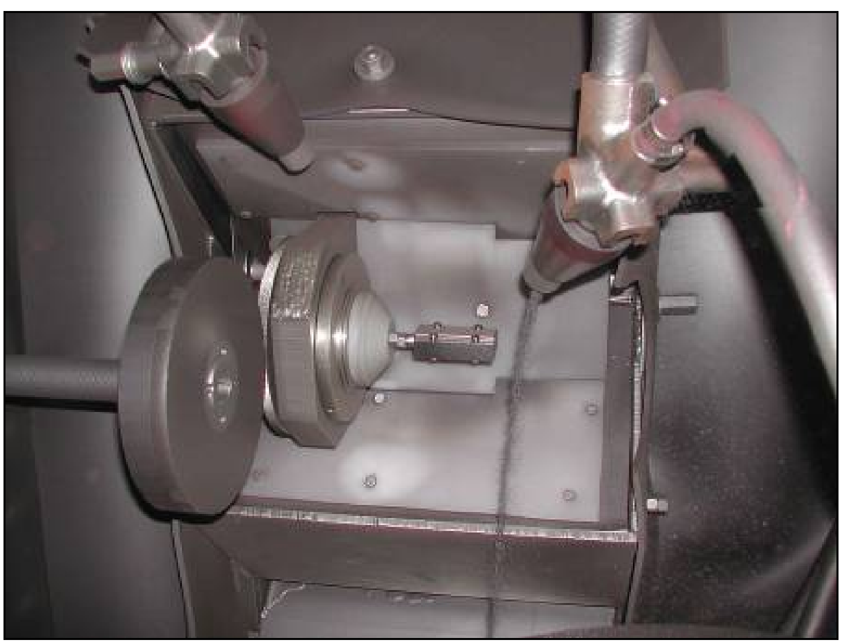


Figure 2. MIC shot-peening setup for almen strips.

4.1.1 Impingement Angle

Increase or decrease the peening angle from the nominal angle in 10º increments (2× production tolerance) to encompass a range of impingement angles from 20° to 90º. For example, for a given impingement angle of 70º (with a production tolerance of ±5º), three Almen strips would be peened at impingement angles of 80° and 90º, as well as impingement angles from 60° to 20º. If the nominal impingement angle used is 85° to 90º, the impingement angle will only be decreased (in 10º increments to ~20º).

4.1.2 Air Pressure

Increase and decrease the nominal air pressure in two 20% increments. For example, 60-psi nominal pressure would be varied to pressures of 72 and 84 psi as well as 48 and 36 psi.

4.1.3 Media Flow Rate

Increase the media flow rate to 120% and 140% of the nominal value. Then decrease the media flow rate to 80% and 60% of the nominal value.

4.1.4 Stand Off/Nozzle Distance

Increase and decrease the nominal nozzle distances to 110% and 120% and 90% and 80%, respectively, of the baseline value. Given the extremely precise requirements for nozzle positioning in the AMS shot-peening specification (*6*) of ±0.062 in, distance percentages were used rather than 0.125-in increments since such small changes in nozzle distance would have a minimal effect on peening intensity.

Table 2 presents the media shot sizes, materials, and nominal intensity requirements for the Almen strip study. Tables 3–6 reflect the plan just described. Each of the listed parameter values are for illustrative purposes only, and the tolerances shown are assumed to be representative of the production tolerances used by MIC in the peening of the test specimens/coupons in appendices C and E. The parameters in each column were varied independently, not in combination with values in adjacent columns. When a parameter was set at a level other than its nominal value, the other three parameters were held at their respective nominal value.

Table 2. Media shot sizes and intensities.

Media Shot Size	Material	Associated Intensity	Nominal Intensity Requirement
S70	Ti-6-4	5–11N	8N ± 0.5N
S110	4340 and 9310	8–12A	10A ± 0.5A
S170	Ti-6-4	8–12A	10A ± 0.5A
S230	7075-T73 Al	10–12A	11A ± 0.5A

Table 3. The S70 media at 8N nominal intensity.

Impingement Angle (°)	**Air Pressure (psi)**	**Media Flow Rate (lb/min)**	**Nozzle Distance (in)**
65 ± 5 (nominal + tolerance)	45 ± 5 (nominal + tolerance)	MIC TBD1$_{70}$	7 (nominal + tolerance)
75 ± 2	36 ± 2	MIC TBD2$_{70}$	9 ± 0.25
85 ± 2	30 ± 1.5	MIC TBD3$_{70}$	11 ± 0.25
90 ± 0.5	54 ± 2.5	—	5 ± 0.25
55 ± 2	63 ± 3	—	3 ± 0.25
45 ± 2	—	—	—
35 ± 2	—	—	—
25 ± 2	—	—	—

Table 4. The S110 media at 10A nominal intensity.

Impingement Angle (°)	**Air Pressure (psi)**	**Media Flow Rate (lb/min)**	**Nozzle Distance (in)**
65 ± 5 (nominal + tolerance)	80 – 5 (nominal + tolerance)	MIC TBD1$_{110}$	7 (nominal + tolerance)
75 ± 2	64 ± 3	MIC TBD2$_{110}$	9 ± 0.25
85 ± 2	48 ± 2.5	MIC TBD3$_{110}$	11 ± 0.25
90 ± 0.5	—	—	5 ± 0.25
55 ± 2	—	—	3 ± 0.25
45 ± 2	—	—	—
35 ± 2	—	—	—
25 ± 2	—	—	—

Table 5. The S170 media at 10A nominal intensity.

Impingement Angle (°)	**Air Pressure (psi)**	**Media Flow Rate (lb/min)**	**Nozzle Distance (in)**
65 ± 5 (nominal + tolerance)	75 ± 5 (nominal + tolerance)	MIC TBD1$_{170}$	7 (nominal + tolerance)
75 ± 2	80 ± 4	MIC TBD2$_{170}$	9 ± 0.25
85 ± 2	60 ± 3	MIC TBD3$_{170}$	11 ± 0.25
90 ± 0.5	45 ± 2.5	—	5 ± 0.25
55 ± 2	—	—	3 ± 0.25
45 ± 2	—	—	—
35 ± 2	—	—	—
25 ± 2	—	—	—

Finally, four sets of Almen strips (three strips per set) were peened to determine the combined effect of varying the four peening parameters. The goal was to achieve the highest and lowest possible production Almen intensities for both the A and N intensity levels. These Almen strips were peened using parameter settings based on the possible variations in the actual (not multiplied) production tolerances for each specific parameter. This resulted in two Almen strip sets (one high and the other low), associated with each of the two peening intensities. All parameter settings were changed simultaneously to the maximum specified or the allowable

Table 6. The S230 media at 11A nominal intensity.

Impingement Angle (°)	Air Pressure (psi)	Media Flow Rate (lb/min)	Nozzle Distance (in)
65 ± 5 (nominal + tolerance)	55 ± 5 (nominal + tolerance)	MIC $TBD1_{230}$	7 (nominal + tolerance)
75 ± 2	66 ± 3.5	MIC $TBD2_{230}$	9 ± 0.25
85 ± 2	77 ± 4	MIC $TBD3_{230}$	11 ± 0.25
90 ± 0.5	44 ± 2.5	—	5 ± 0.25
55 ± 2	33 ± 2	—	3 ± 0.25
45 ± 2	—	—	—
35 ± 2	—	—	—
25 ± 2	—	—	—

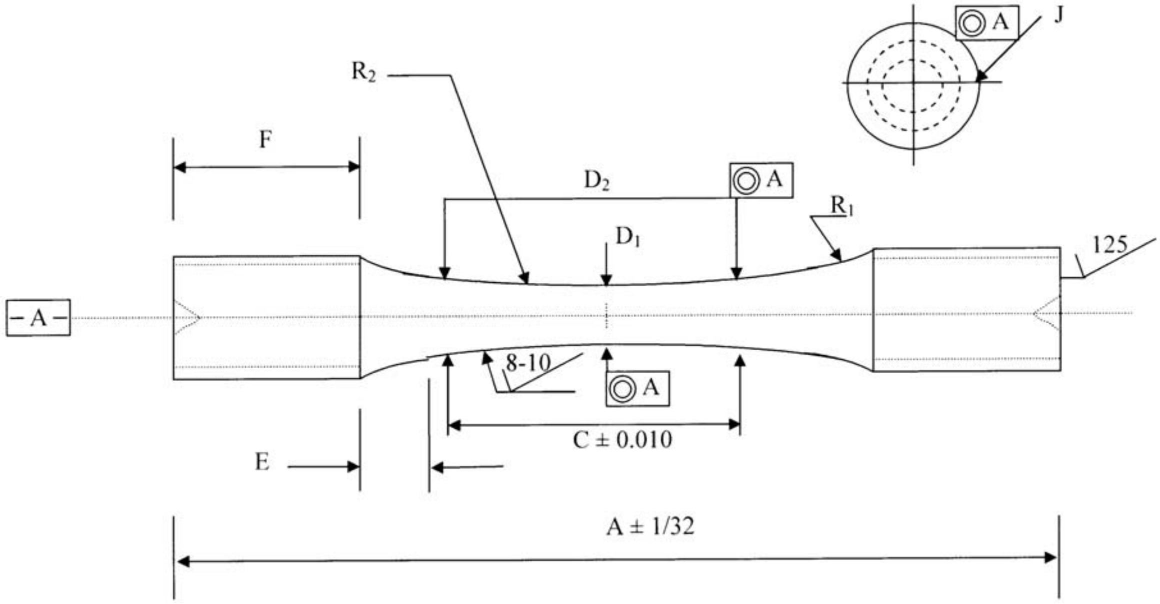
production tolerance in an attempt to determine the highest and the lowest peening intensity for the Almen strips from the combined changes. For example, increasing the impingement angle, air pressure, and media flow rate and decreasing the nozzle distance resulted in higher Almen intensities, so those parameters were changed simultaneously to determine the resultant combined effect on peening intensity. The parameters were then similarly reversed to determine the lowest peening intensity.

4.2 Phase 2. Fatigue/XRD-RSA/Surface Roughness Assessment

Based on the results of the Almen strip study and the component drawing requirements for the individual materials utilized in this study, AMRDEC defined specific peening intensities to investigate the resulting fatigue strengths and relate them to data generated for XRD-RSA and surface roughness under identical conditions.

4.2.1 Fatigue

Three stress intensities ($K_t = 1$, $K_t = 1.75$, and $K_t = 2.5$) and, thus, various geometric configurations were utilized for the fatigue strength assessment. These geometries were based not only on the stress intensity requirements but also on the fatigue test frame capabilities at ARL. Figures 3–7 present the schematics for the utilized specimens. These specimen geometries were approved through AMRDEC. Appendix E fully outlines the fatigue test plan as defined by AMRDEC. Tables 7–10 present the test matrix for each test material. Specimens were shot-peened by MIC and Corpus Christi Army Depot (CCAD) based upon the capabilities of the vendor and the test requirements at AMRDEC discretion. To meet the tight time constraints of this project, fatigue testing was carried out on five individual machines. Fifty- and 100-kip test frames were used, including Instron and MTS systems. All test frames were calibrated by the vendor in April 2005. Tests were performed with sinusoidal oscillation at a frequency of 20 Hz and at an R-ratio (minimum to maximum stress) of 0.1. A Nicolet model 4094 °C oscilloscope was utilized to optimize the conditions of the sinusoidal wave and loop shaping parameters of the closed loop feedback systems on the test frame hardware. All tests were conducted in air at room temperature. The run-out stop point was 2-million cycles. All



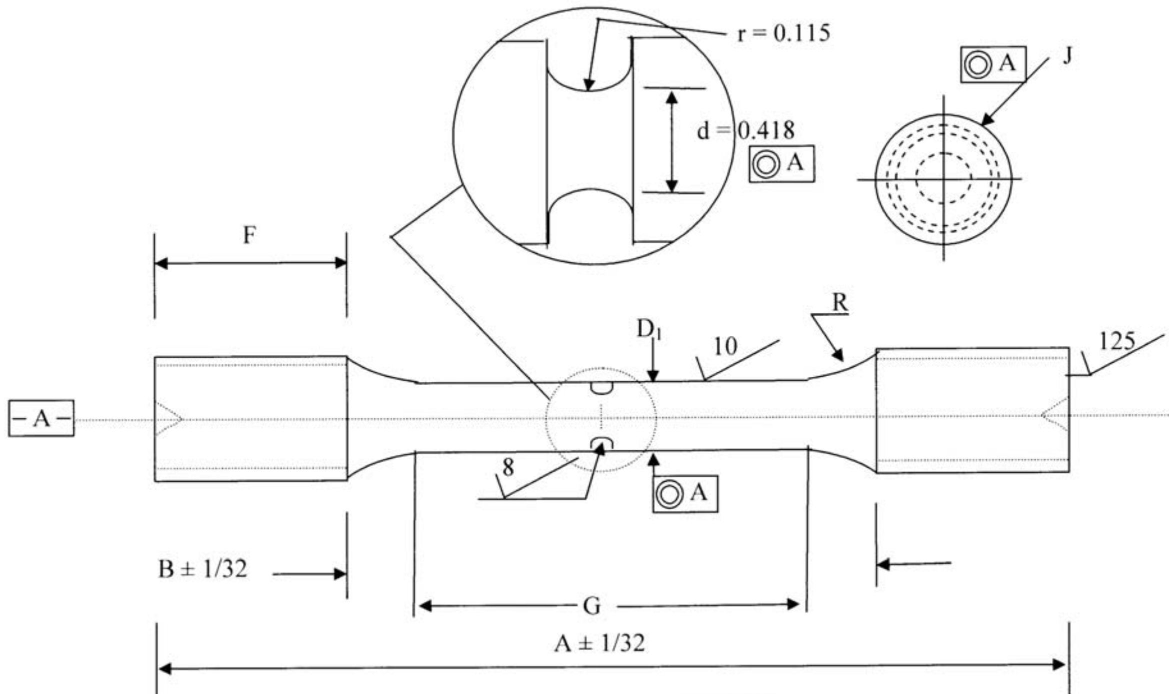
Loc	A	C	D_1	D_2	E	F	J	R_1	R_2
	5-1/2	1.500	0.300	0.375	9/32	1.5	0.75-16-2A	0.375	7.500

Notes:

1. Dimensions in Inches
2. Tolerances
   a. Squareness ⊥ Perpendicular ± 0.001 TIR
   ∥ Parallel ± 0.001 TIR
   b. Diameters ◎ Concentric to – A – ± 0.001 TIR
   c. Fractional ± 1/64
   d. Decimal X.XX ± 0.005
   X.XXX ± 0.001
   X.XXXX ± 0.0005

Figure 3. Schematic of the Kt = 1 specimens.

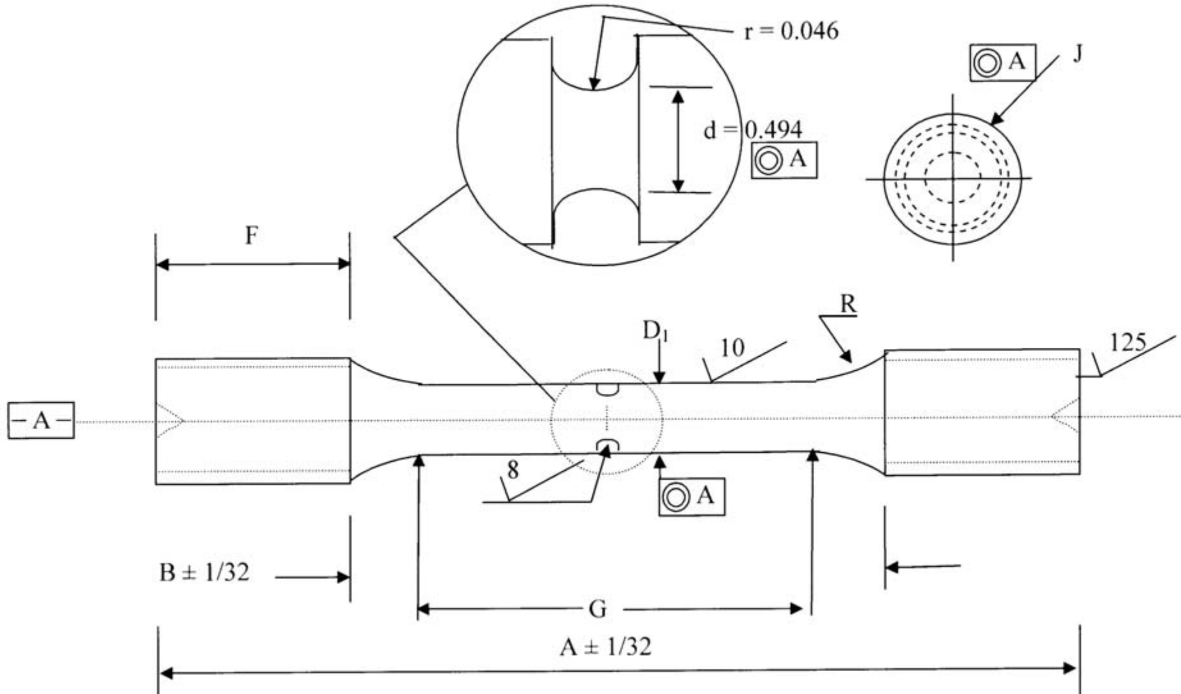
run-outs lasted at least this long; however, weekends and holidays were utilized to their fullest extent, and some run-outs were longer. Figures 8 and 9 depict the typical experimental setup for this work.



Loc	A	B	D1	G	F	J	R
	4-1/4	2.5	0.670	2.00	7/8	1.0-16-2A	0.275

Notes:
1. Dimensions in Inches
2. Tolerances
   a. Squareness ⊥ perpendicular ± 0.001 TIR
      ‖ Parallel ± 0.001 TIR
   b. Diameters ◎ Concentric to – A – ± 0.001 TIR
   c. Fractional ± 1/64
   d. Decimal X.XX ± 0.005
      X.XXX ± 0.001
      X.XXXX ± 0.0005

Figure 4. Schematic of the aluminum Kt = 1.75 specimens.

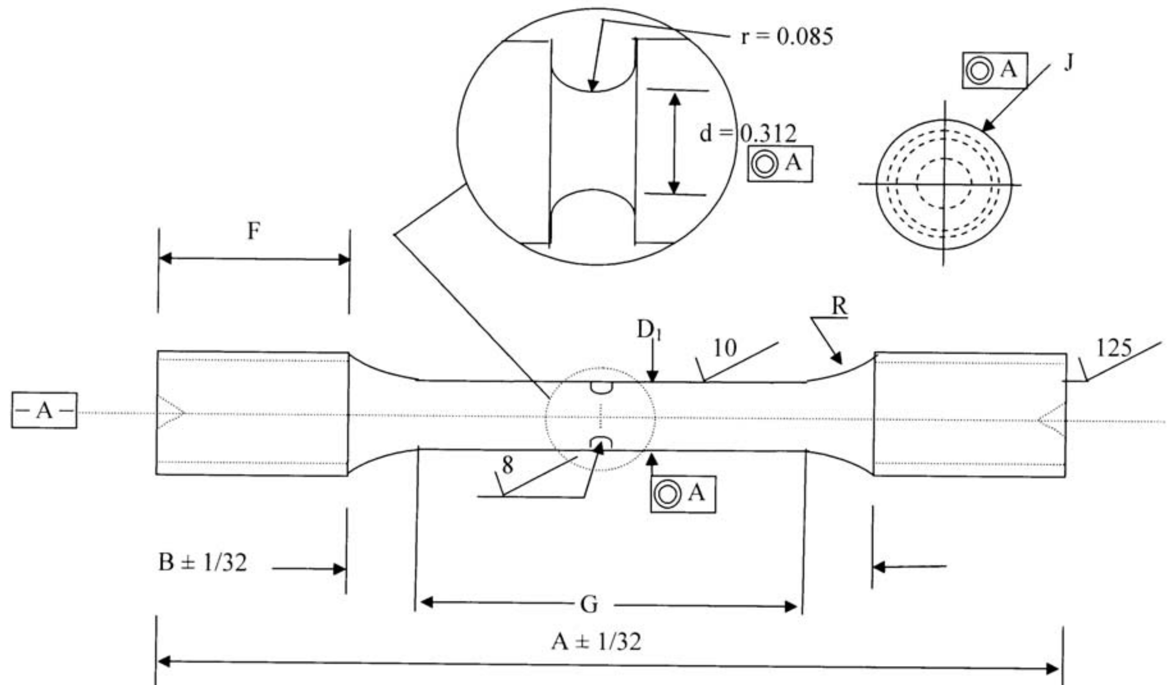


Loc	A	B	D_1	G	F	J	R
	4-1/4	2.5	0.67	2.00	7/8	1.0-16-2A	0.275

Notes:

1. Dimensions in Inches
2. Tolerances
   - a. Squareness — ⊥ Perpendicular ± 0.001 TIR; ∥ Parallel ± 0.001 TIR
   - b. Diameters — ◎ Concentric to –A– ± 0.001 TIR
   - c. Fractional — ± 1/64
   - d. Decimal — X.XX ± 0.005; X.XXX ± 0.001; X.XXXX ± 0.0005

Figure 5. Schematic of the aluminum Kt = 2.5 specimens.

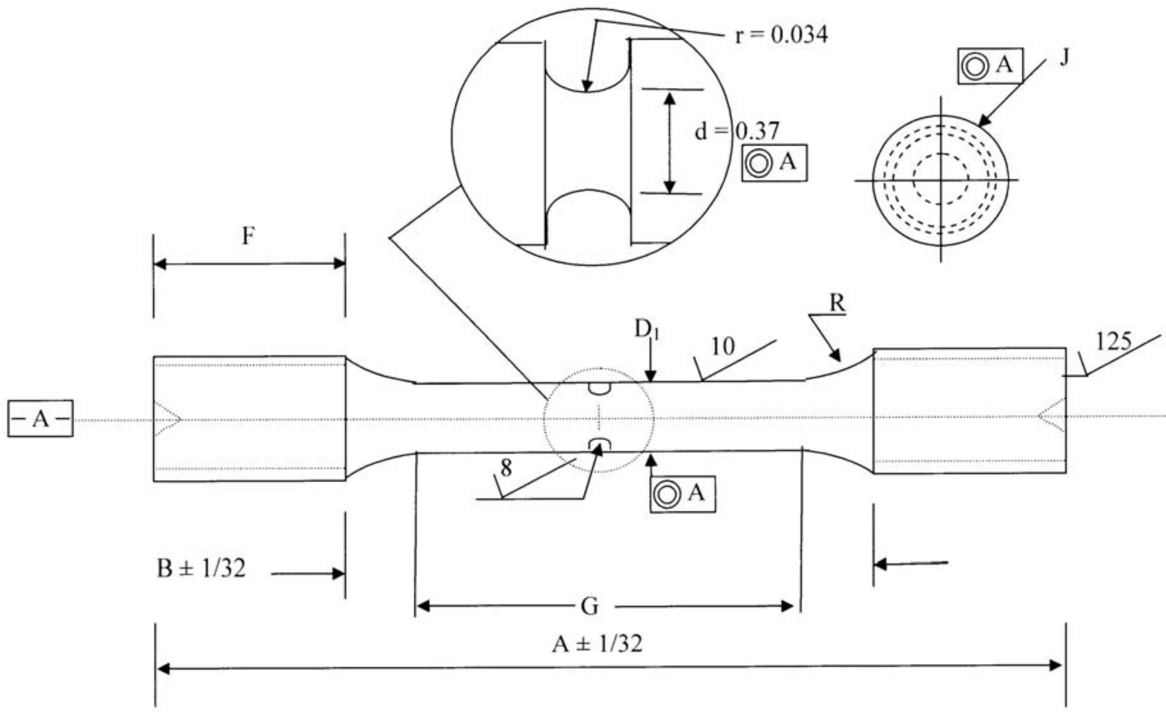


Loc	A	B	D_1	G	F	J	R
	4-1/4	2.5	0.482	2.00	7/8	0.75-16-2A	0.350

Notes:

1. Dimensions in Inches
2. Tolerances
   a. Squareness ⊥ perpendicular ± 0.001 TIR
   ∥ Parallel ± 0.001 TIR
   b. Diameters ◎ Concentric to – A – ± 0.001 TIR
   c. Fractional ± 1/64
   d. Decimal X.XX ± 0.005
   X.XXX ± 0.001
   X.XXXX ± 0.0005

Figure 6. Schematic of the titanium, 4310 steel, and 9310 steel Kt = 1.75 specimens.



Loc	A	B	D_1	G	F	J	R
	4-1/4	2.5	0.500	2.00	7/8	0.75-16-2A	0.350

Notes:

1. Dimensions in Inches
2. Tolerances
   a. Squareness — ⊥ Perpendicular ± 0.001 TIR; ∥ Parallel ± 0.001 TIR
   b. Diameters — ◎ Concentric to –A– ± 0.001 TIR
   c. Fractional — ± 1/64
   d. Decimal — X.XX ± 0.005; X.XXX ± 0.001; X.XXXX ± 0.0005

Figure 7. Schematic of the titanium, 4310 steel, and 9310 steel Kt = 2.5 specimens.

Table 7. Fatigue test matrix for 7075-T73 alloy.

Peening Intensity	Shot-Peen Source(s)	$K_t = 1$	$K_t = 1.75$	$K_t = 2.5$
Unpeened	NA	10	10	10
Low 1, 4A	MIC	10	10	10
Low 2, 10A	MIC	10	10	10
Low 2, 10A	CCAD	10	10	10
High 1, 12A	MIC	10	10	10
High 1, 12A	CCAD	10	10	10
High 2, 14A (–0, +0.5A)	MIC	10	10	10

Note: NA = not applicable.

Table 8. Fatigue test matrix for Ti-6-4 beta-STOA alloy.

Peening Intensity	Shot-Peen Source(s)	$K_t = 1$	$K_t = 1.75$	$K_t = 2.5$
Unpeened	NA	8	8	8
Low 1, 3N	MIC	9	9	9
Low 2, 5N	MIC	9	9	9
High 1, 11N	MIC	9	9	9
High 2, 14N	MIC	9	9	9
Low 1, 4A	MIC	9	9	9
Low 2, 8A	MIC	9	9	9
High 1, 11.5A, (–0, +0.5A)	MIC	9	9	9
High 2, 14A (–0, +0.5A)	CCAD	9	9	9

Note: NA = not applicable.

Table 9. Fatigue test matrix for 4340 steel.

Peening Intensity	Shot-Peen Source(s)	$K_t = 1$	$K_t = 1.75$	$K_t = 2.5$
Unpeened	NA	10	10	10
Low 1, 4A	MIC	10	10	10
Low 2, 8A	MIC	10	10	10
Low 1, 4A	CCAD	10	10	10
Low 2, 8A	CCAD	10	10	10
High 1, 12A	CCAD	10	10	10

Note: NA = not applicable.

Table 10. Fatigue test matrix for 9310 steel.

Peening Intensity	Shot-Peen Source(s)	$K_t = 1$	$K_t = 1.75$	$K_t = 2.5$
Unpeened	NA	10	10	10
Low 1, 4A	MIC	10	10	10
Low 2, 8A	MIC	10	10	10
Low 1, 4A	CCAD	10	10	10
Low 2, 8A	CCAD	10	10	10
High 1, 12A	CCAD	10	10	10

Note: NA = not applicable.

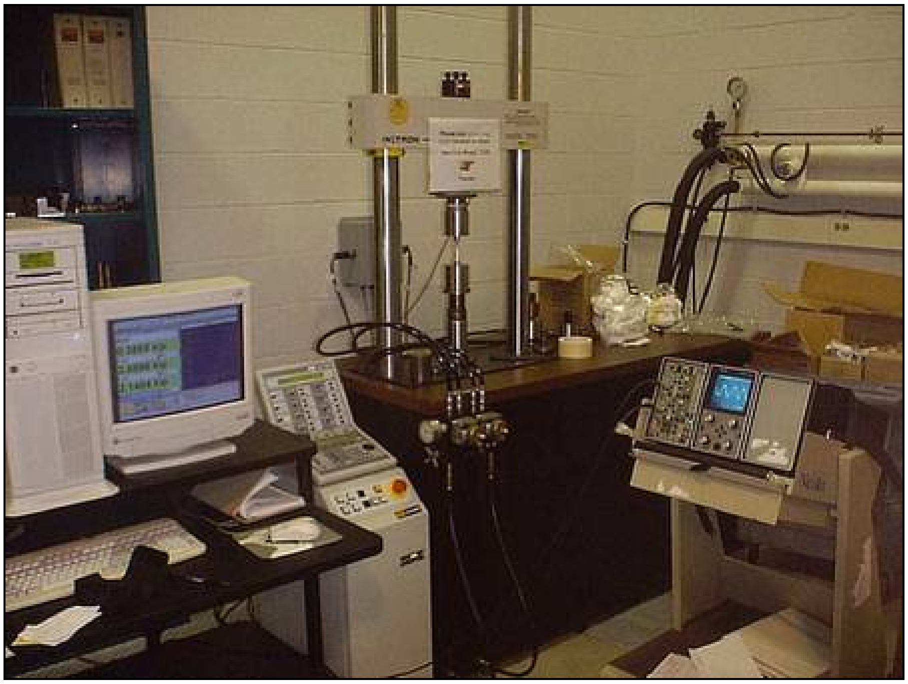


Figure 8. Experimental test setup for aluminum.

Figure 9. Typical experimental setup for fatigue testing.

4.2.2 XRD-RSA

A Technology for Energy Corporation (TEC) model 1610 x-ray stress analysis system employing the $\sin^2\psi$ technique was used for measuring residual stress (strain) on the unpeened and peened disk and fatigue specimens. Based on linear elasticity theory, the nondestructive XRD-RSA method is capable of determining the strain induced in the surface layers of a crystalline material as a consequence of mechanical deformation processes such as machining or shot-peening. All residual stress data were collected from a four- or seven-positive ψ angle arrangement, CuKα radiation diffracted from the (333,511) and (213) lattice planes of the aluminum and titanium specimens, respectively, and CrKα radiation diffracted from the (211) planes of the steel specimens. The incident x-ray beam was collimated to provide a round irradiated area on the aluminum and titanium disk (2-mm diameter) specimens, a round irradiated area on the steel disk specimens (3-mm diameter), and a rectangular irradiated area on the fatigue specimens (1.5 × 5 mm), with the longer dimension aligned axially. X-ray diffraction residual stress measurements were performed on the disk specimens at the center and at a radial outward location (henceforth referred to as the edge) that was 0.2 in from the center on the 0.75-in diameter aluminum and titanium specimens and 0.35 in from the center on the 1-in diameter steel specimens. The orientation of the edge measurement location around the disk specimens was chosen arbitrarily. Measurements were made on the fatigue specimens at 0.45 in from the notch at an arbitrarily chosen 0º orientation and at 120° and 240º from that location. Residual stresses were measured only at the surface on the fatigue specimens. Residual stresses were measured at the surface and at five depths (1, 2, 5, 7, and 10 mil) from the surface on the disk specimens. The subsurface residual stress fields were characterized on the disks by alternately performing XRD measurements then electropolishing away layers of material. The x-ray elastic constants required to calculate the macroscopic residual stress from the measured strain were in agreement with common practice. The experimental setup and the TEC equipment can be observed in figure 10.

4.2.3 Electropolishing

A Struers Lectropol-5 electropolisher was utilized to remove material from the XRD-RSA disks. A 2-cm^2 rectangular mask was used for the Aluminum minor fatigue and Titanium disks, while a larger 5-cm^2 rectangular mask was used for the 9310 and 4340 disks because of their larger diameter.

Two electrolytes were used for the polishing. Aluminum disks employed a mixture of 6.3% perchloric acid, 13.7% water, 10% butyl cellusolve, and 70% ethanol. The electrolyte for the titanium, 9310 steel, and 4340 steel contained 6% perchloric acid, 35% butyl cellusolve, and 59% methanol.

The disks required polishing to absolute depths of 1, 2, 5, 7, and 10 mil. A linear height gage with a vernier was used for measuring the depth of material removed. Attached to the height gage arm was a dial indicator gage with increments of 0.0001 in. The height gage was placed on

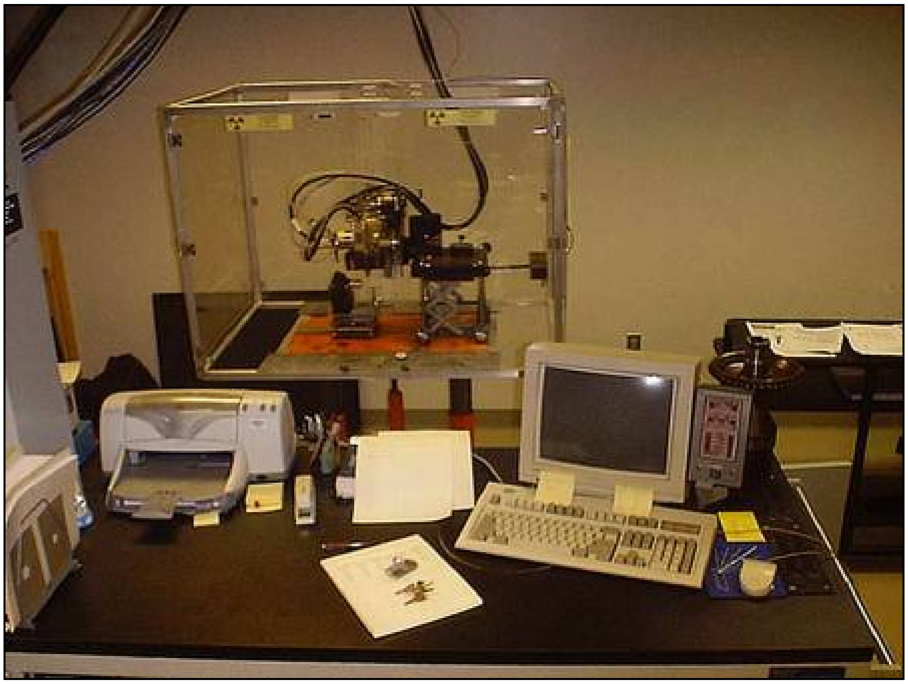


Figure 10. Experimental setup and equipment utilized for XRD-RSA.

a machinist's plate, and a fixture was constructed to ensure the gage location remained unchanged throughout the polishing. Another fixture was created on the surface plate so the depth measurements could be read in the exact same location each time a measurement was taken. The fixture allowed the disks to be measured in the center and at one edge of each disk. The edge measurement was necessary because of the tendency of the center and edge removal rates to vary.

The disk was first inspected to ensure the bottom surface was flat. If it was not, the bottom was polished with 1200-grit silicon carbide paper until flat. Then, after placing the disk on the surface block in the disk fixture, the height gage was lowered until the tip of the dial gage touched the disk. The height gage was then zeroed, and any material removed could be observed with the dial gage reading. The difference between the center point and the edge was recorded before each electropolish iteration to ensure that the removal rates of both were uniform. Once the disk was measured, it was placed on the electropolisher, and the polishing parameters were adjusted if needed. The electropolisher was activated for a preset time, after which the disk was cleaned with ethanol and allowed to dry. The disks were placed back in the fixture, and the amount of material removed could be recorded for the center and for the edge. Often, multiple cycles of polishing and measuring were employed to reach a required depth. This procedure was repeated for each disk until all disks from the group were at the same required depth level. At this point, they were taken for XRD-RSA measurement. This iterative procedure was followed at each depth until 0.01 in was removed from each disk.

4.2.4 Surface Roughness Assessment

A Taylor-Hobson Form Talysurf series 2 was utilized to perform laser surface profilometry of the fatigue specimens and XRD-RSA disks. Measurements were acquired for each peening variable as well as the unpeened condition. Three disks (~0.375 in thick and equal to the diameter of the stock used) were peened alongside the fatigue specimens for each peening condition. Three linear surface roughness measurements were taken across the diameter of each disk at 120° increments. Additionally, two $K_t = 1$ specimens from each group and two $K_t = 1.75$ or $K_t = 2.5$ specimens were selected to obtain surface roughness data. For the fatigue specimens, three linear measurements were acquired at 120° increments around the circumference of the peened area. For the $K_t = 1.75$ or $K_t = 2.5$ specimens, the data was acquired along the outside diameter, not within the notch. The notched area proved too small to allow the laser surface profilometer head the room to function properly. A total of 612 measurements were acquired. The experimental setup can be observed in figure 11.

Figure 11. Experimental setup and equipment utilized for surface roughness analysis.

5. Results

5.1 Phase 1. Almen Strip Intensity Study

MIC provided the results in the form of tabular data sets consisting of the shot-peening intensities measured from Almen strips for each individual test setup. This data is presented in tables 11–14 for S070, S110, S170, and S230 shot, respectively. The MIC shot-peening process reports, including the saturation curve development work, are included in appendix F. The flow rate calculations for each individual test setup were provided as a separate data set and are included in the tables and in appendix G.

5.2 Phase 2. Fatigue/XRD-RSA/Surface Roughness Assessment

5.2.1 Fatigue

The results of the fatigue testing portion of this study are presented in both tabular and graphic form. Tables 15–17 present the cyclic fatigue data for 7075-T73 aluminum $K_t = 1$, $K_t = 1.75$, and $K_t = 2.5$, respectively. Tables 18–20 present the cyclic fatigue data for beta-STOA Ti-6-4 $K_t = 1$, $K_t = 1.7,5$ and $K_t = 2.5$, respectively. Tables 21–23 present the cyclic fatigue data for 4340 steel $K_t = 1$, $K_t = 1.75$, and $K_t = 2.5$, respectively. Tables 24–26 present the cyclic fatigue data for 9310 steel $K_t = 1$, $K_t = 1.75$, and $K_t = 2.5$, respectively. Graphical representations of this data are depicted in figures 12-15 for each respective material. For clarity, each material's fatigue data is further broken down by stress intensity in figures 16–27.

5.2.2 XRD-RSA

The results of the XRD-RSA analysis are presented in tabular and graphic form. The average error in the observed residual stress data for the different material disk and fatigue specimens is listed in table 27. Tables 28–31 present the observed (as-collected) XRD-RSA acquired from fatigue specimens for 7075-T73 aluminum, beta-STOA Ti-6-4, 4340 steel, and 9310 steel, respectively. The disk specimen observed data were corrected for residual stress relaxation caused by electropolishing layer removal and for the x-ray beam penetration at the different ψ angles. Tabular records of the XRD-RSA disk data are located in tables 32–35 for 7075-T73 aluminum, beta-STOA Ti-6-4, 4340 steel, and 9310 steel, respectively. The corrected residual stress disk data are plotted vs. depth from the surface in figures 28–55 for each respective material and shot-peening intensity. This error is the larger value of either the counting statistics error or probable error, both of which are generated for each measurement from statistical error analysis. Counting statistics error results from the statistical nature of the x-rays counted in the detector. Probable error is due to metallurgical and stress effects and systematic error.

Table 11. Almen intensity results for S070 shot.

Group No.	Shot Size	Air Pressure	Nozzle Angle	Air Jet Size	Nozzle Distance	Intensity 1	Intensity 2	Intensity 3	Intensity Average	Flow Rate
Baseline	S070	10	65	1/4	7	0.0097	0.0094	0.0093	0.0095	9.2
2B1	S070	25	65	1/4	7	0.0142	0.0144	0.0142	0.0143	8.7
2B2	S070	20	65	1/4	7	0.0140	0.0140	0.0142	0.0141	8.8
2B3	S070	15	65	1/4	7	0.0108	0.0107	0.0106	0.0107	9.0
2C1	S070	10	65	1/8	7	0.0029	0.0025	0.0028	0.0027	10.0
2C2	S070	10	65	3/16	7	0.0064	0.0065	0.0066	0.0065	12.0
2D1	S070	10	65	1/4	3	0.0104	0.0102	0.0102	0.0103	9.2
2D2	S070	10	65	1/4	5	0.0095	0.0098	0.0098	0.0097	9.2
2D3	S070	10	65	1/4	9	0.0091	0.0089	0.0091	0.0090	9.2
2D4	S070	10	65	1/4	11	0.0090	0.0090	0.0091	0.0090	9.2
2A1	S070	10	90	1/4	7	0.0103	0.0103	0.0103	0.0103	9.2
2A2	S070	10	85	1/4	7	0.0102	0.0100	0.0101	0.0101	9.2
2A3	S070	10	75	1/4	7	0.0096	0.0095	0.0098	0.0096	9.2
2A4	S070	10	55	1/4	7	0.0092	0.0090	0.0092	0.0091	9.2
2A5	S070	10	45	1/4	7	0.0087	0.0085	0.0082	0.0085	9.2
2A6	S070	10	35	1/4	7	0.0080	0.0079	0.0079	0.0079	9.2
2A7	S070	10	25	1/4	7	0.0070	0.0066	0.0068	0.0068	9.2
Low 2A8	S070	10	25	1/4	11	0.0059	0.0053	0.0058	0.0057	9.2
High 2A9	S070	25	90	1/4	3	0.0156	0.0161	0.0160	0.0159	8.7

Table 12. Almen intensity results for S110 shot.

Group No.	Shot Size	Air Pressure	Nozzle Angle	Air Jet Size	Nozzle Distance	Intensity 1	Intensity 2	Intensity 3	Intensity Average	Flow Rate
Baseline	S110	75	65	1/4	7	0.0099	0.0096	0.0097	0.0097	7.75
3D1	S110	75	65	1/4	3	0.0103	0.0103	0.0101	0.0102	7.75
3D2	S110	75	65	1/4	5	0.0097	0.0094	0.0095	0.0095	7.75
3D3	S110	75	65	1/4	9	0.0081	0.0084	0.0084	0.0083	7.75
3D4	S110	75	65	1/4	11	0.0078	0.0077	0.0080	0.0078	7.75
3B1	S110	60	65	1/4	7	0.0078	0.0078	0.0079	0.0078	8.5
3B2	S110	45	65	1/4	7	0.0069	0.0068	0.0069	0.0069	8.75
3B3	S110	80	65	1/4	7	0.0096	0.0095	0.0096	0.0096	7.5
3C1	S110	75	65	1/8	7	0.0036	0.0036	0.0036	0.0036	17.0
3C2	S110	75	65	3/16	7	0.0069	0.0066	0.0065	0.0066	16.75
3A1	S110	75	90	1/4	7	0.0096	0.0098	0.0099	0.0098	7.75
3A2	S110	75	85	1/4	7	0.0097	0.0098	0.0096	0.0097	7.75
3A3	S110	75	75	1/4	7	0.0098	0.0099	0.0099	0.0099	7.75
3A4	S110	75	55	1/4	7	0.0086	0.0082	0.0084	0.0084	7.75
3A5	S110	75	45	1/4	7	0.0080	0.0081	0.0082	0.0081	7.75
3A6	S110	75	35	1/4	7	0.0074	0.0070	0.0072	0.0072	7.75
3A7	S110	75	25	1/4	7	0.0061	0.0062	0.0060	0.0061	7.75
Low 3A9	S110	45	25	1/4	11	0.0042	0.0042	0.0043	0.0042	8.75
High 3A8	S110	80	90	1/4	3	0.0100	0.0101	0.0101	0.0101	7.5

Table 13. Almen intensity results for S170 shot.

Group No.	Shot Size	Air Pressure	Nozzle Angle	Air Jet Size	Nozzle Distance	Intensity 1	Intensity 2	Intensity 3	Intensity Average	Flow Rate
Baseline	S170	75	65	1/4	7	0.0100	0.0101	0.0101	0.0101	9.5
4B1	S170	80	65	1/4	7	0.0109	0.0109	0.0108	0.0109	9.5
4B2	S170	60	65	1/4	7	0.0094	0.0094	0.0096	0.0095	9.33
4B3	S170	45	65	1/4	7	0.0087	0.0090	0.0087	0.0088	10.0
4C1	S170	75	65	1/8	7	0.0038	0.0040	0.0039	0.0039	18.0
4C2	S170	75	65	3/16	7	0.0083	0.0080	0.0083	0.0082	19.0
4D1	S170	75	65	1/4	3	0.0105	0.0104	0.0103	0.0104	9.5
4D2	S170	75	65	1/4	5	0.0102	0.0102	0.0100	0.0101	9.5
4D3	S170	75	65	1/4	9	0.0099	0.0102	0.0100	0.0100	9.5
4D4	S170	75	65	1/4	11	0.0096	0.0094	0.0096	0.0095	9.5
4A1	S170	75	90	1/4	7	0.0105	0.0105	0.0104	0.0105	9.5
4A2	S170	75	85	1/4	7	0.0102	0.0103	0.0104	0.0103	9.5
4A3	S170	75	75	1/4	7	0.0104	0.0102	0.0104	0.0103	9.5
4A4	S170	75	55	1/4	7	0.0098	0.0097	0.0098	0.0098	9.5
4A5	S170	75	45	1/4	7	0.0092	0.0091	0.0092	0.0092	9.5
4A6	S170	75	35	1/4	7	0.0088	0.0090	0.0090	0.0089	9.5
4A7	S170	75	25	1/4	7	0.0083	0.0083	0.0084	0.0083	9.5
Low 4A9	S170	45	25	1/4	11	0.0070	0.0074	0.0072	0.0072	9.75
High 4A8	S170	80	90	1/4	3	0.0114	0.0116	0.0114	0.0115	9.33

Table 14. Almen intensity results for S230 shot.

Group No.	Shot Size	Air Pressure	Nozzle Angle	Air Jet Size	Nozzle Distance	Intensity 1	Intensity 2	Intensity 3	Intensity Average	Flow Rate
Baseline	S230	60	65	1/4	7	0.0111	0.0111	0.0110	0.0111	10.5
5B1	S230	80	65	1/4	7	0.0132	0.0134	0.0130	0.0132	9.8
5B2	S230	72	65	1/4	7	0.0117	0.0120	0.0116	0.0118	10.1
5B3	S230	48	65	1/4	7	0.0101	0.0101	0.0099	0.0100	10.3
5B4	S230	36	65	1/4	7	0.0089	0.0085	0.0089	0.0088	10.1
5C1	S230	60	65	1/8	7	0.0044	0.0043	0.0043	0.0043	25.0
5C2	S230	60	65	3/16	7	0.0087	0.0087	0.0089	0.0088	21.0
5A1	S230	60	90	1/4	7	0.0112	0.0113	0.0113	0.0113	10.5
5A2	S230	60	85	1/4	7	0.0112	0.0111	0.0110	0.0111	10.5
5A3	S230	60	75	1/4	7	0.0110	0.0110	0.0108	0.0109	10.5
5A4	S230	60	55	1/4	7	0.0102	0.0103	0.0101	0.0102	10.5
5A5	S230	60	45	1/4	7	0.0097	0.0096	0.0094	0.0096	10.5
5A6	S230	60	35	1/4	7	0.0095	0.0096	0.0091	0.0094	10.5
5A7	S230	60	25	1/4	7	0.0078	0.0077	0.0080	0.0078	10.5
5D1	S230	60	65	1/4	3	0.0114	0.0116	0.0119	0.0116	10.5
5D2	S230	60	65	1/4	5	0.0108	0.0108	0.0112	0.0109	10.5
5D3	S230	60	65	1/4	9	0.0109	0.0107	0.0110	0.0109	10.5
5D4	S230	60	65	1/4	11	0.0100	0.0102	0.0102	0.0101	10.5
Low	S230	36	25	1/4	11	0.0063	0.0061	0.0064	0.0063	10.1
High	S230	80	90	1/4	3	0.0145	0.0141	0.0144	0.0143	9.8

Table 15. The 7075-T73 aluminum, K_t = 1 cyclic fatigue data.

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
Al-10-A	1	None	NA	41.00	22.550	4.10	18.45	0.1	—	156,621 broke in outer gage 0.325 dia.
Al-11-A	1	None	NA	51.00	28.050	5.10	22.95	0.1	—	1,623,638 broke two places in threads
Al-12-A	1	None	NA	51.00	28.050	5.10	22.95	0.1	128,098	—
Al-1-A	1	None	NA	60.00	33.000	6.00	27.00	0.1	39,005	—
Al-2-A	1	None	NA	53.60	29.480	5.36	24.12	0.1	107,796	2% bad levels on machine
Al-3-A	1	None	NA	41.00	22.550	4.10	18.45	0.1		Broke in threads
Al-4-A	1	None	NA	47.50	26.125	4.75	21.38	0.1	237,829	—
Al-5-A	1	None	NA	48.80	26.840	4.88	21.96	0.1	120,971	2% bad levels on machine
Al-6-A	1	None	NA	45.00	24.750	4.50	20.25	0.1	—	115203 bad data
Al-7-A	1	None	NA	66.00	36.300	6.60	29.70	0.1	11,298	—
Al-8-A	1	None	NA	45.00	24.750	4.50	20.25	0.1	685,925	Cycled 2M cycles at 3094/312 amp 1392
Al-13-A	1	None	NA	45.00	24.750	4.50	20.25	0.1	2,125,793	—
Al-15-A	1	None	NA	47.50	26.125	4.75	21.38	0.1	223,585	—
Al-16-A	1	None	NA	45.00	24.750	4.50	20.25	0.1	343,848	—
Al-20-A	1	None	NA	43.00	23.650	4.30	19.35	0.1	—	—
Al-21-A	1	None	NA	43.00	23.650	4.30	19.35	0.1	973,039	—
Al-18-A	1	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-19-A	1	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-33-A	1	MIC	L1, 4A	43.00	23.650	4.30	19.35	0.1	—	—
Al-38-A	1	MIC	L1, 4A	45.00	24.750	4.50	20.25	0.1	690,786	—
Al-62-A	1	MIC	L1, 4A	45.00	24.750	4.50	20.25	0.1	414,347	—
Al-63-A	1	MIC	L1, 4A	47.50	26.125	4.75	21.38	0.1	215,202	—
Al-64-A	1	MIC	L1, 4A	47.50	26.125	4.75	21.38	0.1	191,359	—
Al-65-A	1	MIC	L1, 4A	50.00	27.500	5.00	22.50	0.1	171,102	—
Al-66-A	1	MIC	L1, 4A	43.00	23.650	4.30	19.35	0.1	847,234	—
Al-67-A	1	MIC	L1, 4A	60.00	33.000	6.00	27.00	0.1	60,754	—
Al-69-A	1	MIC	L1, 4A	44.00	24.200	4.40	19.80	0.1	1,321,803	—
Al-70-A	1	MIC	L1, 4A	43.00	23.650	4.30	19.35	0.1	1,680,000	—
Al-36-A	1	MIC	L2, 10A	39.00	21.450	3.90	17.55	0.1	—	Broke in threads 1,590,109
Al-72-A	1	MIC	L2, 10A	40.00	22.000	4.00	18.00	0.1	542,961	—
Al-73-A	1	MIC	L2, 10A	41.00	22.550	4.10	18.45	0.1	392,611	—
Al-74-A	1	MIC	L2, 10A	45.00	24.750	4.50	20.25	0.1	214,910	—
Al-75-A	1	MIC	L2, 10A	45.00	24.750	4.50	20.25	0.1	193,304	—
Al-76-A	1	MIC	L2, 10A	60.00	33.000	6.00	27.00	0.1	34,451	—
Al-77-A	1	MIC	L2, 10A	39.00	21.450	3.90	17.55	0.1	3,000,000	Runout
Al-78-A	1	MIC	L2, 10A	43.00	23.650	4.30	19.35	0.1	344,274	—
Al-79-A	1	MIC	L2, 10A	41.00	22.550	4.10	18.45	0.1	339,488	—
Al-80-A	1	MIC	L2, 10A	50.00	27.500	5.00	22.50	0.1	114,334	—
Al-31-A	1	MIC	H1, 12A	50.00	27.500	5.00	22.50	0.1	107,002	—
Al-32-A	1	MIC	H1, 12A	60.00	33.000	6.00	27.00	0.1	15,138	—
Al-34-A	1	MIC	H1, 12A	43.00	23.650	4.30	19.35	0.1	176,615	—
Al-35-A	1	MIC	H1, 12A	43.00	23.650	4.30	19.35	0.1	261,208	—
Al-37-A	1	MIC	H1, 12A	41.00	22.550	4.10	18.45	0.1	551,661	—
Al-39-A	1	MIC	H1, 12A	41.00	22.550	4.10	18.45	0.1	462,858	—
Al-40-A	1	MIC	H1, 12A	39.00	21.450	3.90	17.55	0.1	620,543	—
Al-61-A	1	MIC	H1, 12A	45.00	24.750	4.50	20.25	0.1	191,545	—
Al-68-A	1	MIC	H1, 12A	39.00	21.450	3.90	17.55	0.1	3,000,000	Runout
Al-71-A	1	MIC	H1, 12A	39.00	21.450	3.90	17.55	0.1	—	—
Al-51-A	1	MIC	H2, 14A	45.00	24.750	4.50	20.25	0.1	169,194	—
Al-52-A	1	MIC	H2, 14A	50.00	27.500	5.00	22.50	0.1	88,058	—
Al-53-A	1	MIC	H2, 14A	60.00	33.000	6.00	27.00	0.1	24,353	—
Al-54-A	1	MIC	H2, 14A	41.00	22.550	4.10	18.45	0.1	362,596	—
Al-55-A	1	MIC	H2, 14A	38.00	20.900	3.80	17.10	0.1	2,602,898	Internal failure
Al-56-A	1	MIC	H2, 14A	38.00	20.900	3.80	17.10	0.1	666,561	—
Al-57-A	1	MIC	H2, 14A	39.00	21.450	3.90	17.55	0.1	420,863	—
Al-58-A	1	MIC	H2, 14A	43.00	23.650	4.30	19.35	0.1	282,337	—
Al-59-A	1	MIC	H2, 14A	43.00	23.650	4.30	19.35	0.1	318,871	—
Al-60-A	1	MIC	H2, 14A	37.00	20.350	3.70	16.65	0.1	—	—

Table 15. The 7075-T73 aluminum, Kt = 1 cyclic fatigue data (continued).

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
Al-22-A	1	CCAD	L2, 10A	50.00	27.500	5.00	22.50	0.1	149,461	—
Al-23-A	1	CCAD	L2, 10A	39.00	21.450	3.90	17.55	0.1	4,871,005	Runout
Al-24-A	1	CCAD	L2, 10A	45.00	24.750	4.50	20.25	0.1	181,162	—
Al-25-A	1	CCAD	L2, 10A	40.00	22.000	4.00	18.00	0.1	1,563,939	—
Al-26-A	1	CCAD	L2, 10A	45.00	24.750	4.50	20.25	0.1	228,151	—
Al-27-A	1	CCAD	L2, 10A	60.00	33.000	6.00	27.00	0.1	28,253	—
Al-28-A	1	CCAD	L2, 10A	43.00	23.650	4.30	19.35	0.1	348,719	—
Al-29-A	1	CCAD	L2, 10A	43.00	23.650	4.30	19.35	0.1	410,442	—
Al-30-A	1	CCAD	L2, 10A	41.00	22.550	4.10	18.45	0.1	467,330	—
Al-41-A	1	CCAD	L2, 10A	41.00	22.550	4.10	18.45	0.1	496,822	—
Al-42-A	1	CCAD	H1, 12A	43.00	23.650	4.30	19.35	0.1	1,011,776	—
Al-43-A	1	CCAD	H1, 12A	41.00	22.550	4.10	18.45	0.1	2,096,193	—
Al-44-A	1	CCAD	H1, 12A	47.50	26.125	4.75	21.38	0.1	239,091	—
Al-45-A	1	CCAD	H1, 12A	45.00	24.750	4.50	20.25	0.1	345,697	—
Al-46-A	1	CCAD	H1, 12A	50.00	27.500	5.00	22.50	0.1	161,740	—
Al-47-A	1	CCAD	H1, 12A	43.00	23.650	4.30	19.35	0.1	682,039	—
Al-48-A	1	CCAD	H1, 12A	60.00	33.000	6.00	27.00	0.1	26,208	—
Al-49-A	1	CCAD	H1, 12A	45.00	24.750	4.50	20.25	0.1	209,324	—
Al-50-A	1	CCAD	H1, 12A	41.00	22.550	4.10	18.45	0.1	2,862,516	Runout
Al-9-A	1	CCAD	H1, 12A	43.00	23.650	4.30	19.35	0.1	349,829	—

Note: NA = not applicable.

Table 16. The 7075-T73 aluminum, $K_t = 1.75$ cyclic fatigue data.

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
Al-10-C	1.75	None	NA	33.50	18.425	3.35	15.08	0.1	56,092	—
Al-1-C	1.75	None	NA	32.75	18.013	3.28	14.74	0.1	269,230	—
Al-21-C	1.75	None	NA	35.00	19.250	3.50	15.75	0.1	37,497	—
Al-22-C	1.75	None	NA	35.00	19.250	3.50	15.75	0.1	58,016	—
Al-24-C	1.75	None	NA	41.00	22.550	4.10	18.45	0.1	—	—
Al-2-C	1.75	None	NA	29.00	15.950	2.90	13.05	0.1	2,000,000	Runout
Al-32-C	1.75	None	NA	44.00	24.200	4.40	19.80	0.1	22,504	—
Al-3-C	1.75	None	NA	32.00	17.600	3.20	14.40	0.1	2,000,000	Runout
Al-4-C	1.75	None	NA	41.00	22.550	4.10	18.45	0.1	26,138	—
Al-5-C	1.75	None	NA	32.00	17.600	3.20	14.40	0.1	3,327,920	—
Al-8-C	1.75	None	NA	33.50	18.425	3.35	15.08	0.1	70,728	—
Al-9-C	1.75	None	NA	32.75	18.013	3.28	14.74	0.1	526,727	—
Al-25-C	1.75	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-30-C	1.75	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-31-C	1.75	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-33-C	1.75	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-34-C	1.75	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-41-C	1.75	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-14-C	1.75	MIC	L1, 4A	41.00	22.550	4.10	18.45	0.1	42,994	—
Al-16-C	1.75	MIC	L1, 4A	35.00	19.250	3.50	15.75	0.1	71,561	—
Al-17-C	1.75	MIC	L1, 4A	35.00	19.250	3.50	15.75	0.1	73,851	—
Al-18-C	1.75	MIC	L1, 4A	32.00	17.600	3.20	14.40	0.1	204,413	—
Al-28-C	1.75	MIC	L1, 4A	32.00	17.600	3.20	14.40	0.1	187,842	—
Al-29-C	1.75	MIC	L1, 4A	33.50	18.425	3.35	15.08	0.1	183,410	—
Al-43-C	1.75	MIC	L1, 4A	31.00	17.050	3.10	13.95	0.1	282,273	—
Al-45-C	1.75	MIC	L1, 4A	30.00	16.500	3.00	13.50	0.1	786,523	—
Al-6-C	1.75	MIC	L1, 4A	29.00	15.950	2.90	13.05	0.1	2,847,700	—
Al-7-C	1.75	MIC	L1, 4A	38.00	20.900	3.80	17.10	0.1	49,047	—
Al-11-C	1.75	MIC	L2, 10A	41.00	22.550	4.10	18.45	0.1	44,966	—
Al-12-C	1.75	MIC	L2, 10A	35.00	19.250	3.50	15.75	0.1	133,782	—
Al-13-C	1.75	MIC	L2, 10A	35.00	19.250	3.50	15.75	0.1	130,894	—
Al-15-C	1.75	MIC	L2, 10A	32.00	17.600	3.20	14.40	0.1	201,426	—
Al-19-C	1.75	MIC	L2, 10A	32.00	17.600	3.20	14.40	0.1	170,307	—
Al-20-C	1.75	MIC	L2, 10A	31.00	17.050	3.10	13.95	0.1	293,176	—
Al-27-C	1.75	MIC	L2, 10A	29.00	15.950	2.90	13.05	0.1	545,378	—
Al-42-C	1.75	MIC	L2, 10A	29.00	15.950	2.90	13.05	0.1	716,572	—
Al-49-C	1.75	MIC	L2, 10A	30.00	16.500	3.00	13.50	0.1	362,183	—
Al-53-C	1.75	MIC	L2, 10A	38.00	20.900	3.80	17.10	0.1	95,241	—
Al-36-C	1.75	MIC	H1, 12A	28.00	15.400	2.80	12.60	0.1	3,030,899	Runout
Al-37-C	1.75	MIC	H1, 12A	30.00	16.500	3.00	13.50	0.1	305,732	—
Al-44-C	1.75	MIC	H1, 12A	35.00	19.250	3.50	15.75	0.1	146,352	—
Al-48-C	1.75	MIC	H1, 12A	32.00	17.600	3.20	14.40	0.1	105,874	—
Al-52-C	1.75	MIC	H1, 12A	32.00	17.600	3.20	14.40	0.1	147,594	—
Al-54-C	1.75	MIC	H1, 12A	41.00	22.550	4.10	18.45	0.1	52,050	—
Al-56-C	1.75	MIC	H1, 12A	29.00	15.950	2.90	13.05	0.1	—	—
Al-58-C	1.75	MIC	H1, 12A	29.00	15.950	2.90	13.05	0.1	800,476	—
Al-66-C	1.75	MIC	H1, 12A	30.00	16.500	3.00	13.50	0.1	477,809	—
Al-68-C	1.75	MIC	H1, 12A	38.00	20.900	3.80	17.10	0.1	82,629	—
Al-35-C	1.75	MIC	H2, 14A	30.00	16.500	3.00	13.50	0.1	264,329	—
Al-38-C	1.75	MIC	H2, 14A	35.00	19.250	3.50	15.75	0.1	86,423	—
Al-50-C	1.75	MIC	H2, 14A	28.00	15.400	2.80	12.60	0.1	725,651	—
Al-57-C	1.75	MIC	H2, 14A	32.00	17.600	3.20	14.40	0.1	162,191	—
Al-59-C	1.75	MIC	H2, 14A	32.00	17.600	3.20	14.40	0.1	244,728	—
Al-61-C	1.75	MIC	H2, 14A	41.00	22.550	4.10	18.45	0.1	42,692	—
Al-63-C	1.75	MIC	H2, 14A	31.00	17.050	3.10	13.95	0.1	290,258	—
Al-64-C	1.75	MIC	H2, 14A	29.00	15.950	2.90	13.05	0.1	342,280	—
Al-65-C	1.75	MIC	H2, 14A	27.00	14.850	2.70	12.15	0.1	906,240	—
Al-70-C	1.75	MIC	H2, 14A	28.00	15.400	2.80	12.60	0.1	549,667	—

Table 16. The 7075-T73 aluminum, K_t = 1.75 cyclic fatigue data (continued).

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
Al-39-C	1.75	CCAD	L2, 10A	29.00	15.950	2.90	13.05	0.1	—	—
Al-40-C	1.75	CCAD	L2, 10A	35.00	19.250	3.50	15.75	0.1	118,207	—
Al-46-C	1.75	CCAD	L2, 10A	32.00	17.600	3.20	14.40	0.1	221,197	—
Al-47-C	1.75	CCAD	L2, 10A	32.00	17.600	3.20	14.40	0.1	213,536	—
Al-51-C	1.75	CCAD	L2, 10A	29.00	15.950	2.90	13.05	0.1	308,976	—
Al-55-C	1.75	CCAD	L2, 10A	30.00	16.500	3.00	13.50	0.1	331,822	—
Al-60-C	1.75	CCAD	L2, 10A	28.00	15.400	2.80	12.60	0.1	1,475,512	—
Al-62-C	1.75	CCAD	L2, 10A	41.00	22.550	4.10	18.45	0.1	55,868	—
Al-67-C	1.75	CCAD	L2, 10A	30.00	16.500	3.00	13.50	0.1	305,951	—
Al-69-C	1.75	CCAD	L2, 10A	38.00	20.900	3.80	17.10	0.1	63,881	—
Al-71-C	1.75	CCAD	H1, 12A	41.00	22.550	4.10	18.45	0.1	91,750	—
Al-72-C	1.75	CCAD	H1, 12A	32.00	17.600	3.20	14.40	0.1	173,302	—
Al-73-C	1.75	CCAD	H1, 12A	38.00	20.900	3.80	17.10	0.1	81,107	—
Al-74-C	1.75	CCAD	H1, 12A	29.00	15.950	2.90	13.05	0.1	771,681	—
Al-75-C	1.75	CCAD	H1, 12A	32.00	17.600	3.20	14.40	0.1	274,876	—
Al-76-C	1.75	CCAD	H1, 12A	30.00	16.500	3.00	13.50	0.1	290,697	—
Al-77-C	1.75	CCAD	H1, 12A	29.00	15.950	2.90	13.05	0.1	527,501	—
Al-78-C	1.75	CCAD	H1, 12A	28.00	15.400	2.80	12.60	0.1	3,423,814	—
Al-79-C	1.75	CCAD	H1, 12A	30.00	16.500	3.00	13.50	0.1	329,961	—
Al-80-C	1.75	CCAD	H1, 12A	35.00	19.250	3.50	15.75	0.1	117,730	—

Note: NA = not applicable.

Table 17. The 7075-T73 aluminum, $K_t = 2.5$ cyclic fatigue data.

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
Al-10-B	2.5	None	NA	24.00	13.200	2.40	10.80	0.1	83,762	—
Al-13-B	2.5	None	NA	21.00	11.550	2.10	9.45	0.1	4,016,022	—
Al-14-B	2.5	None	NA	24.00	13.200	2.40	10.80	0.1	90,557	—
Al-15-B	2.5	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-16-B	2.5	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-17-B	2.5	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-18-B	2.5	None	NA	30.00	16.500	3.00	13.50	0.1	28,805	—
Al-19-B	2.5	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-1-B	2.5	None	NA	33.00	18.150	3.30	14.85	0.1	20,210	—
Al-20-B	2.5	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-2-B	2.5	None	NA	33.00	18.150	3.30	14.85	0.1	19,074	—
Al-4-B	2.5	None	NA	30.00	16.500	3.00	13.50	0.1	26,084	—
Al-6-B	2.5	None	NA	23.00	12.650	2.30	10.35	0.1	678,116	—
Al-7-B	2.5	None	NA	27.00	14.850	2.70	12.15	0.1	47,552	—
Al-9-B	2.5	None	NA	27.00	14.850	2.70	12.15	0.1	43,568	—
Al-21-B	2.5	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-23-B	2.5	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-27-B	2.5	None	NA	—	0.000	0.00	0.00	NA	—	—
Al-8-B	2.5	MIC	L1, 4A	30.00	16.500	3.00	13.50	0.1	36,860	—
Al-26-B	2.5	MIC	L1, 4A	27.00	14.850	2.70	12.15	0.1	111,367	—
Al-29-B	2.5	MIC	L1, 4A	24.00	13.200	2.40	10.80	0.1	141,151	—
Al-33-B	2.5	MIC	L1, 4A	24.00	13.200	2.40	10.80	0.1	188,946	—
Al-41-B	2.5	MIC	L1, 4A	21.00	11.550	2.10	9.45	0.1	2,015,876	—
Al-42-B	2.5	MIC	L1, 4A	33.00	18.150	3.30	14.85	0.1	34,058	—
Al-43-B	2.5	MIC	L1, 4A	22.00	12.100	2.20	9.90	0.1	350,647	—
Al-47-B	2.5	MIC	L1, 4A	21.00	11.550	2.10	9.45	0.1	7,371,295	—
Al-54-B	2.5	MIC	L1, 4A	27.00	14.850	2.70	12.15	0.1	102,865	—
Al-59-B	2.5	MIC	L1, 4A	23.00	12.650	2.30	10.35	0.1	226,519	—
Al-30-B	2.5	MIC	L2, 10A	24.00	13.200	2.40	10.80	0.1	283,135	—
Al-31-B	2.5	MIC	L2, 10A	33.00	18.150	3.30	14.85	0.1	51,435	—
Al-34-B	2.5	MIC	L2, 10A	24.00	13.200	2.40	10.80	0.1	241,342	—
Al-35-B	2.5	MIC	L2, 10A	27.00	14.850	2.70	12.15	0.1	136,371	—
Al-38-B	2.5	MIC	L2, 10A	23.00	12.650	2.30	10.35	0.1	488,561	—
Al-39-B	2.5	MIC	L2, 10A	22.00	12.100	2.20	9.90	0.1	1,936,732	—
Al-44-B	2.5	MIC	L2, 10A	30.00	16.500	3.00	13.50	0.1	85,021	—
Al-50-B	2.5	MIC	L2, 10A	23.00	12.650	2.30	10.35	0.1	565,477	—
Al-5-B	2.5	MIC	L2, 10A	26.00	14.300	2.60	11.70	0.1	166,302	—
Al-68-B	2.5	MIC	L2, 10A	25.00	13.750	2.50	11.25	0.1	236,266	—
Al-11-B	2.5	MIC	H1, 12A	26.00	14.300	2.60	11.70	0.1	191,054	—
Al-12-B	2.5	MIC	H1, 12A	33.00	18.150	3.30	14.85	0.1	45,488	—
Al-25-B	2.5	MIC	H1, 12A	26.00	14.300	2.60	11.70	0.1	300,532	—
Al-32-B	2.5	MIC	H1, 12A	25.00	13.750	2.50	11.25	0.1	615,293	—
Al-36-B	2.5	MIC	H1, 12A	24.00	13.200	2.40	10.80	0.1	1,204,215	—
Al-37-B	2.5	MIC	H1, 12A	25.00	13.750	2.50	11.25	0.1	541,114	—
Al-3-B	2.5	MIC	H1, 12A	24.00	13.200	2.40	10.80	0.1	1,423,653	—
Al-45-B	2.5	MIC	H1, 12A	23.00	12.650	2.30	10.35	0.1	—	—
Al-64-B	2.5	MIC	H1, 12A	30.00	16.500	3.00	13.50	0.1	73,460	—
Al-70-B	2.5	MIC	H1, 12A	27.00	14.850	2.70	12.15	0.1	133,347	—
Al-24-B	2.5	MIC	H2, 14A	26.00	14.300	2.60	11.70	0.1	305,566	—
Al-28-B	2.5	MIC	H2, 14A	27.00	14.850	2.70	12.15	0.1	190,423	—
Al-40-B	2.5	MIC	H2, 14A	23.00	12.650	2.30	10.35	0.1	6,981,225	Runout
Al-46-B	2.5	MIC	H2, 14A	30.00	16.500	3.00	13.50	0.1	96,030	—
Al-48-B	2.5	MIC	H2, 14A	33.00	18.150	3.30	14.85	0.1	31,875	—
Al-53-B	2.5	MIC	H2, 14A	26.00	14.300	2.60	11.70	0.1	273,140	—
Al-58-B	2.5	MIC	H2, 14A	25.00	13.750	2.50	11.25	0.1	1,260,989	—
Al-62-B	2.5	MIC	H2, 14A	24.00	13.200	2.40	10.80	0.1	2,206,765	Runout
Al-69-B	2.5	MIC	H2, 14A	24.00	13.200	2.40	10.80	0.1	—	—
Al-71-B	2.5	MIC	H2, 14A	25.00	13.750	2.50	11.25	0.1	1,364,116	—

Table 17. The 7075-T73 aluminum, K_t = 2.5 cyclic fatigue data (continued).

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
Al-51-B	2.5	CCAD	L2, 10A	30.00	16.500	3.00	13.50	0.1	94,188	—
Al-52-B	2.5	CCAD	L2, 10A	21.00	11.550	2.10	9.45	0.1	1,485,259	—
Al-55-B	2.5	CCAD	L2, 10A	24.00	13.200	2.40	10.80	0.1	255,499	—
Al-56-B	2.5	CCAD	L2, 10A	22.00	12.100	2.20	9.90	0.1	441,494	—
Al-57-B	2.5	CCAD	L2, 10A	23.00	12.650	2.30	10.35	0.1	503,307	—
Al-60-B	2.5	CCAD	L2, 10A	21.00	11.550	2.10	9.45	0.1	8,147,043	Runout
Al-61-B	2.5	CCAD	L2, 10A	33.00	18.150	3.30	14.85	0.1	62,345	—
Al-63-B	2.5	CCAD	L2, 10A	24.00	13.200	2.40	10.80	0.1	337,845	—
Al-65-B	2.5	CCAD	L2, 10A	22.00	12.100	2.20	9.90	0.1	2,301,551	—
Al-66-B	2.5	CCAD	L2, 10A	27.00	14.850	2.70	12.15	0.1	174,160	—
Al-67-B	2.5	CCAD	H1, 12A	27.00	14.850	2.70	12.15	0.1	159,943	—
Al-72-B	2.5	CCAD	H1, 12A	30.00	16.500	3.00	13.50	0.1	116,876	—
Al-73-B	2.5	CCAD	H1, 12A	21.00	11.550	2.10	9.45	0.1	2,718,528	—
Al-74-B	2.5	CCAD	H1, 12A	22.00	12.100	2.20	9.90	0.1	2,914,967	—
Al-75-B	2.5	CCAD	H1, 12A	22.00	12.100	2.20	9.90	0.1	1,155,906	—
Al-76-B	2.5	CCAD	H1, 12A	33.00	18.150	3.30	14.85	0.1	49,694	—
Al-77-B	2.5	CCAD	H1, 12A	21.00	11.550	2.10	9.45	0.1	6,807,101	Runout
Al-78-B	2.5	CCAD	H1, 12A	24.00	13.200	2.40	10.80	0.1	301,249	—
Al-79-B	2.5	CCAD	H1, 12A	24.00	13.200	2.40	10.80	0.1	336,665	—
Al-80-B	2.5	CCAD	H1, 12A	23.00	12.650	2.30	10.35	0.1	542,855	—

Note: NA = not applicable.

Table 18. The Ti-6-4 beta-STOA, K_t = 1 cyclic fatigue data.

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
Ti-8-A	1	None	NA	135.00	74.250	13.5	60.75	0.1	94,515	—
Ti-40-A	1	None	NA	127.50	70.125	12.8	57.38	0.1	264,496	—
Ti-3-A	1	None	NA	111.26	61.195	11.1	50.07	0.1	2,000,000	Runout
Ti-3a-A	1	None	NA	140.00	77.000	14.0	63.00	0.1	31,860	Reuse of specimen no. 3
Ti-54-A	1	None	NA	126.25	69.438	12.6	56.81	0.1	2,000,000	Runout
Ti-6-A	1	None	NA	96.12	52.868	9.6	43.25	0.1	2,000,000	Runout
Ti-6a-A	1	None	NA	130.00	71.500	13.0	58.50	0.1	—	Reuse of specimen no. 6
Ti-4-A	1	None	NA	130.00	71.500	13.0	58.50	0.1	165,800	—
Ti-2-A	1	None	NA	125.00	68.750	12.5	56.25	0.1	2,000,000	Runout
Ti-7-A	1	None	NA	121.75	66.961	12.2	54.79	0.1	2,000,000	Runout
Ti-7a-A	1	None	NA	127.50	70.125	12.8	57.38	0.1	471,494	Reuse of specimen no. 7
Ti-43-A	1	MIC	L1-3N	131.25	72.188	13.1	59.06	0.1	—	—
Ti-72-A	1	MIC	L1-3N	132.50	72.875	13.3	59.63	0.1	—	—
Ti-73-A	1	MIC	L1-3N	130.00	71.500	13.0	58.50	0.1	1,170,112	—
Ti-74-A	1	MIC	L1-3N	135.00	74.250	13.5	60.75	0.1	178,753	—
Ti-75-A	1	MIC	L1-3N	132.50	72.875	13.3	59.63	0.1	—	—
Ti-76-A	1	MIC	L1-3N	140.00	77.000	14.0	63.00	0.1	67,943	—
Ti-77-A	1	MIC	L1-3N	137.50	75.625	13.8	61.88	0.1	106,539	—
Ti-79-A	1	MIC	L1-3N	132.50	72.875	13.3	59.63	0.1	2,000,000	Runout
Ti-80-A	1	MIC	L1-3N	135.00	74.250	13.5	60.75	0.1	313,732	—
Ti-42-A	1	MIC	L2-5N	135.00	74.250	13.5	60.75	0.1	731,716	—
Ti-63-A	1	MIC	L2-5N	132.50	72.875	13.3	59.63	0.1	—	—
Ti-64-A	1	MIC	L2-5N	137.50	75.625	13.8	61.88	0.1	279,700	—
Ti-65-A	1	MIC	L2-5N	132.50	72.875	13.3	59.63	0.1	—	—
Ti-66-A	1	MIC	L2-5N	135.00	74.250	13.5	60.75	0.1	848,602	—
Ti-67-A	1	MIC	L2-5N	133.75	73.563	13.4	60.19	0.1	1,174,384	—
Ti-68-A	1	MIC	L2-5N	137.50	75.625	13.8	61.88	0.1	155,275	—
Ti-70-A	1	MIC	L2-5N	133.75	73.563	13.4	60.19	0.1	837,537	—
Ti-71-A	1	MIC	L2-5N	140.00	77.000	14.0	63.00	0.1	53,796	—
Ti-27-A	1	MIC	H1-11N	135.00	74.250	13.5	60.75	0.1	149,257	—
Ti-28-A	1	MIC	H1-11N	137.50	75.625	13.8	61.88	0.1	80,627	—
Ti-29-A	1	MIC	H1-11N	140.00	77.000	14.0	63.00	0.1	51,041	—
Ti-30-A	1	MIC	H1-11N	130.00	71.500	13.0	58.50	0.1	—	—
Ti-31-A	1	MIC	H1-11N	130.00	71.500	13.0	58.50	0.1	2,110,254	—
Ti-32-A	1	MIC	H1-11N	137.50	75.625	13.8	61.88	0.1	65,400	—
Ti-33-A	1	MIC	H1-11N	132.50	72.875	13.3	59.63	0.1	451,742	—
Ti-34-A	1	MIC	H1-11N	133.75	73.563	13.4	60.19	0.1	327,519	—
Ti-41-A	1	MIC	H1-11N	133.75	73.563	13.4	60.19	0.1	367,474	—
Ti-18-A	1	MIC	H2-14N	135.00	74.250	13.5	60.75	0.1	2,150,000	Runout
Ti-19-A	1	MIC	H2-14N	137.00	75.350	13.7	61.65	0.1	336,729	—
Ti-20-A	1	MIC	H2-14N	137.00	75.350	13.7	61.65	0.1	257,076	—
Ti-21-A	1	MIC	H2-14N	140.00	77.000	14.0	63.00	0.1	21,312	—
Ti-23-A	1	MIC	H2-14N	135.00	74.250	13.5	60.75	0.1	292,530	—
Ti-24-A	1	MIC	H2-14N	135.00	74.250	13.5	60.75	0.1	227,477	—
Ti-25-A	1	MIC	H2-14N	132.50	72.875	13.3	59.63	0.1	2,150,000	Runout
Ti-26-A	1	MIC	H2-14N	132.50	72.875	13.3	59.63	0.1	2,834,988	Runout
Ti-39-A	1	MIC	H2-14N	133.75	73.563	13.4	60.19	0.1	2,280,904	—
Ti-16-A	1	MIC	L1-4A	132.50	72.875	13.3	59.63	0.1	327,814	—
Ti-46-A	1	MIC	L1-4A	135.00	74.250	13.5	60.75	0.1	151,590	—
Ti-47-A	1	MIC	L1-4A	130.00	71.500	13.0	58.50	0.1	2,000,000	Runout
Ti-48-A	1	MIC	L1-4A	132.50	72.875	13.3	59.63	0.1	436,939	—
Ti-49-A	1	MIC	L1-4A	130.00	71.500	13.0	58.50	0.1	—	—
Ti-50-A	1	MIC	L1-4A	135.00	74.250	13.5	60.75	0.1	89,272	—
Ti-51-A	1	MIC	L1-4A	137.50	75.625	13.8	61.88	0.1	44,307	—
Ti-52-A	1	MIC	L1-4A	131.25	72.188	13.1	59.06	0.1	380,524	—
Ti-53-A	1	MIC	L1-4A	131.25	72.188	13.1	59.06	0.1	661,910	—

Table 18. The Ti-6-4 beta-STOA, K_t = 1 cyclic fatigue data (continued).

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
Ti-10-A	1	MIC	L2-8A	137.50	75.625	13.8	61.88	0.1	62,089	—
Ti-11-A	1	MIC	L2-8A	132.50	72.875	13.3	59.63	0.1	266,813	—
Ti-12-A	1	MIC	L2-8A	130.00	71.500	13.0	58.50	0.1	846,952	Internal failure
Ti-13-A	1	MIC	L2-8A	130.00	71.500	13.0	58.50	0.1	619,064	—
Ti-14-A	1	MIC	L2-8A	127.50	70.125	12.8	57.38	0.1	1,622,441	—
Ti-15-A	1	MIC	L2-8A	127.50	70.125	12.8	57.38	0.1	2,084,903	—
Ti-17-A	1	MIC	L2-8A	132.50	72.875	13.3	59.63	0.1	137,464	—
Ti-37-A	1	MIC	L2-8A	135.00	74.250	13.5	60.75	0.1	70,867	—
Ti-9-A	1	MIC	L2-8A	126.25	69.438	12.6	56.81	0.1	—	—
Ti-35-A	1	MIC	H1-11.5A	132.50	72.875	13.3	59.63	0.1	83,069	—
Ti-36-A	1	MIC	H1-11.5A	127.50	70.125	12.8	57.38	0.1	534,759	—
Ti-38-A	1	MIC	H1-11.5A	137.50	75.625	13.8	61.88	0.1	19,029	—
Ti-44-A	1	MIC	H1-11.5A	135.00	74.250	13.5	60.75	0.1	90,828	—
Ti-45-A	1	MIC	H1-11.5A	130.00	71.500	13.0	58.50	0.1	158,264	—
Ti-62-A	1	MIC	H1-11.5A	126.25	69.438	12.6	56.81	0.1	897,526	—
Ti-69-A	1	MIC	H1-11.5A	135.00	74.250	13.5	60.75	0.1	50,843	—
Ti-78-A	1	MIC	H1-11.5A	126.25	69.438	12.6	56.81	0.1	—	—
Ti-22-A	1	MIC	H1-11.5A	127.50	70.125	12.8	57.38	0.1	541,764	—
Ti-1-A	1	CCAD	H2-14A	135.00	74.250	13.5	60.75	0.1	30,707	—
Ti-5-A	1	CCAD	H2-14A	132.50	72.875	13.3	59.63	0.1	93,413	—
Ti-55-A	1	CCAD	H2-14A	130.00	71.500	13.0	58.50	0.1	164,488	—
Ti-56-A	1	CCAD	H2-14A	127.50	70.125	12.8	57.38	0.1	550,105	—
Ti-57-A	1	CCAD	H2-14A	127.50	70.125	12.8	57.38	0.1	300,899	—
Ti-58-A	1	CCAD	H2-14A	130.00	71.500	13.0	58.50	0.1	135,577	—
Ti-59-A	1	CCAD	H2-14A	125.00	68.750	12.5	56.25	0.1	2,000,000	Runout
Ti-60-A	1	CCAD	H2-14A	126.25	69.438	12.6	56.81	0.1	426,347	—
Ti-61-A	1	CCAD	H2-14A	125.00	68.750	12.5	56.25	0.1	—	—

Note: NA = not applicable.

Table 19. The Ti-6-4 beta-STOA, K_t = 1.75 cyclic fatigue data.

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
Ti-11-C	1.75	None	NA	95.00	52.250	9.5	42.75	0.1	28,988	—
Ti-12-C	1.75	None	NA	90.00	49.500	9.0	40.50	0.1	269,351	—
Ti-16-C	1.75	None	NA	87.50	48.125	8.8	39.38	0.1	2,630,211	Runout
Ti-17-C	1.75	None	NA	92.50	50.875	9.3	41.63	0.1	46,836	—
Ti-18-C	1.75	None	NA	90.00	49.500	9.0	40.50	0.1	93,108	—
Ti-19-C	1.75	None	NA	88.75	48.813	8.9	39.94	0.1	462,650	—
Ti-20-C	1.75	None	NA	88.75	48.813	8.9	39.94	0.1	329,562	—
Ti-5-C	1.75	None	NA	100.00	55.000	10.0	45.00	0.1	9,859	—
Ti-10-C	1.75	MIC	L1-3N	100.00	55.000	10.0	45.00	0.1	1,076,892	—
Ti-44-C	1.75	MIC	L1-3N	95.00	52.250	9.5	42.75	0.1	965,935	—
Ti-53-C	1.75	MIC	L1-3N	115.00	63.250	11.5	51.75	0.1	46,374	—
Ti-56-C	1.75	MIC	L1-3N	92.50	50.875	9.3	41.63	0.1	2,068,609	—
Ti-57-C	1.75	MIC	L1-3N	95.00	52.250	9.5	42.75	0.1	1,487,872	—
Ti-58-C	1.75	MIC	L1-3N	105.00	57.750	10.5	47.25	0.1	726,786	—
Ti-66-C	1.75	MIC	L1-3N	105.00	57.750	10.5	47.25	0.1	—	—
Ti-67-C	1.75	MIC	L1-3N	110.00	60.500	11.0	49.50	0.1	83,358	—
Ti-70-C	1.75	MIC	L1-3N	92.50	50.875	9.3	41.63	0.1	940,969	—
Ti-1-C	1.75	MIC	L2-5N	100.00	55.000	10.0	45.00	0.1	162,771	—
Ti-2-C	1.75	MIC	L2-5N	95.00	52.250	9.5	42.75	0.1	200,952	—
Ti-3-C	1.75	MIC	L2-5N	100.00	55.000	10.0	45.00	0.1	106,176	—
Ti-4-C	1.75	MIC	L2-5N	92.50	50.875	9.3	41.63	0.1	2,030,298	—
Ti-6-C	1.75	MIC	L2-5N	95.00	52.250	9.5	42.75	0.1	1,323,613	—
Ti-8-C	1.75	MIC	L2-5N	95.00	52.250	9.5	42.75	0.1	727,514	—
Ti-9-C	1.75	MIC	L2-5N	105.00	57.750	10.5	47.25	0.1	29,543	—
Ti-13-C	1.75	MIC	L2-5N	97.50	53.625	9.8	43.88	0.1	113,503	—
Ti-14-C	1.75	MIC	L2-5N	97.50	53.625	9.8	43.88	0.1	1,922,370	—
Ti-7-C	1.75	MIC	H1-11N	100.00	55.000	10.0	45.00	0.1	75,196	—
Ti-28-C	1.75	MIC	H1-11N	95.00	52.250	9.5	42.75	0.1	137,887	—
Ti-40-C	1.75	MIC	H1-11N	97.50	53.625	9.8	43.88	0.1	119,423	—
Ti-47-C	1.75	MIC	H1-11N	92.50	50.875	9.3	41.63	0.1	271,603	—
Ti-59-C	1.75	MIC	H1-11N	95.00	52.250	9.5	42.75	0.1	211,652	—
Ti-60-C	1.75	MIC	H1-11N	91.25	50.188	9.1	41.06	0.1	168,053	—
Ti-64-C	1.75	MIC	H1-11N	105.00	57.750	10.5	47.25	0.1	50,547	—
Ti-65-C	1.75	MIC	H1-11N	90.00	49.500	9.0	40.50	0.1	2,427,426	—
Ti-69-C	1.75	MIC	H1-11N	90.00	49.500	9.0	40.50	0.1	—	—
Ti-27-C	1.75	MIC	H2-14N	97.50	53.625	9.8	43.88	0.1	130,678	—
Ti-30-C	1.75	MIC	H2-14N	95.00	52.250	9.5	42.75	0.1	135,146	—
Ti-43-C	1.75	MIC	H2-14N	90.00	49.500	9.0	40.50	0.1	1,702,604	—
Ti-46-C	1.75	MIC	H2-14N	100.00	55.000	10.0	45.00	0.1	64,241	—
Ti-48-C	1.75	MIC	H2-14N	92.50	50.875	9.3	41.63	0.1	214,617	—
Ti-54-C	1.75	MIC	H2-14N	91.25	50.188	9.1	41.06	0.1	1,907,624	—
Ti-62-C	1.75	MIC	H2-14N	95.00	52.250	9.5	42.75	0.1	151,319	—
Ti-63-C	1.75	MIC	H2-14N	88.75	48.813	8.9	39.94	0.1	1,993,620	—
Ti-68-C	1.75	MIC	H2-14N	91.25	50.188	9.1	41.06	0.1	381,785	—
Ti-15-C	1.75	MIC	L1-4A	88.75	48.813	8.9	39.94	0.1	2,349,123	—
Ti-25-C	1.75	MIC	L1-4A	100.00	55.000	10.0	45.00	0.1	33,900	—
Ti-26-C	1.75	MIC	L1-4A	88.75	48.813	8.9	39.94	0.1	1,879,487	—
Ti-29-C	1.75	MIC	L1-4A	92.50	50.875	9.3	41.63	0.1	159,110	—
Ti-31-C	1.75	MIC	L1-4A	95.00	52.250	9.5	42.75	0.1	92,399	—
Ti-32-C	1.75	MIC	L1-4A	87.50	48.125	8.8	39.38	0.1	—	—
Ti-41-C	1.75	MIC	L1-4A	90.00	49.500	9.0	40.50	0.1	702,358	—
Ti-45-C	1.75	MIC	L1-4A	92.50	50.875	9.3	41.63	0.1	180,947	—
Ti-61-C	1.75	MIC	L1-4A	90.00	49.500	9.0	40.50	0.1	318,264	—
Ti-21-C	1.75	MIC	L2-8A	100.00	55.000	10.0	45.00	0.1	84,103	—
Ti-22-C	1.75	MIC	L2-8A	92.50	50.875	9.3	41.63	0.1	264,648	—
Ti-23-C	1.75	MIC	L2-8A	86.25	47.438	8.6	38.81	0.1	870,393	
Ti-35-C	1.75	MIC	L2-8A	86.25	47.438	8.6	38.81	0.1	518,940	—
Ti-36-C	1.75	MIC	L2-8A	87.50	48.125	8.8	39.38	0.1	407,694	—
Ti-37-C	1.75	MIC	L2-8A	95.00	52.250	9.5	42.75	0.1	161,660	—
Ti-38-C	1.75	MIC	L2-8A	87.50	48.125	8.8	39.38	0.1	546,735	—
Ti-71-C	1.75	MIC	L2-8A	85.00	46.750	8.5	38.25	0.1	—	Threads 1552612
Ti-72-C	1.75	MIC	L2-8A	90.00	49.500	9.0	40.50	0.1	349,838	—

Table 19. The Ti-6-4 beta-STOA, K_t = 1.75 cyclic fatigue data (continued).

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
Ti-24-C	1.75	MIC	H1-11.5A	95.00	52.250	9.5	42.75	0.1	108,612	—
Ti-33-C	1.75	MIC	H1-11.5A	100.00	55.000	10.0	45.00	0.1	81,830	—
Ti-34-C	1.75	MIC	H1-11.5A	90.00	49.500	9.0	40.50	0.1	150,137	—
Ti-39-C	1.75	MIC	H1-11.5A	87.50	48.125	8.8	39.38	0.1	305,461	—
Ti-42-C	1.75	MIC	H1-11.5A	86.25	47.438	8.6	38.81	0.1	702,303	—
Ti-49-C	1.75	MIC	H1-11.5A	90.00	49.500	9.0	40.50	0.1	165,680	—
Ti-50-C	1.75	MIC	H1-11.5A	105.00	57.750	10.5	47.25	0.1	72,433	—
Ti-51-C	1.75	MIC	H1-11.5A	86.25	47.438	8.6	38.81	0.1	405,394	—
Ti-55-C	1.75	MIC	H1-11.5A	92.50	50.875	9.3	41.63	0.1	156,567	—
Ti-52-C	1.75	CCAD	H2-12A	100.00	55.000	10.0	45.00	0.1	43,419	—
Ti-73-C	1.75	CCAD	H2-12A	90.00	49.500	9.0	40.50	0.1	197,647	—
Ti-74-C	1.75	CCAD	H2-12A	92.50	50.875	9.3	41.63	0.1	185,001	—
Ti-75-C	1.75	CCAD	H2-12A	95.00	52.250	9.5	42.75	0.1	74,626	—
Ti-76-C	1.75	CCAD	H2-12A	85.00	46.750	8.5	38.25	0.1	617,134	—
Ti-77-C	1.75	CCAD	H2-12A	86.25	47.438	8.6	38.81	0.1	372,859	—
Ti-78-C	1.75	CCAD	H2-12A	85.00	46.750	8.5	38.25	0.1	2,318,387	—
Ti-79-C	1.75	CCAD	H2-12A	86.25	47.438	8.6	38.81	0.1	456,067	—
Ti-80-C	1.75	CCAD	H2-12A	90.00	49.500	9.0	40.50	0.1	201,857	—

Note: NA = not applicable.

Table 20. The Ti-6-4 beta-STOA, K_t = 2.5 cyclic fatigue data.

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
Ti-4-B	2.5	None	NA	75.00	41.250	7.5	33.75	0.1	20,302	—
Ti-7-B	2.5	None	NA	72.50	39.875	7.3	32.63	0.1	36,820	—
Ti-20-B	2.5	None	NA	70.00	38.500	7.0	31.50	0.1	104,926	—
Ti-10-B	2.5	None	NA	72.50	39.875	7.3	32.63	0.1	30,979	—
Ti-5-B	2.5	None	NA	63.75	35.063	6.4	28.69	0.1	2,000,000	Runout
Ti-80-B	2.5	None	NA	70.00	38.500	7.0	31.50	0.1	290,252	—
Ti-1-B	2.5	None	NA	65.00	35.750	6.5	29.25	0.1	641,141	—
Ti-6-B	2.5	None	NA	62.50	34.375	6.3	28.13	0.1	2,270,495	Runout
Ti-3-B	2.5	MIC	L2-5N	72.50	39.875	7.3	32.63	0.1	178,791	—
Ti-9-B	2.5	MIC	L2-5N	75.00	41.250	7.5	33.75	0.1	108,037	—
Ti-16-B	2.5	MIC	L2-5N	73.75	40.563	7.4	33.19	0.1	159,123	—
Ti-21-B	2.5	MIC	L2-5N	72.50	39.875	7.3	32.63	0.1	551,344	—
Ti-29-B	2.5	MIC	L2-5N	67.50	37.125	6.8	30.38	0.1	2,940,095	Runout
Ti-40-B	2.5	MIC	L2-5N	85.00	46.750	8.5	38.25	0.1	—	—
Ti-41-B	2.5	MIC	L2-5N	70.00	38.500	7.0	31.50	0.1	3,560,595	—
Ti-42-B	2.5	MIC	L2-5N	80.00	44.000	8.0	36.00	0.1	42,269	—
Ti-71-B	2.5	MIC	L2-5N	70.00	38.500	7.0	31.50	0.1	752,561	—
Ti-12-B	2.5	MIC	H1-11N	72.50	39.875	7.3	32.63	0.1	137,661	—
Ti-26-B	2.5	MIC	H1-11N	75.00	41.250	7.5	33.75	0.1	110,597	—
Ti-27-B	2.5	MIC	H1-11N	70.00	38.500	7.0	31.50	0.1	2,922,358	—
Ti-30-B	2.5	MIC	H1-11N	80.00	44.000	8.0	36.00	0.1	52,036	—
Ti-36-B	2.5	MIC	H1-11N	70.00	38.500	7.0	31.50	0.1	1,587,050	—
Ti-38-B	2.5	MIC	H1-11N	71.25	39.188	7.1	32.06	0.1	600,618	—
Ti-65-B	2.5	MIC	H1-11N	71.25	39.188	7.1	32.06	0.1	556,246	—
Ti-70-B	2.5	MIC	H1-11N	75.00	41.250	7.5	33.75	0.1	135,684	—
Ti-75-B	2.5	MIC	H1-11N	72.50	39.875	7.3	32.63	0.1	143,701	—
Ti-2-B	2.5	MIC	L1-3N	75.00	41.250	7.5	33.75	0.1	82,798	—
Ti-14-B	2.5	MIC	L1-3N	73.75	40.563	7.4	33.19	0.1	75,723	—
Ti-15-B	2.5	MIC	L1-3N	72.50	39.875	7.3	32.63	0.1	137,899	—
Ti-17-B	2.5	MIC	L1-3N	70.00	38.500	7.0	31.50	0.1	2,937,244	Runout
Ti-32-B	2.5	MIC	L1-3N	71.25	39.188	7.1	32.06	0.1	3,359,391	—
Ti-33-B	2.5	MIC	L1-3N	85.00	46.750	8.5	38.25	0.1	18,620	—
Ti-49-B	2.5	MIC	L1-3N	72.50	39.875	7.3	32.63	0.1	150,173	—
Ti-51-B	2.5	MIC	L1-3N	80.00	44.000	8.0	36.00	0.1	39,886	—
Ti-78-B	2.5	MIC	L1-3N	75.00	41.250	7.5	33.75	0.1	99,470	—
Ti-8-B	2.5	MIC	H2-14N	70.00	38.500	7.0	31.50	0.1	211,565	—
Ti-11-B	2.5	MIC	H2-14N	67.50	37.125	6.8	30.38	0.1	300,565	—
Ti-19-B	2.5	MIC	H2-14N	75.00	41.250	7.5	33.75	0.1	76,648	—
Ti-23-B	2.5	MIC	H2-14N	72.50	39.875	7.3	32.63	0.1	131,941	—
Ti-25-B	2.5	MIC	H2-14N	80.00	44.000	8.0	36.00	0.1	—	—
Ti-31-B	2.5	MIC	H2-14N	70.00	38.500	7.0	31.50	0.1	296,132	—
Ti-34-B	2.5	MIC	H2-14N	67.50	37.125	6.8	30.38	0.1	674,839	—
Ti-35-B	2.5	MIC	H2-14N	65.00	35.750	6.5	29.25	0.1	2,875,586	Runout
Ti-73-B	2.5	MIC	H2-14N	72.50	39.875	7.3	32.63	0.1	241,091	—
Ti-24-B	2.5	MIC	L1-4A	70.00	38.500	7.0	31.50	0.1	169,647	—
Ti-54-B	2.5	MIC	L1-4A	70.00	38.500	7.0	31.50	0.1	167,631	—
Ti-55-B	2.5	MIC	L1-4A	67.50	37.125	6.8	30.38	0.1	170,586	—
Ti-58-B	2.5	MIC	L1-4A	67.50	37.125	6.8	30.38	0.1	173,336	—
Ti-59-B	2.5	MIC	L1-4A	75.00	41.250	7.5	33.75	0.1	51,583	—
Ti-72-B	2.5	MIC	L1-4A	72.50	39.875	7.3	32.63	0.1	106,426	—
Ti-74-B	2.5	MIC	L1-4A	72.50	39.875	7.3	32.63	0.1	60,397	—
Ti-77-B	2.5	MIC	L1-4A	65.00	35.750	6.5	29.25	0.1	2,020,019	Runout
Ti-79-B	2.5	MIC	L1-4A	80.00	44.000	8.0	36.00	0.1	—	—
Ti-22-B	2.5	MIC	L2-8A	62.50	34.375	6.3	28.13	0.1	2,998,353	Runout
Ti-39-B	2.5	MIC	L2-8A	65.00	35.750	6.5	29.25	0.1	917,157	—
Ti-43-B	2.5	MIC	L2-8A	67.50	37.125	6.8	30.38	0.1	231,375	—
Ti-44-B	2.5	MIC	L2-8A	67.50	37.125	6.8	30.38	0.1	238,259	—
Ti-50-B	2.5	MIC	L2-8A	75.00	41.250	7.5	33.75	0.1	126,950	—
Ti-53-B	2.5	MIC	L2-8A	72.50	39.875	7.3	32.63	0.1	215,112	—
Ti-56-B	2.5	MIC	L2-8A	72.50	39.875	7.3	32.63	0.1	157,450	—
Ti-57-B	2.5	MIC	L2-8A	65.00	35.750	6.5	29.25	0.1	309,408	—
Ti-64-B	2.5	MIC	L2-8A	63.75	35.063	6.4	28.69	0.1	1,339,003	—

Table 20. The Ti-6-4 beta-STOA, K_t = 2.5 cyclic fatigue data (continued).

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
Ti-13-B	2.5	MIC	H1-11.5A	70.00	38.500	7.0	31.50	0.1	160,942	—
Ti-28-B	2.5	MIC	H1-11.5A	80.00	44.000	8.0	36.00	0.1	49,334	—
Ti-37-B	2.5	MIC	H1-11.5A	67.50	37.125	6.8	30.38	0.1	209,897	—
Ti-45-B	2.5	MIC	H1-11.5A	67.50	37.125	6.8	30.38	0.1	873,014	—
Ti-46-B	2.5	MIC	H1-11.5A	75.00	41.250	7.5	33.75	0.1	79,502	—
Ti-47-B	2.5	MIC	H1-11.5A	72.50	39.875	7.3	32.63	0.1	128,949	—
Ti-60-B	2.5	MIC	H1-11.5A	72.50	39.875	7.3	32.63	0.1	97,501	—
Ti-66-B	2.5	MIC	H1-11.5A	65.00	35.750	6.5	29.25	0.1	6,516,424	—
Ti-67-B	2.5	MIC	H1-11.5A	65.00	35.750	6.5	29.25	0.1	—	—
Ti-18-B	2.5	CCAD	H2-14A	70.00	38.500	7.0	31.50	0.1	75,496	—
Ti-48-B	2.5	CCAD	H2-14A	75.00	41.250	7.5	33.75	0.1	94,760	—
Ti-52-B	2.5	CCAD	H2-14A	67.50	37.125	6.8	30.38	0.1	295,011	—
Ti-61-B	2.5	CCAD	H2-14A	67.50	37.125	6.8	30.38	0.1	163,995	—
Ti-62-B	2.5	CCAD	H2-14A	62.50	34.375	6.3	28.13	0.1	12,040,703	Runout
Ti-63-B	2.5	CCAD	H2-14A	62.50	34.375	6.3	28.13	0.1	1,315,686	—
Ti-68-B	2.5	CCAD	H2-14A	61.25	33.688	6.1	27.56	0.1	6,284,337	Runout
Ti-69-B	2.5	CCAD	H2-14A	65.00	35.750	6.5	29.25	0.1	—	—
Ti-76-B	2.5	CCAD	H2-14A	65.00	35.750	6.5	29.25	0.1	199,850	—

Note: NA = not applicable.

Table 21. The 4340 steel, K_t = 1 cyclic fatigue data.

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
4340-21-A	1	None	NA	145.00	79.750	14.50	65.25	0.1	21,303	—
4340-24-A	1	None	NA	140.00	77.000	14.00	63.00	0.1	54,603	—
4340-35-A	1	None	NA	135.00	74.250	13.50	60.75	0.1	76,153	—
4340-37-A	1	None	NA	131.25	72.188	13.13	59.06	0.1	646,377	—
4340-42-A	1	None	NA	130.00	71.500	13.00	58.50	0.1	2,074,680	—
4340-44-A	1	None	NA	131.25	72.188	13.13	59.06	0.1	—	1736936 broke in threads
4340-46-A	1	None	NA	131.25	72.188	13.13	59.06	0.1	312,872	—
4340-47-A	1	None	NA	131.25	72.188	13.13	59.06	0.1	3,500,000	Runout
4340-49-A	1	None	NA	132.50	72.875	13.25	59.63	0.1	165,707	—
4340-50-A	1	None	NA	132.50	72.875	13.25	59.63	0.1	125,403	—
4340-10-A	1	MIC	L1-4A	145.00	79.750	14.50	65.25	0.1	110,526	—
4340-12-A	1	MIC	L1-4A	140.00	77.000	14.00	63.00	0.1	141,003	—
4340-13-A	1	MIC	L1-4A	137.50	75.625	13.75	61.88	0.1	406,146	—
4340-14-A	1	MIC	L1-4A	135.00	74.250	13.50	60.75	0.1	2,000,000	Runout
4340-17-A	1	MIC	L1-4A	137.50	75.625	13.75	61.88	0.1	163,254	—
4340-19-A	1	MIC	L1-4A	136.25	74.938	13.63	61.31	0.1	8,399,611	Runout
4340-20-A	1	MIC	L1-4A	140.00	77.000	14.00	63.00	0.1	372,532	—
4340-2-A	1	MIC	L1-4A	136.25	74.938	13.63	61.31	0.1	—	—
4340-5-A	1	MIC	L1-4A	135.00	74.250	13.50	60.75	0.1	—	—
4340-8-A	1	MIC	L1-4A	133.75	73.563	13.38	60.19	0.1	6,905,245	Runout
4340-11-A	1	MIC	L2-8A	145.00	79.750	14.50	65.25	0.1	38,561	—
4340-15-A	1	MIC	L2-8A	140.00	77.000	14.00	63.00	0.1	284,243	—
4340-16-A	1	MIC	L2-8A	137.50	75.625	13.75	61.88	0.1	784,586	—
4340-18-A	1	MIC	L2-8A	135.00	74.250	13.50	60.75	0.1	3,134,886	Runout
4340-1-A	1	MIC	L2-8A	133.75	73.563	13.38	60.19	0.1	—	—
4340-3-A	1	MIC	L2-8A	133.75	73.563	13.38	60.19	0.1	1,701,284	—
4340-4-A	1	MIC	L2-8A	137.50	75.625	13.75	61.88	0.1	322,910	—
4340-6-A	1	MIC	L2-8A	135.00	74.250	13.50	60.75	0.1	748,453	—
4340-7-A	1	MIC	L2-8A	140.00	77.000	14.00	63.00	0.1	424,610	—
4340-9-A	1	MIC	L2-8A	142.50	78.375	14.25	64.13	0.1	51,989	—
4340-22-A	1	CCAD	L2-8A	145.00	79.750	14.50	65.25	0.1	—	—
4340-25-A	1	CCAD	L2-8A	140.00	77.000	14.00	63.00	0.1	38,291	—
4340-28-A	1	CCAD	L2-8A	137.50	75.625	13.75	61.88	0.1	138,556	—
4340-29-A	1	CCAD	L2-8A	135.00	74.250	13.50	60.75	0.1	150,269	—
4340-31-A	1	CCAD	L2-8A	133.75	73.563	13.38	60.19	0.1	2,852,466	Runout
4340-32-A	1	CCAD	L2-8A	133.75	73.563	13.38	60.19	0.1	1,365,709	—
4340-34-A	1	CCAD	L2-8A	137.50	75.625	13.75	61.88	0.1	452,162	—
4340-38-A	1	CCAD	L2-8A	135.00	74.250	13.50	60.75	0.1	2,000,000	Runout
4340-40-A	1	CCAD	L2-8A	140.00	77.000	14.00	63.00	0.1	95,691	—
4340-41-A	1	CCAD	L2-8A	142.50	78.375	14.25	64.13	0.1	27,278	—
4340-48-A	1	CCAD	H1-12A	145.00	79.750	14.50	65.25	0.1	16,736	—
4340-51-A	1	CCAD	H1-12A	140.00	77.000	14.00	63.00	0.1	73,769	—
4340-52-A	1	CCAD	H1-12A	137.50	75.625	13.75	61.88	0.1	385,512	—
4340-53-A	1	CCAD	H1-12A	135.00	74.250	13.50	60.75	0.1	433,156	—
4340-54-A	1	CCAD	H1-12A	137.50	75.625	13.75	61.88	0.1	364,880	—
4340-55-A	1	CCAD	H1-12A	132.50	72.875	13.25	59.63	0.1	596,092	—
4340-56-A	1	CCAD	H1-12A	130.00	71.500	13.00	58.50	0.1	6,293,796	Runout
4340-57-A	1	CCAD	H1-12A	132.50	72.875	13.25	59.63	0.1	543,103	—
4340-58-A	1	CCAD	H1-12A	135.00	74.250	13.50	60.75	0.1	450,827	—
4340-59-A	1	CCAD	H1-12A	140.00	77.000	14.00	63.00	0.1	61,605	—
4340-60-A	1	CCAD	L1-4A	145.00	79.750	14.50	65.25	0.1	29,382	—
4340-61-A	1	CCAD	L1-4A	140.00	77.000	14.00	63.00	0.1	99,694	—
4340-62-A	1	CCAD	L1-4A	137.50	75.625	13.75	61.88	0.1	447,468	—
4340-63-A	1	CCAD	L1-4A	140.00	77.000	14.00	63.00	0.1	272,680	—
4340-64-A	1	CCAD	L1-4A	137.50	75.625	13.75	61.88	0.1	—	Threads 647,229
4340-65-A	1	CCAD	L1-4A	137.50	75.625	13.75	61.88	0.1	2,999,997	—
4340-66-A	1	CCAD	L1-4A	138.75	76.313	13.88	62.44	0.1	2,000,000	—
4340-67-A	1	CCAD	L1-4A	136.25	74.938	13.63	61.31	0.1	3,186,724	—
4340-68-A	1	CCAD	L1-4A	136.25	74.938	13.63	61.31	0.1	605,293	—
4340-69-A	1	CCAD	L1-4A	138.75	76.313	13.88	62.44	0.1	293,020	—

Note: NA = not applicable.

Table 22. The 4340 steel, K_t = 1.75 cyclic fatigue data.

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
4340-30-C	1.75	None	NA	92.50	50.875	9.25	41.63	0.1	273,013	—
4340-31-C	1.75	None	NA	90.00	49.500	9.00	40.50	0.1	2,250,000	Runout
4340-32-C	1.75	None	NA	107.50	59.125	10.75	48.38	0.1	25,201	—
4340-33-C	1.75	None	NA	87.50	48.125	8.75	39.38	0.1	8,031,038	Runout
4340-34-C	1.75	None	NA	92.50	50.875	9.25	41.63	0.1	334,391	—
4340-35-C	1.75	None	NA	95.00	52.250	9.50	42.75	0.1	220,758	—
4340-36-C	1.75	None	NA	97.50	53.625	9.75	43.88	0.1	132,537	—
4340-37-C	1.75	None	NA	80.00	44.000	8.00	36.00	0.1	—	—
4340-38-C	1.75	None	NA	100.00	55.000	10.00	45.00	0.1	70,510	—
4340-39-C	1.75	None	NA	95.00	52.250	9.50	42.75	0.1	189,455	—
4340-1-C	1.75	MIC	L1-4A	107.50	59.125	10.75	48.38	0.1	62,310	—
4340-2-C	1.75	MIC	L1-4A	`97.50	53.625	9.75	43.88	0.1	299,300	—
4340-3-C	1.75	MIC	L1-4A	97.50	53.625	9.75	43.88	0.1	230,241	—
4340-4-C	1.75	MIC	L1-4A	95.00	52.250	9.50	42.75	0.1	433,093	—
4340-5-C	1.75	MIC	L1-4A	96.25	52.938	9.63	43.31	0.1	452,196	—
4340-6-C	1.75	MIC	L1-4A	95.00	52.250	9.50	42.75	0.1	2,046,318	Runout
4340-7-C	1.75	MIC	L1-4A	96.25	52.938	9.63	43.31	0.1	4,650,509	Runout
4340-8-C	1.75	MIC	L1-4A	100.00	55.000	10.00	45.00	0.1	168,688	—
4340-9-C	1.75	MIC	L1-4A	95.00	52.250	9.50	42.75	0.1	2,866,329	Runout
4340-13-C	1.75	MIC	L1-4A	94.00	51.700	9.40	42.30	0.1	—	—
4340-10-C	1.75	MIC	L2-8A	97.50	53.625	9.75	43.88	0.1	183,458	—
4340-11-C	1.75	MIC	L2-8A	100.00	55.000	10.00	45.00	0.1	139,999	—
4340-12-C	1.75	MIC	L2-8A	95.00	52.250	9.50	42.75	0.1	162,664	—
4340-14-C	1.75	MIC	L2-8A	91.25	50.188	9.13	41.06	0.1	347,840	—
4340-15-C	1.75	MIC	L2-8A	87.50	48.125	8.75	39.38	0.1	1,070,248	—
4340-16-C	1.75	MIC	L2-8A	92.50	50.875	9.25	41.63	0.1	302,592	—
4340-17-C	1.75	MIC	L2-8A	93.75	51.563	9.38	42.19	0.1	247,769	—
4340-18-C	1.75	MIC	L2-8A	107.50	59.125	10.75	48.38	0.1	80,066	—
4340-19-C	1.75	MIC	L2-8A	88.75	48.813	8.88	39.94	0.1	659,643	—
4340-20-C	1.75	MIC	L2-8A	90.00	49.500	9.00	40.50	0.1	379,423	—
4340-22-C	1.75	CCAD	L2-8A	97.50	53.625	9.75	43.88	0.1	158,047	—
4340-23-C	1.75	CCAD	L2-8A	100.00	55.000	10.00	45.00	0.1	109,063	—
4340-24-C	1.75	CCAD	L2-8A	95.00	52.250	9.50	42.75	0.1	154,201	—
4340-25-C	1.75	CCAD	L2-8A	86.25	47.438	8.63	38.81	0.1	4,797,246	Runout
4340-26-C	1.75	CCAD	L2-8A	87.50	48.125	8.75	39.38	0.1	539,726	—
4340-27-C	1.75	CCAD	L2-8A	92.50	50.875	9.25	41.63	0.1	256,601	—
4340-28-C	1.75	CCAD	L2-8A	87.50	48.125	8.75	39.38	0.1	581,687	—
4340-29-C	1.75	CCAD	L2-8A	107.50	59.125	10.75	48.38	0.1	68,003	—
4340-57-C	1.75	CCAD	L2-8A	86.25	47.438	8.63	38.81	0.1	4,548,782	Runout
4340-68-C	1.75	CCAD	L2-8A	90.00	49.500	9.00	40.50	0.1	312,441	—
4340-21-C	1.75	CCAD	H1-12A	97.50	53.625	9.75	43.88	0.1	102,171	—
4340-40-C	1.75	CCAD	H1-12A	85.00	46.750	8.50	38.25	0.1	558,187	—
4340-51-C	1.75	CCAD	H1-12A	83.75	46.063	8.38	37.69	0.1	748,254	—
4340-52-C	1.75	CCAD	H1-12A	100.00	55.000	10.00	45.00	0.1	114,216	—
4340-53-C	1.75	CCAD	H1-12A	87.50	48.125	8.75	39.38	0.1	314,870	—
4340-54-C	1.75	CCAD	H1-12A	85.00	46.750	8.50	38.25	0.1	514,819	—
4340-55-C	1.75	CCAD	H1-12A	107.50	59.125	10.75	48.38	0.1	59,967	—
4340-56-C	1.75	CCAD	H1-12A	107.50	59.125	10.75	48.38	0.1	75,311	—
4340-58-C	1.75	CCAD	H1-12A	87.50	48.125	8.75	39.38	0.1	329,907	—
4340-59-C	1.75	CCAD	H1-12A	82.5	45.375	8.25	37.13	0.1	2,243,023	Runout
4340-41-C	1.75	CCAD	L1-4A	92.50	50.875	9.25	41.63	0.1	514,714	—
4340-43-C	1.75	CCAD	L1-4A	97.50	53.625	9.75	43.88	0.1	124,423	—
4340-44-C	1.75	CCAD	L1-4A	97.50	53.625	9.75	43.88	0.1	178,502	—
4340-45-C	1.75	CCAD	L1-4A	95.00	52.250	9.50	42.75	0.1	173,426	—
4340-46-C	1.75	CCAD	L1-4A	92.50	50.875	9.25	41.63	0.1	2,000,000	Runout
4340-47-C	1.75	CCAD	L1-4A	95.00	52.250	9.50	42.75	0.1	157,402	—
4340-48-C	1.75	CCAD	L1-4A	91.25	50.188	9.13	41.06	0.1	770,590	—
4340-49-C	1.75	CCAD	L1-4A	100.00	55.000	10.00	45.00	0.1	101,346	—
4340-50-C	1.75	CCAD	L1-4A	93.75	51.563	9.38	42.19	0.1	395,777	—
4340-64-C	1.75	CCAD	L1-4A	107.50	59.125	10.75	48.38	0.1	94,299	—

Note: NA = not applicable.

Table 23. The 4340 steel, K_t = 2.5 cyclic fatigue data.

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
4340-21-B	2.5	None	NA	67.50	37.125	6.75	30.38	0.1	244,130	—
4340-23-B	2.5	None	NA	67.50	37.125	6.75	30.38	0.1	2,000,000	Runout
4340-24-B	2.5	None	NA	65.00	35.750	6.50	29.25	0.1	448,764	—
4340-25-B	2.5	None	NA	77.50	42.625	7.75	34.88	0.1	69,756	—
4340-28-B	2.5	None	NA	82.50	45.375	8.25	37.13	0.1	39,931	—
4340-29-B	2.5	None	NA	72.50	39.875	7.25	32.63	0.1	130,833	—
4340-30-B	2.5	None	NA	72.50	39.875	7.25	32.63	0.1	214,503	—
4340-31-B	2.5	None	NA	70.00	38.500	7.00	31.50	0.1	199,400	—
4340-32-B	2.5	None	NA	63.75	35.063	6.38	28.69	0.1	5,175,715	Runout
4340-35-B	2.5	None	NA	75.00	41.250	7.50	33.75	0.1	157,307	—
4340-3-B	2.5	MIC	L1-4A	71.25	39.188	7.13	32.06	0.1	636,794	—
4340-4-B	2.5	MIC	L1-4A	71.25	39.188	7.13	32.06	0.1	—	—
4340-5-B	2.5	MIC	L1-4A	82.50	45.375	8.25	37.13	0.1	86,723	—
4340-7-B	2.5	MIC	L1-4A	77.50	42.625	7.75	34.88	0.1	119,516	—
4340-8-B	2.5	MIC	L1-4A	75.00	41.250	7.50	33.75	0.1	—	—
4340-11-B	2.5	MIC	L1-4A	72.50	39.875	7.25	32.63	0.1	308,571	—
4340-12-B	2.5	MIC	L1-4A	72.50	39.875	7.25	32.63	0.1	337,893	—
4340-14-B	2.5	MIC	L1-4A	70.00	38.500	7.00	31.50	0.1	706,844	—
4340-15-B	2.5	MIC	L1-4A	70.00	38.500	7.00	31.50	0.1	2,944,173	Runout
4340-18-B	2.5	MIC	L1-4A	75.00	41.250	7.50	33.75	0.1	199,855	—
4340-1-B	2.5	MIC	L2-8A	70.00	38.500	7.00	31.50	0.1	383,874	—
4340-2-B	2.5	MIC	L2-8A	70.00	38.500	7.00	31.50	0.1	—	—
4340-6-B	2.5	MIC	L2-8A	75.00	41.250	7.50	33.75	0.1	210,298	—
4340-9-B	2.5	MIC	L2-8A	82.50	45.375	8.25	37.13	0.1	86,306	—
4340-10-B	2.5	MIC	L2-8A	71.25	39.188	7.13	32.06	0.1	517,496	—
4340-13-B	2.5	MIC	L2-8A	70.00	38.500	7.00	31.50	0.1	2,031,085	—
4340-16-B	2.5	MIC	L2-8A	71.25	39.188	7.13	32.06	0.1	536,196	—
4340-17-B	2.5	MIC	L2-8A	77.50	42.625	7.75	34.88	0.1	124,409	—
4340-19-B	2.5	MIC	L2-8A	72.50	39.875	7.25	32.63	0.1	340,550	—
4340-20-B	2.5	MIC	L2-8A	72.50	39.875	7.25	32.63	0.1	326,245	—
4340-22-B	2.5	CCAD	H1-12A	82.5	43.75	8.25	37.13	0.1	—	—
4340-26-B	2.5	CCAD	H1-12A	70.00	38.500	7.00	31.50	0.1	243,887	—
4340-27-B	2.5	CCAD	H1-12A	75.00	41.250	7.50	33.75	0.1	165,572	—
4340-33-B	2.5	CCAD	H1-12A	71.25	39.188	7.13	32.06	0.1	301,362	—
4340-34-B	2.5	CCAD	H1-12A	71.25	39.188	7.13	32.06	0.1	—	—
4340-36-B	2.5	CCAD	H1-12A	70.00	38.500	7.00	31.50	0.1	2,000,000	Runout
4340-37-B	2.5	CCAD	H1-12A	67.5	37.125	6.75	30.38	0.1	—	—
4340-38-B	2.5	CCAD	H1-12A	77.50	42.625	7.75	34.88	0.1	116,576	—
4340-40-B	2.5	CCAD	H1-12A	72.50	39.875	7.25	32.63	0.1	282,757	—
4340-42-B	2.5	CCAD	H1-12A	72.50	39.875	7.25	32.63	0.1	154,854	—
4340-43-B	2.5	CCAD	L2-8A	70.00	38.500	7.00	31.50	0.1	308,123	—
4340-44-B	2.5	CCAD	L2-8A	67.50	37.125	6.75	30.38	0.1	—	—
4340-48-B	2.5	CCAD	L2-8A	75.00	41.250	7.50	33.75	0.1	181,852	—
4340-50-B	2.5	CCAD	L2-8A	67.50	37.125	6.75	30.38	0.1	584,601	—
4340-51-B	2.5	CCAD	L2-8A	66.25	36.438	6.63	29.81	0.1	617,419	—
4340-52-B	2.5	CCAD	L2-8A	68.75	37.813	6.88	30.94	0.1	339,621	—
4340-54-B	2.5	CCAD	L2-8A	82.50	45.375	8.25	37.13	0.1	77,623	—
4340-59-B	2.5	CCAD	L2-8A	77.50	42.625	7.75	34.88	0.1	172,120	—
4340-60-B	2.5	CCAD	L2-8A	72.50	39.875	7.25	32.63	0.1	231,737	—
4340-66-B	2.5	CCAD	L2-8A	65.00	35.75	6.50	29.25	0.1	2,627,337	Runout
4340-53-B	2.5	CCAD	L1-4A	68.75	37.813	6.88	30.94	0.1	3,700,402	Runout
4340-55-B	2.5	CCAD	L1-4A	82.50	45.375	8.25	37.13	0.1	89,015	—
4340-56-B	2.5	CCAD	L1-4A	68.75	37.813	6.88	30.94	0.1	—	—
4340-61-B	2.5	CCAD	L1-4A	77.50	42.625	7.75	34.88	0.1	193,184	—
4340-62-B	2.5	CCAD	L1-4A	75.00	41.250	7.50	33.75	0.1	228,445	—
4340-63-B	2.5	CCAD	L1-4A	72.50	39.875	7.25	32.63	0.1	191,406	—
4340-64-B	2.5	CCAD	L1-4A	72.50	39.875	7.25	32.63	0.1	232,297	—
4340-67-B	2.5	CCAD	L1-4A	70.00	38.500	7.00	31.50	0.1	532,641	—
4340-69-B	2.5	CCAD	L1-4A	70.00	38.500	7.00	31.50	0.1	943,146	—
4340-70-B	2.5	CCAD	L1-4A	75.00	41.250	7.50	33.75	0.1	226,525	—

Note: NA = not applicable.

Table 24. The 9310 steel, $K_t = 1$ cyclic fatigue data.

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
9310-1-A	1	None	NA	160.00	88.000	16.00	72.00	0.1	41,997	—
9310-2-A	1	None	NA	145.00	79.750	14.50	65.25	0.1	156,859	—
9310-3-A	1	None	NA	140.00	77.000	14.00	63.00	0.1	2,000,000	—
9310-4-A	1	None	NA	150.00	82.500	15.00	67.50	0.1	199,652	—
9310-5-A	1	None	NA	155.00	85.250	15.50	69.75	0.1	63,461	—
9310-6-A	1	None	NA	150.00	82.500	15.00	67.50	0.1	125,131	—
9310-7-A	1	None	NA	145.00	79.750	14.50	65.25	0.1	190,867	—
9310-8-A	1	None	NA	141.25	77.688	14.13	63.56	0.1	5,125,807	—
9310-9-A	1	None	NA	142.50	78.375	14.25	64.13	0.1	206,432	—
9310-10-A	1	None	NA	142.50	78.375	14.25	64.13	0.1	415,291	—
9310-21-A	1	CCAD	H1-12A	138.50	76.175	13.85	62.33	0.1	255,684	—
9310-22-A	1	CCAD	H1-12A	146.25	80.438	14.63	65.81	0.1	108,089	—
9310-23-A	1	CCAD	H1-12A	140.00	77.000	14.00	63.00	0.1	211,183	—
9310-24-A	1	CCAD	H1-12A	150.00	82.500	15.00	67.50	0.1	113,847	—
9310-25-A	1	CCAD	H1-12A	155.00	85.250	15.50	69.75	0.1	59,923	—
9310-26-A	1	CCAD	H1-12A	150.00	82.500	15.00	67.50	0.1	117,558	—
9310-27-A	1	CCAD	H1-12A	146.25	80.438	14.63	65.81	0.1	163,718	—
9310-28-A	1	CCAD	H1-12A	135.00	74.250	13.50	60.75	0.1	213,486	—
9310-29-A	1	CCAD	H1-12A	142.50	78.375	14.25	64.13	0.1	75,935	—
9310-30-A	1	CCAD	H1-12A	142.50	78.375	14.25	64.13	0.1	102,802	—
9310-31-A	1	CCAD	L2-8A	143.75	79.063	14.38	64.69	0.1	172,244	—
9310-32-A	1	CCAD	L2-8A	145.00	79.750	14.50	65.25	0.1	166,589	—
9310-33-A	1	CCAD	L2-8A	143.75	79.063	14.38	64.69	0.1	408,664	—
9310-34-A	1	CCAD	L2-8A	150.00	82.500	15.00	67.50	0.1	90,351	—
9310-35-A	1	CCAD	L2-8A	155.00	85.250	15.50	69.75	0.1	51,459	—
9310-36-A	1	CCAD	L2-8A	147.50	81.125	14.75	66.38	0.1	137,454	—
9310-37-A	1	CCAD	L2-8A	145.00	79.750	14.50	65.25	0.1	240,596	—
9310-38-A	1	CCAD	L2-8A	147.50	81.125	14.75	66.38	0.1	—	—
9310-39-A	1	CCAD	L2-8A	142.50	78.375	14.25	64.13	0.1	2,014,875	Runout
9310-40-A	1	CCAD	L2-8A	142.50	78.375	14.25	64.13	0.1	—	—
9310-41-A	1	CCAD	L1-4A	160.00	88.000	16.00	72.00	0.1	38,911	—
9340-42-A	1	CCAD	L1-4A	146.25	80.438	14.63	65.81	0.1	1,960,009	—
9310-43-A	1	CCAD	L1-4A	146.25	80.438	14.63	65.81	0.1	763,224	—
9310-44-A	1	CCAD	L1-4A	150.00	82.500	15.00	67.50	0.1	167,240	—
9310-45-A	1	CCAD	L1-4A	155.00	85.250	15.50	69.75	0.1	70,597	—
9310-46-A	1	CCAD	L1-4A	150.00	82.500	15.00	67.50	0.1	161,326	—
9310-47-A	1	CCAD	L1-4A	145.00	79.750	14.50	65.25	0.1	2,918,507	—
9310-48-A	1	CCAD	L1-4A	147.50	81.125	14.75	66.38	0.1	269,456	—
9310-49-A	1	CCAD	L1-4A	142.50	78.375	14.25	64.13	0.1	—	—
9310-50-A	1	CCAD	L1-4A	147.50	81.125	14.75	66.38	0.1	—	—
9310-51-A	1	MIC	L1-4A	160.00	88.000	16.00	72.00	0.1	61,817	—
9310-52-A	1	MIC	L1-4A	146.25	80.438	14.63	65.81	0.1	352,983	—
9310-53-A	1	MIC	L1-4A	146.25	80.438	14.63	65.81	0.1	169,247	—
9310-54-A	1	MIC	L1-4A	150.00	82.500	15.00	67.50	0.1	112,057	—
9310-55-A	1	MIC	L1-4A	155.00	85.250	15.50	69.75	0.1	67,760	—
9310-56-A	1	MIC	L1-4A	150.00	82.500	15.00	67.50	0.1	175,080	—
9310-57-A	1	MIC	L1-4A	145.00	79.750	14.50	65.25	0.1	2,000,000	Runout
9310-58-A	1	MIC	L1-4A	147.50	81.125	14.75	66.38	0.1	110,535	—
9310-59-A	1	MIC	L1-4A	142.50	78.375	14.25	64.13	0.1	2,003,023	Runout
9310-60-A	1	MIC	L1-4A	147.50	81.125	14.75	66.38	0.1	115,625	—
9310-61-A	1	MIC	L2-8A	138.75	76.313	13.88	62.44	0.1	1,605,295	—
9310-62-A	1	MIC	L2-8A	145.00	79.750	14.50	65.25	0.1	111,416	—
9310-63-A	1	MIC	L2-8A	140.00	77.000	14.00	63.00	0.1	342,495	—
9310-64-A	1	MIC	L2-8A	150.00	82.500	15.00	67.50	0.1	93,138	—
9310-65-A	1	MIC	L2-8A	155.00	85.250	15.50	69.75	0.1	85,438	—
9310-66-A	1	MIC	L2-8A	150.00	82.500	15.00	67.50	0.1	89,570	—
9310-67-A	1	MIC	L2-8A	145.00	79.750	14.50	65.25	0.1	105,252	—
9310-68-A	1	MIC	L2-8A	141.25	77.688	14.13	63.56	0.1	367,467	—
9310-69-A	1	MIC	L2-8A	142.50	78.375	14.25	64.13	0.1	174,595	—
9310-70-A	1	MIC	L2-8A	142.50	78.375	14.25	64.13	0.1	139,102	—

Note: NA = not applicable.

Table 25. The 9310 steel, K_t = 1.75 cyclic fatigue data.

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
9310-1-C	1.75	None	NA	125.00	68.750	12.50	56.25	0.1	31,404	—
9310-2-C	1.75	None	NA	110.00	60.500	11.00	49.50	0.1	1,817,909	—
9310-3-C	1.75	None	NA	120.00	66.000	12.00	54.00	0.1	46,551	—
9310-4-C	1.75	None	NA	115.00	63.250	11.50	51.75	0.1	68,819	—
9310-5-C	1.75	None	NA	117.50	64.625	11.75	52.88	0.1	59,168	—
9310-6-C	1.75	None	NA	115.00	63.250	11.50	51.75	0.1	64,773	—
9310-7-C	1.75	None	NA	117.50	64.625	11.75	52.88	0.1	58,548	—
9310-8-C	1.75	None	NA	111.25	61.188	11.13	50.06	0.1	387,337	—
9310-9-C	1.75	None	NA	112.50	61.875	11.25	50.63	0.1	107,569	—
9310-10-C	1.75	None	NA	112.50	61.875	11.25	50.63	0.1	97,504	—
9310-21-C	1.75	CCAD	L2-8A	100.00	55.00	10.00	45.00	0.1	81,136	—
9310-22-C	1.75	CCAD	L2-8A	110.00	60.50	11.00	49.50	0.1	81,123	—
9310-23-C	1.75	CCAD	L2-8A	85.00	46.75	8.50	38.25	0.1	2,958,458	—
9310-24-C	1.75	CCAD	L2-8A	85.00	46.75	8.50	38.25	0.1	8,953,417	—
9310-25-C	1.75	CCAD	L2-8A	95.00	52.25	9.50	42.75	0.1	196,907	—
9310-26-C	1.75	CCAD	L2-8A	100.00	55.00	10.00	45.00	0.1	99,901	—
9310-27-C	1.75	CCAD	L2-8A	87.50	48.125	8.75	39.375	0.1	229,476	—
9310-28-C	1.75	CCAD	L2-8A	92.50	50.875	9.25	41.625	0.1	123,509	—
9310-29-C	1.75	CCAD	L2-8A	82.50	45.375	8.25	37.125	0.1	—	—
9310-30-C	1.75	CCAD	L2-8A	90.00	49.50	9.00	40.50	0.1	212,180	—
9310-31-C	1.75	CCAD	H1-12A	100.00	55.00	10.00	45.00	0.1	103,561	—
9310-32-C	1.75	CCAD	H1-12A	88.75	48.813	8.875	39.94	0.1	6,441,532	Runout
9310-33-C	1.75	CCAD	H1-12A	95.00	52.25	9.50	42.75	0.1	126,466	—
9310-34-C	1.75	CCAD	H1-12A	85.00	46.75	8.500	38.25	0.1	196,623	—
9310-35-C	1.75	CCAD	H1-12A	95.00	52.25	9.500	42.75	0.1	96,063	—
9310-36-C	1.75	CCAD	H1-12A	100.00	55.00	10.00	45.00	0.1	132,355	—
9310-37-C	1.75	CCAD	H1-12A	90.00	49.50	9.00	40.50	0.1	131,4010	—
9310-38-C	1.75	CCAD	H1-12A	87.5	48.125	8.75	39.38	0.1	5,412,206	Runout
9310-39-C	1.75	CCAD	H1-12A	87.5	48.125	8.75	39.38	0.1	1,009,908	—
9310-40-C	1.75	CCAD	H1-12A	82.5	45.375	8.25	37.125	0.1	2,104,868	Runout
9310-41-C	1.75	CCAD	L1-4A	95.00	52.250	9.50	42.75	0.1	1,759,797	Runout
9340-42-C	1.75	CCAD	L1-4A	110.00	60.500	11.00	49.50	0.1	83,710	—
9310-43-C	1.75	CCAD	L1-4A	120.00	66.000	12.00	54.00	0.1	55,933	—
9310-44-C	1.75	CCAD	L1-4A	100.00	55.000	10.00	45.00	0.1	2,000,010	Runout
9310-45-C	1.75	CCAD	L1-4A	100.00	55.000	10.00	45.00	0.1	157,982	—
9310-46-C	1.75	CCAD	L1-4A	115.00	63.250	11.50	51.75	0.1	84,132	—
9310-47-C	1.75	CCAD	L1-4A	105.00	57.750	10.50	47.25	0.1	152,394	—
9310-48-C	1.75	CCAD	L1-4A	111.25	61.188	11.13	50.06	0.1	95,683	—
9310-49-C	1.75	CCAD	L1-4A	112.50	61.875	11.25	50.63	0.1	110,910	—
9310-50-C	1.75	CCAD	L1-4A	97.50	53.625	9.75	43.88	0.1	317,703	—
9310-51-C	1.75	MIC	L2-8A	110.00	60.500	11.00	49.50	0.1	68,838	—
9310-52-C	1.75	MIC	L2-8A	110.00	60.500	11.00	49.50	0.1	59,007	—
9310-53-C	1.75	MIC	L2-8A	105.00	57.750	10.50	47.25	0.1	115,808	—
9310-54-C	1.75	MIC	L2-8A	115.00	63.250	11.50	51.75	0.1	48,461	—
9310-55-C	1.75	MIC	L2-8A	100.00	55.000	10.00	45.00	0.1	128,296	—
9310-56-C	1.75	MIC	L2-8A	95.00	52.250	9.50	42.75	0.1	286,098	—
9310-57-C	1.75	MIC	L2-8A	92.50	50.875	9.25	41.63	0.1	600,239	—
9310-58-C	1.75	MIC	L2-8A	100.00	55.000	10.00	45.00	0.1	85,478	—
9310-59-C	1.75	MIC	L2-8A	95.00	52.250	9.50	42.75	0.1	221,427	—
9310-60-C	1.75	MIC	L2-8A	91.25	50.188	9.13	41.06	0.1	762,400	—
9310-61-C	1.75	MIC	L1-4A	110.00	60.500	11.00	49.50	0.1	78,157	—
9310-62-C	1.75	MIC	L1-4A	110.00	60.500	11.00	49.50	0.1	94,958	—
9310-63-C	1.75	MIC	L1-4A	105.00	57.750	10.50	47.25	0.1	151,786	—
9310-64-C	1.75	MIC	L1-4A	115.00	63.250	11.50	51.75	0.1	57,553	—
9310-65-C	1.75	MIC	L1-4A	100.00	55.000	10.00	45.00	0.1	137,477	—
9310-66-C	1.75	MIC	L1-4A	95.00	52.250	9.50	42.75	0.1	302,310	—
9310-67-C	1.75	MIC	L1-4A	90.00	49.500	9.00	40.50	0.1	2,075,994	Runout
9310-68-C	1.75	MIC	L1-4A	100.00	55.000	10.00	45.00	0.1	230,498	—
9310-69-C	1.75	MIC	L1-4A	112.50	61.875	11.25	50.63	0.1	53,518	—
9310-70-C	1.75	MIC	L1-4A	112.50	61.875	11.25	50.63	0.1	59,598	—

Note: NA = not applicable.

Table 26. The 9310 steel, K_t = 2.5 cyclic fatigue data.

Specimen No.	K_t	Vendor	SP Intensity	Max Stress	Mean Stress	Min Stress	Stress Amplitude	R	Cycles	Notes
9310-1-B	2.5	None	NA	80.00	44.000	8.00	36.00	0.1	77,373	—
9310-2-B	2.5	None	NA	77.50	42.625	7.75	34.88	0.1	98,148	—
9310-3-B	2.5	None	NA	85.00	46.750	8.50	38.25	0.1	54,437	—
9310-4-B	2.5	None	NA	68.75	37.813	6.88	30.94	0.1	511,932	—
9310-5-B	2.5	None	NA	77.50	42.625	7.75	34.88	0.1	127,446	—
9310-6-B	2.5	None	NA	72.50	39.875	7.25	32.63	0.1	167,141	—
9310-7-B	2.5	None	NA	68.75	37.813	6.88	30.94	0.1	374,576	—
9310-8-B	2.5	None	NA	70.00	38.500	7.00	31.50	0.1	222,092	—
9310-9-B	2.5	None	NA	72.50	39.875	7.25	32.63	0.1	175,992	—
9310-10-B	2.5	None	NA	67.50	37.125	6.75	30.38	0.1	2,000,000	Runout
9310-31-B	2.5	CCAD	L1-4A	80.00	44.000	8.00	36.00	0.1	172,478	—
9310-32-B	2.5	CCAD	L1-4A	77.50	42.625	7.75	34.88	0.1	146,616	—
9310-33-B	2.5	CCAD	L1-4A	85.00	46.750	8.50	38.25	0.1	138,638	—
9310-34-B	2.5	CCAD	L1-4A	75.00	41.250	7.50	33.75	0.1	160,758	—
9310-35-B	2.5	CCAD	L1-4A	80.00	44.000	8.00	36.00	0.1	163,305	—
9310-36-B	2.5	CCAD	L1-4A	72.50	39.875	7.25	32.63	0.1	4,528,839	Runout
9310-37-B	2.5	CCAD	L1-4A	77.50	42.625	7.75	34.88	0.1	202,582	—
9310-38-B	2.5	CCAD	L1-4A	75.00	41.250	7.50	33.75	0.1	247,736	—
9310-39-B	2.5	CCAD	L1-4A	72.50	39.875	7.25	32.63	0.1	2,963,727	Runout
9310-40-B	2.5	CCAD	L1-4A	75.00	41.250	7.50	33.75	0.1	312,731	—
9310-21-B	2.5	CCAD	L2-8A	80.00	44.000	8.00	36.00	0.1	116,105	—
9310-22-B	2.5	CCAD	L2-8A	77.50	42.625	7.75	34.88	0.1	195,493	—
9310-23-B	2.5	CCAD	L2-8A	85.00	46.750	8.50	38.25	0.1	87,364	—
9310-24-B	2.5	CCAD	L2-8A	76.25	41.938	7.625	34.31	0.1	165,837	—
9310-25-B	2.5	CCAD	L2-8A	77.50	42.625	7.75	34.88	0.1	445,487	—
9310-26-B	2.5	CCAD	L2-8A	72.50	39.875	7.25	32.63	0.1	592,776	—
9310-27-B	2.5	CCAD	L2-8A	75.00	41.250	7.50	33.75	0.1	176,153	—
9310-28-B	2.5	CCAD	L2-8A	70.00	38.500	7.00	31.50	0.1	2,698,518	Runout
9310-29-B	2.5	CCAD	L2-8A	72.50	39.875	7.25	32.63	0.1	365,850	—
9310-30-B	2.5	CCAD	L2-8A	73.75	40.563	7.38	33.19	0.1	284,954	—
9310-51-B	2.5	MIC	L1-4A	80.00	44.000	8.00	36.00	0.1	78,723	—
9310-52-B	2.5	MIC	L1-4A	77.50	42.625	7.75	34.88	0.1	135,923	—
9310-53-B	2.5	MIC	L1-4A	85.00	46.750	8.50	38.25	0.1	72,009	—
9310-54-B	2.5	MIC	L1-4A	80.00	44.000	8.00	36.00	0.1	89,883	—
9310-55-B	2.5	MIC	L1-4A	77.50	42.625	7.75	34.88	0.1	134,907	—
9310-56-B	2.5	MIC	L1-4A	72.50	39.875	7.25	32.63	0.1	6,302,535	—
9310-57-B	2.5	MIC	L1-4A	75.00	41.250	7.50	33.75	0.1	584,702	—
9310-58-B	2.5	MIC	L1-4A	87.50	48.125	8.75	39.38	0.1	51,682	—
9310-59-B	2.5	MIC	L1-4A	73.75	40.563	7.38	33.19	0.1	781,901	—
9310-60-B	2.5	MIC	L1-4A	75.00	41.250	7.50	33.75	0.1	303,454	—
9310-41-B	2.5	CCAD	H1-12A	80.00	44.000	8.00	36.00	0.1	172,449	—
9340-42-B	2.5	CCAD	H1-12A	70.00	38.500	7.00	31.50	0.1	8,888,058	Runout
9310-43-B	2.5	CCAD	H1-12A	70.00	38.500	7.00	31.50	0.1	162,139	—
9310-44-B	2.5	CCAD	H1-12A	75.00	41.250	7.50	33.75	0.1	255,045	—
9310-45-B	2.5	CCAD	H1-12A	68.75	37.813	6.88	30.94	0.1	459,183	—
9310-46-B	2.5	CCAD	H1-12A	77.50	42.625	7.75	34.88	0.1	121,948	—
9310-47-B	2.5	CCAD	H1-12A	75.00	41.250	7.50	33.75	0.1	159,326	—
9310-48-B	2.5	CCAD	H1-12A	67.50	37.125	6.75	30.38	0.1	2,000,000	Runout
9310-49-B	2.5	CCAD	H1-12A	72.50	39.875	7.25	32.63	0.1	218,734	—
9310-50-B	2.5	CCAD	H1-12A	68.75	37.813	6.88	30.94	0.1		—
9310-61-B	2.5	MIC	L2-8A	80.00	44.000	8.00	36.00	0.1	250,848	—
9310-62-B	2.5	MIC	L2-8A	77.50	42.625	7.75	34.88	0.1	461,629	—
9310-66-B	2.5	MIC	L2-8A	72.50	39.875	7.25	32.63	0.1	1,404,100	—
9310-67-B	2.5	MIC	L2-8A	85.00	46.750	8.50	38.25	0.1	203,059	—
9310-69-B	2.5	MIC	L2-8A	72.50	39.875	7.25	32.63	0.1	2,860,975	Runout
9310-63-B	2.5	MIC	L2-8A	85.00	46.750	8.50	38.25	0.1	79,995	—
9310-64-B	2.5	MIC	L2-8A	72.50	39.875	7.25	32.63	0.1	584,702	—
9310-65-B	2.5	MIC	L2-8A	77.50	42.625	7.75	34.88	0.1	167,179	—
9310-68-B	2.5	MIC	L2-8A	71.25	39.188	7.13	32.06	0.1	1,210,223	—
9310-70-B	2.5	MIC	L2-8A	80.00	44.000	8.00	36.00	0.1	206,261	—

Note: NA = not applicable.

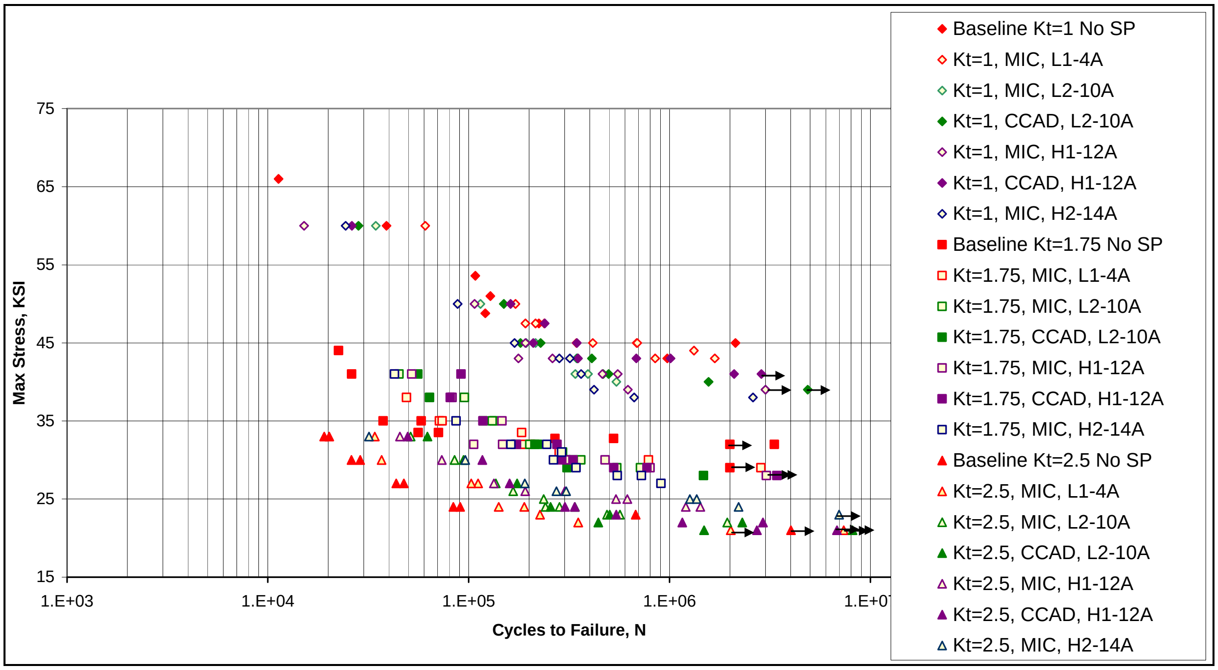


Figure 12. The 7075T-73 aluminum cyclic fatigue data.

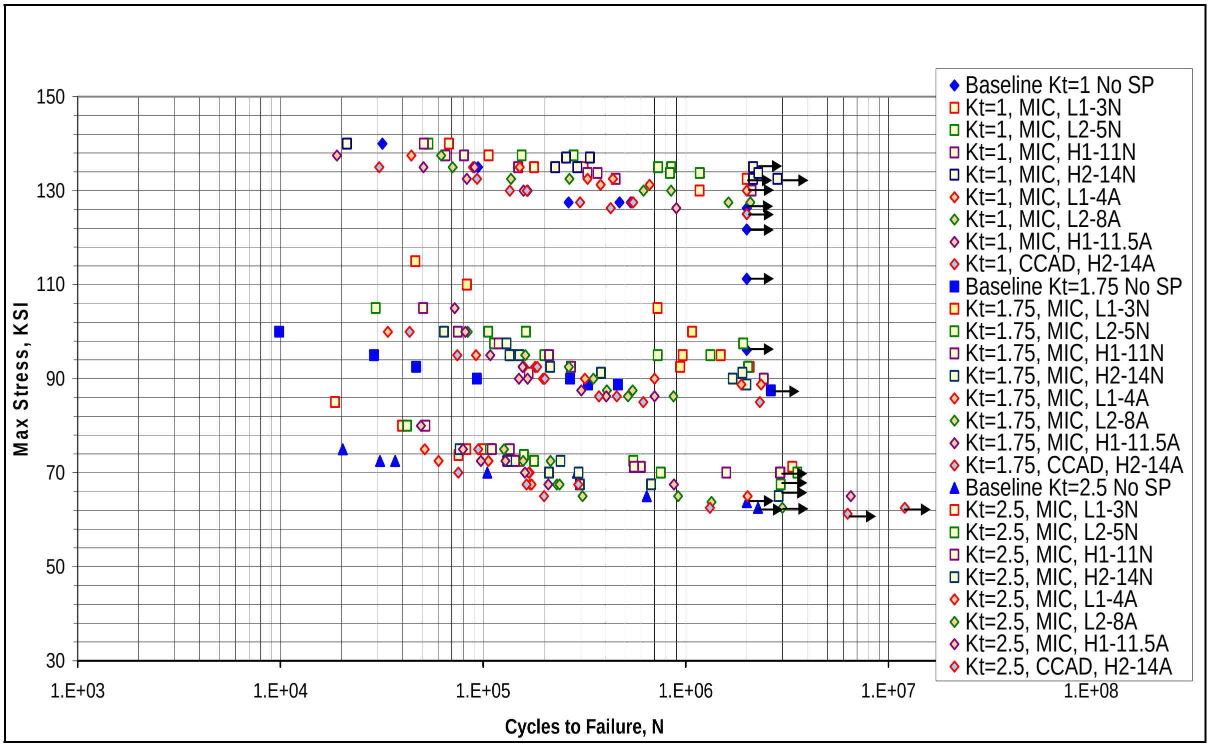


Figure 13. The beta-STOA titanium cyclic fatigue data.

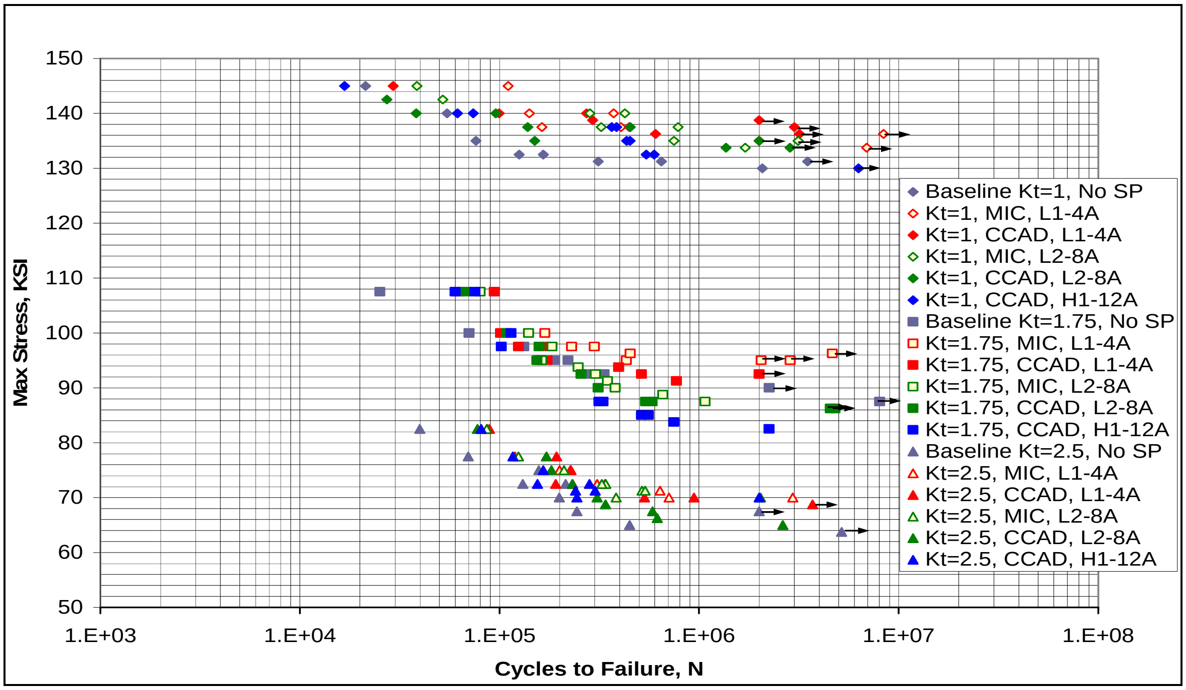


Figure 14. The 4340 steel cyclic fatigue data.

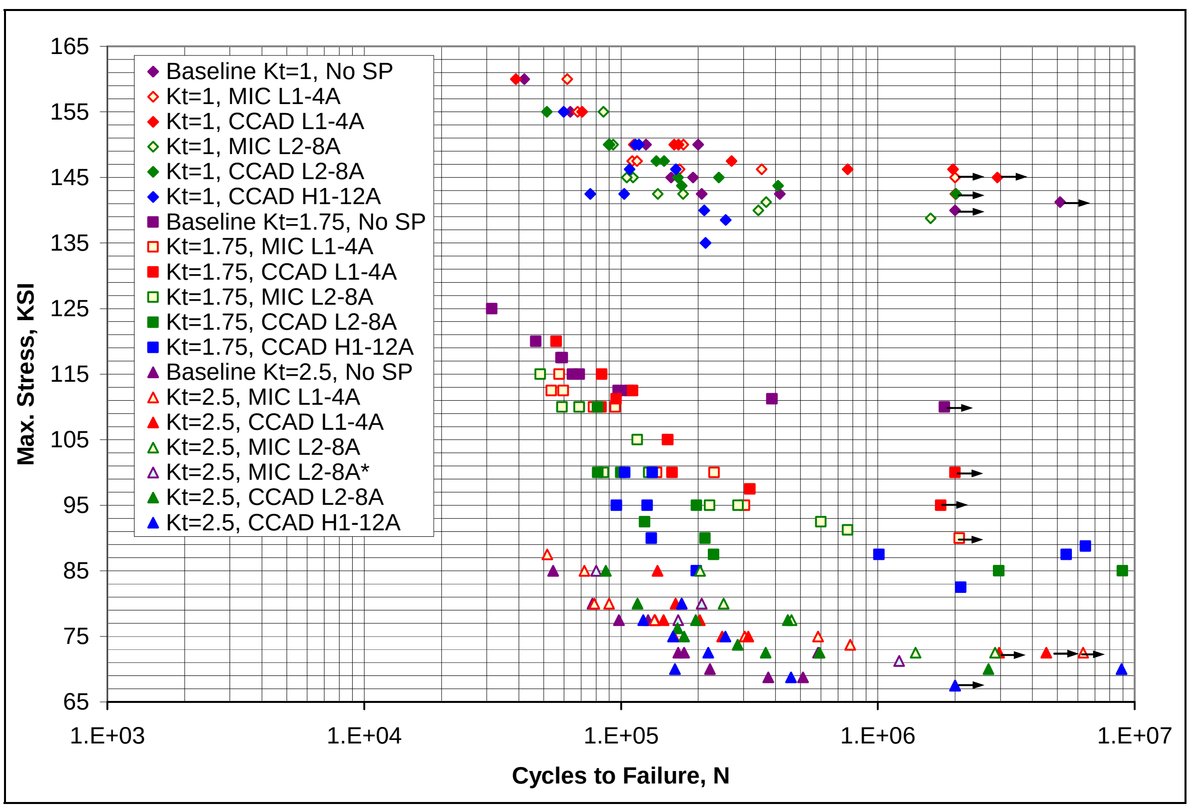


Figure 15. The 9310 steel cyclic fatigue data.

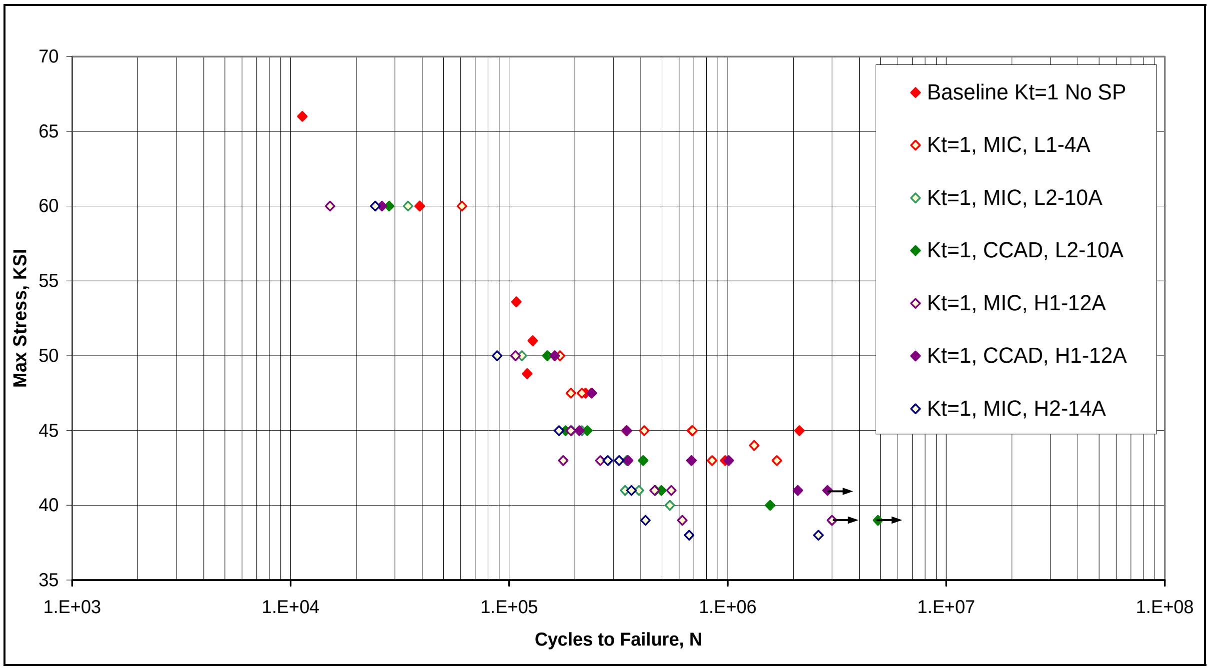


Figure 16. The 7075T-73 aluminum, K_t = 1 cyclic fatigue data.

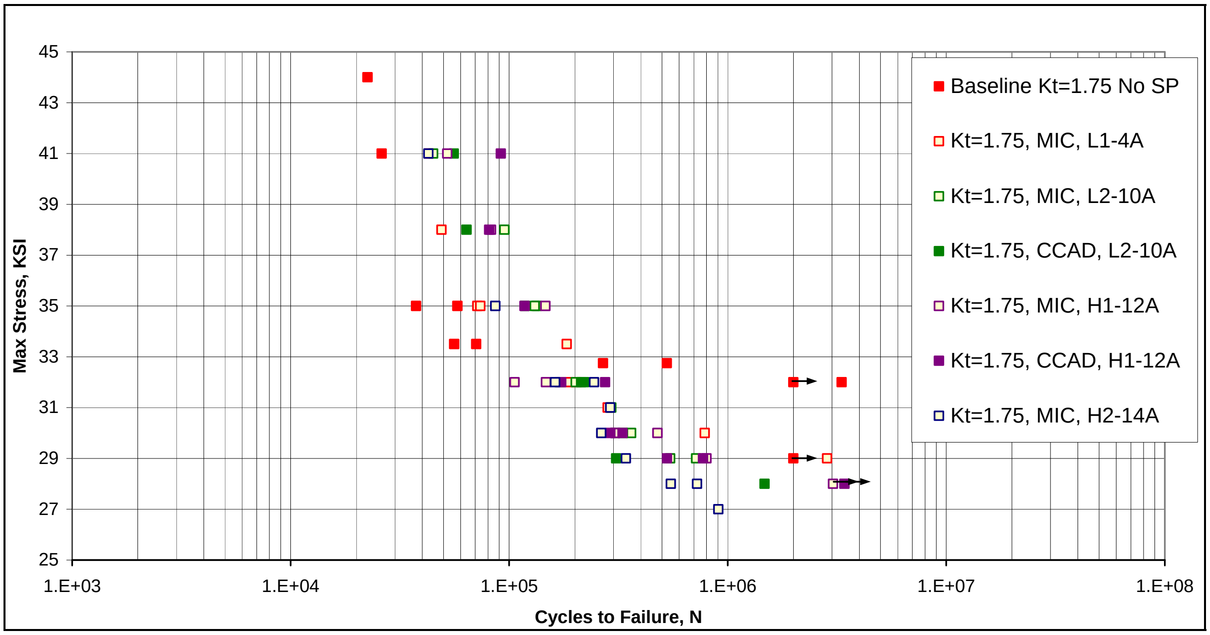


Figure 17. The 7075T-73 aluminum, K_t = 1.75 cyclic fatigue data.

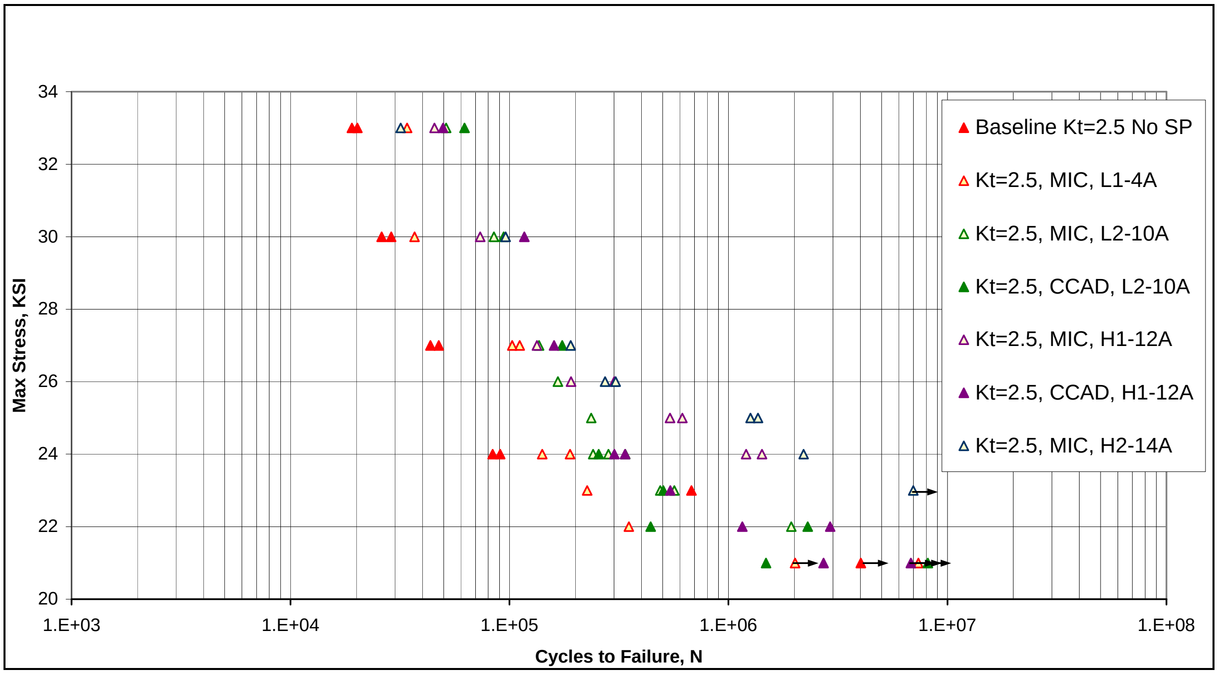


Figure 18. The 7075T-73 aluminum, $K_t = 2.5$ cyclic fatigue data.

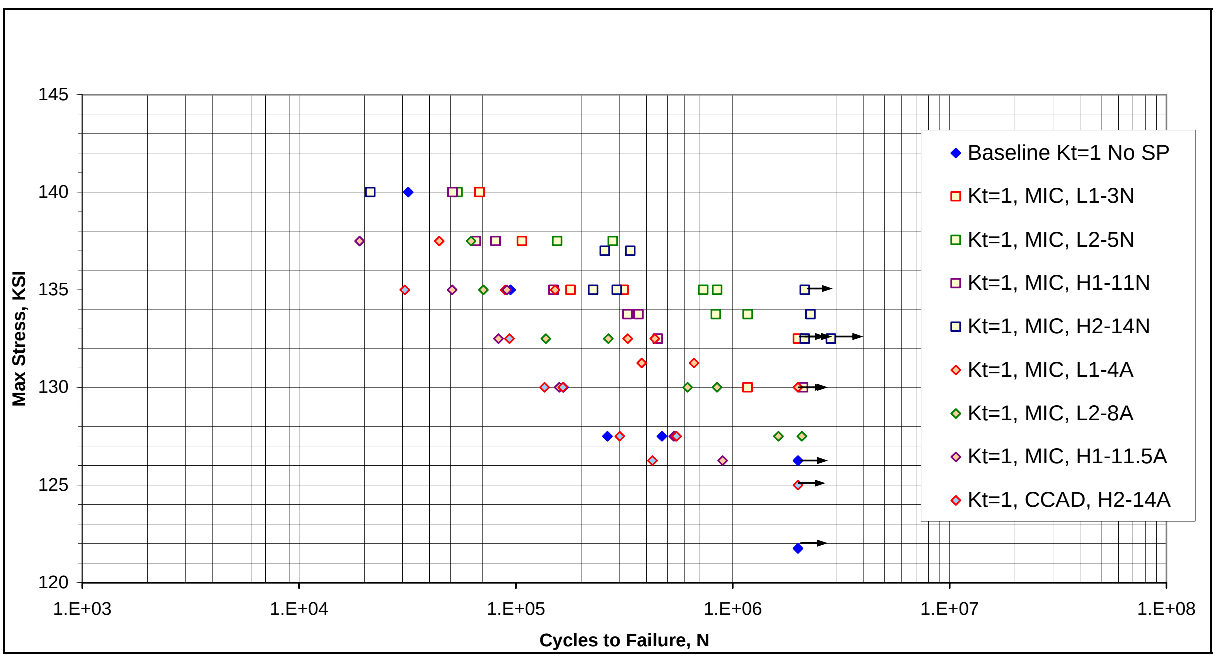


Figure 19. The beta-STOA titanium, $K_t = 1$ cyclic fatigue data.

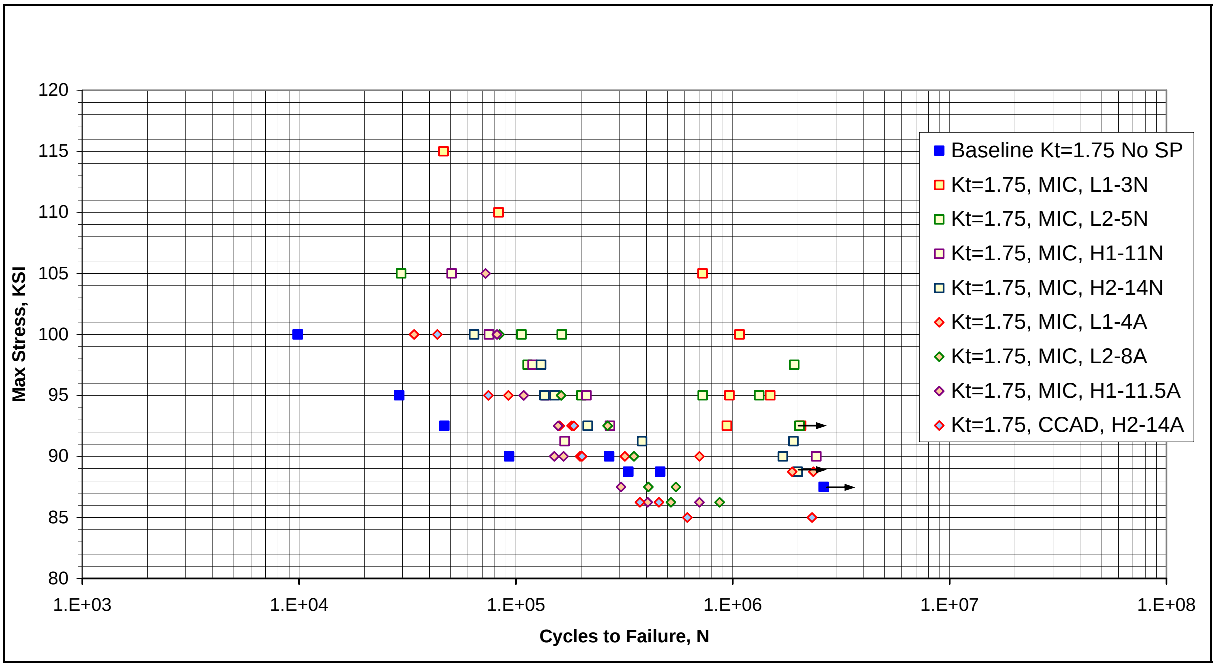


Figure 20. The beta-STOA titanium, K_t = 1.75 cyclic fatigue data.

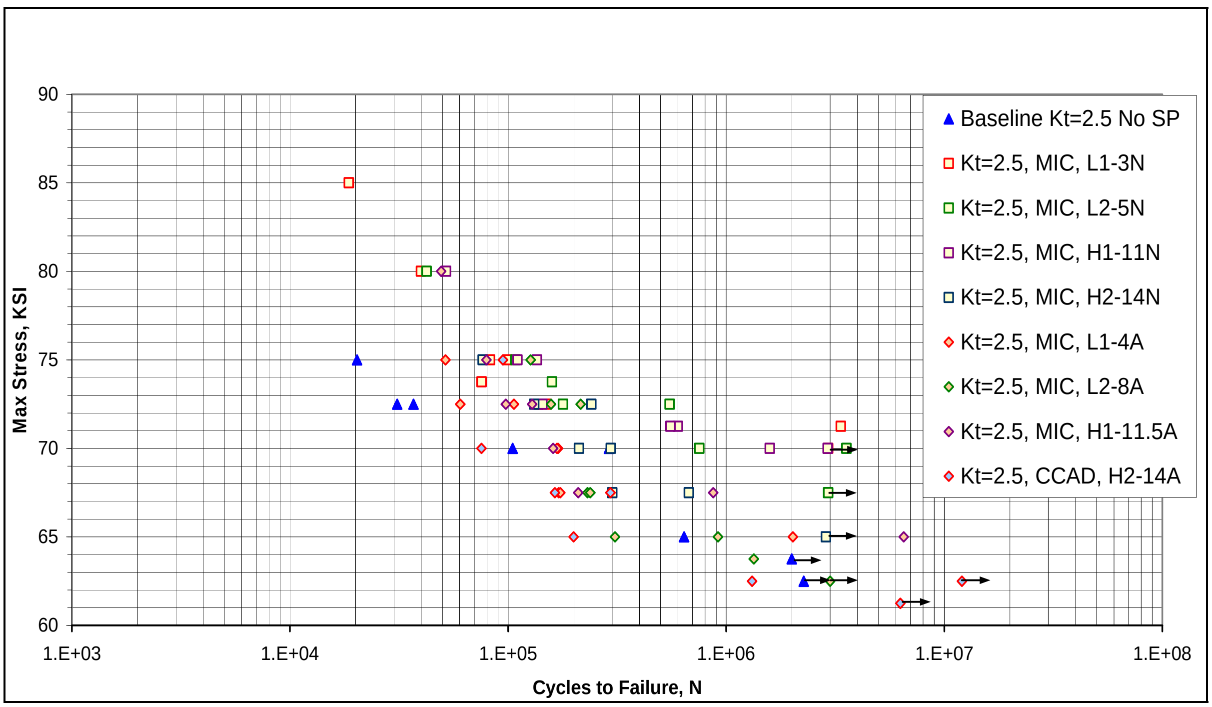


Figure 21. The beta-STOA titanium, K_t = 2.5 cyclic fatigue data.

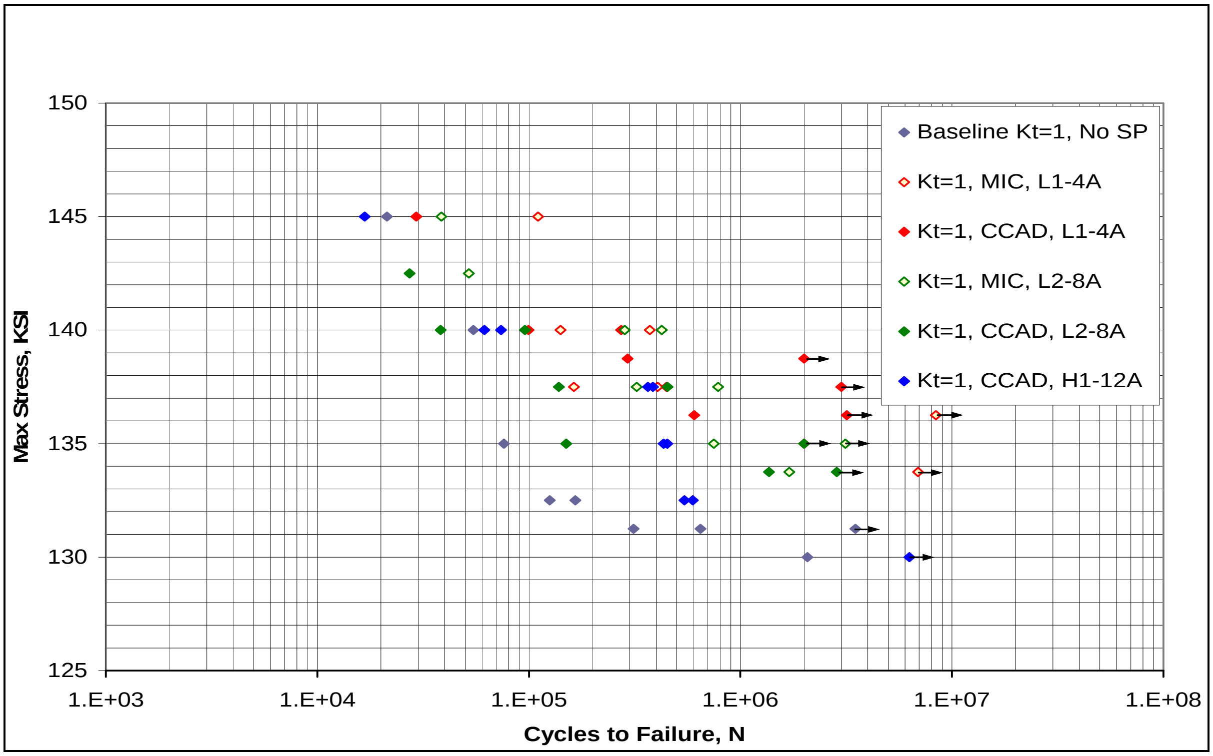


Figure 22. The 4340 steel, $K_t = 1$ cyclic fatigue data.

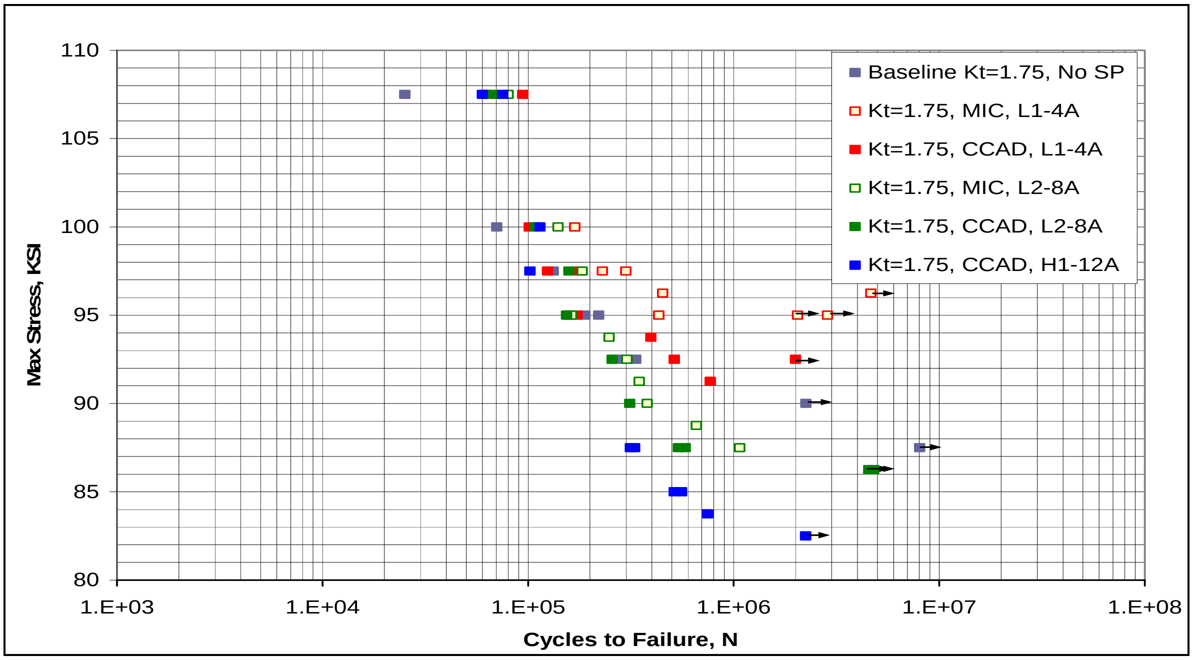


Figure 23. The 4340 steel, $K_t = 1.75$ cyclic fatigue data.

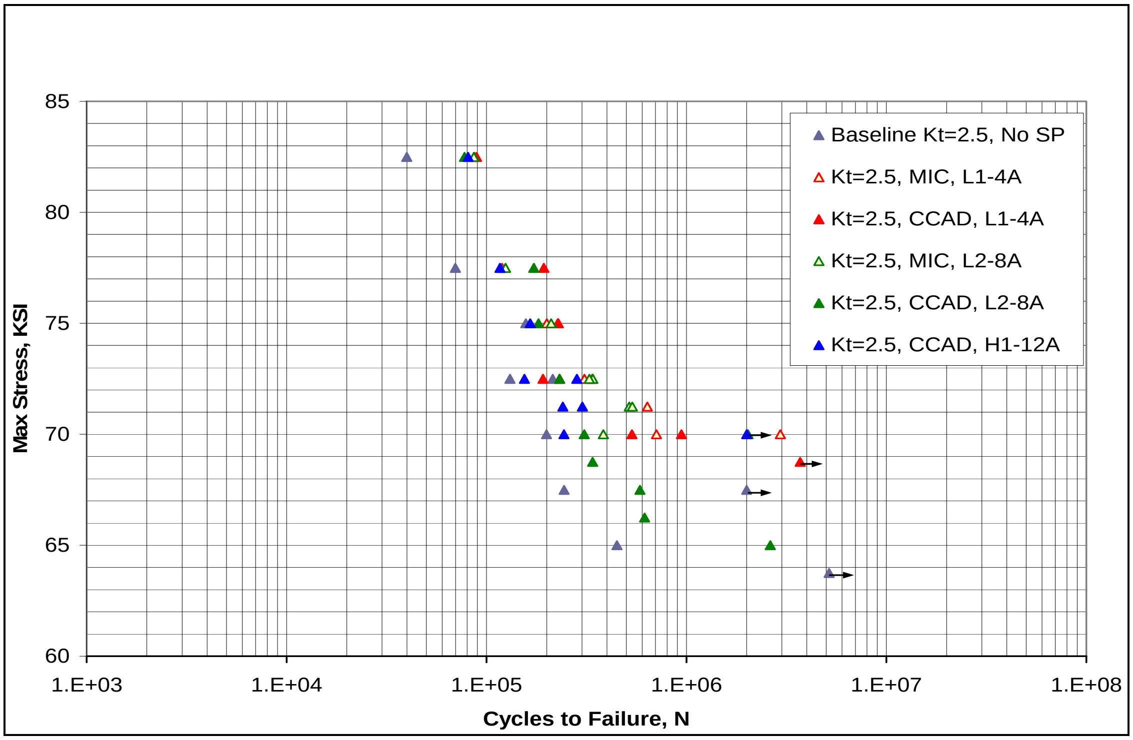


Figure 24. The 4340 steel, $K_t = 2.5$ cyclic fatigue data.

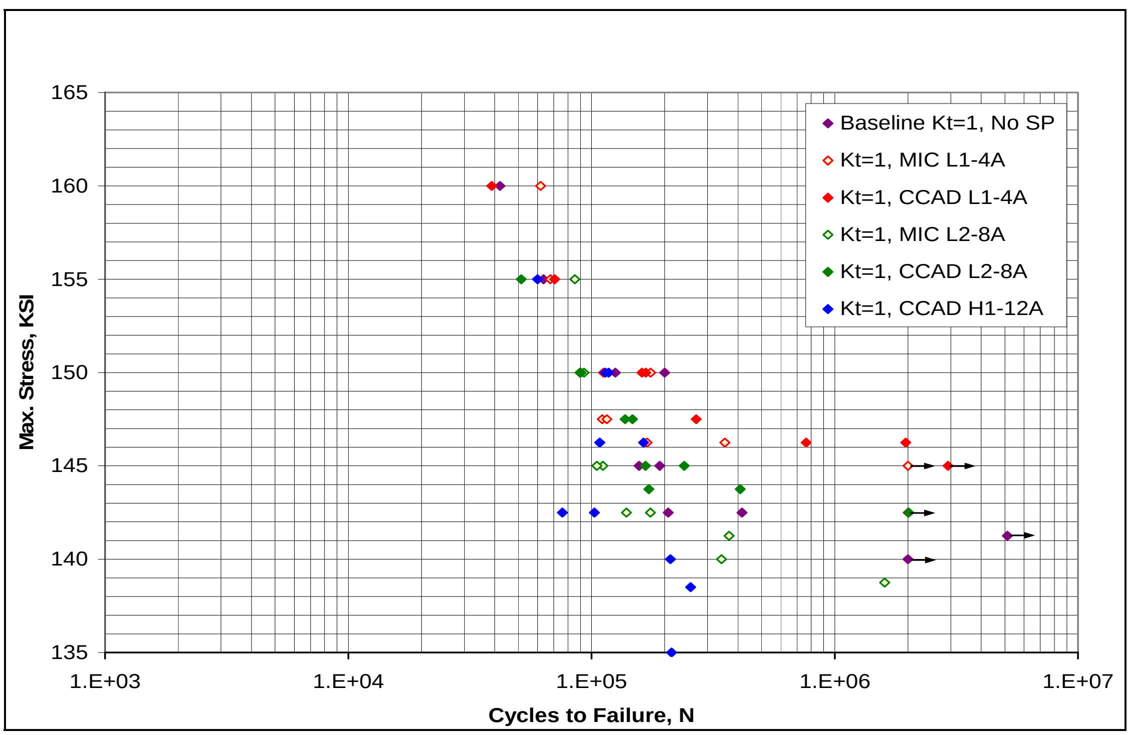


Figure 25. The 9310 steel, $K_t = 1$ cyclic fatigue data.

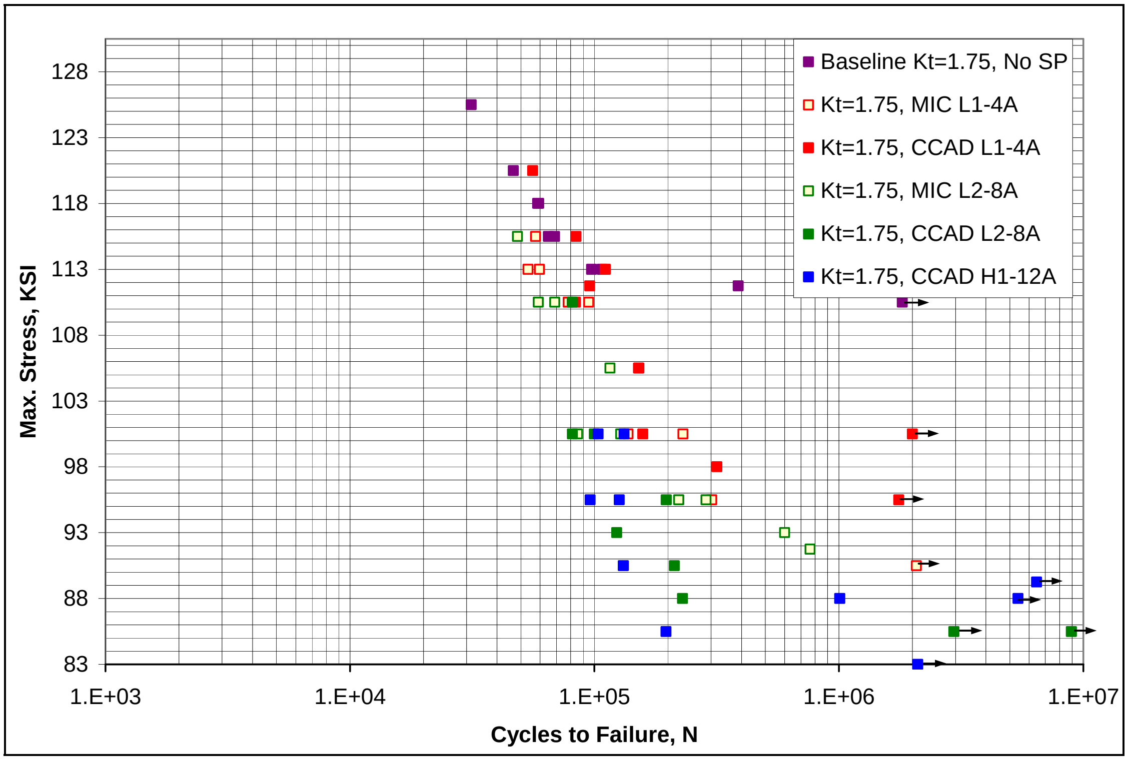


Figure 26. The 9310 steel, K_t = 1.75 cyclic fatigue data.

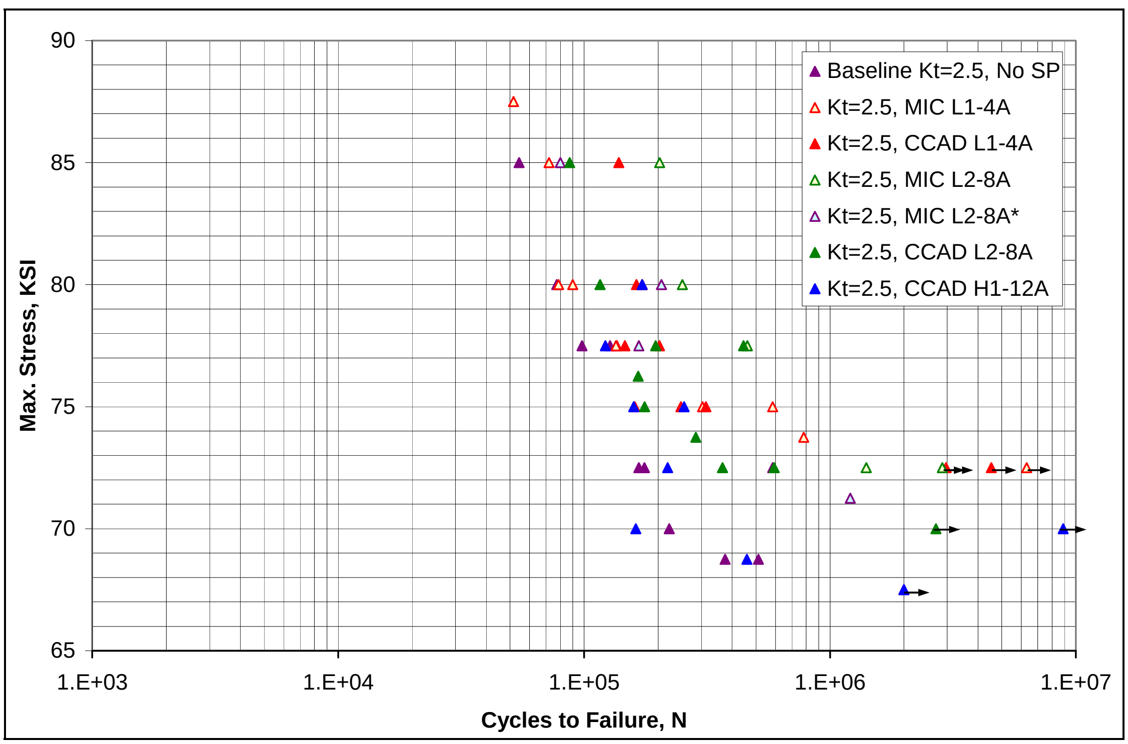


Figure 27. The 9310 steel, K_t = 2.5 cyclic fatigue data.

Table 27. Error in observed (as-collected) residual stress data.

Material	Disk Specimens		Fatigue Specimens	
	(ksi)	(MPa)	(ksi)	(MPa)
Aluminum 7075-T73	1.5	10.3	1.4	9.7
Titanium 6Al-4V	2.0	13.8	5.2	35.9
4340 steel	1.6	11.0	1.8	12.4
9310 steel	2.0	13.8	2.8	19.3

Table 28. The 7075-T73 aluminum XRD-RSA fatigue specimen data.

Specimen	Surface Condition	Orientation (°)	Stress (ksi)	Stress (MPa)
Al-2-C	Machined	0	–3.6	–24.9
Al-2-C	Machined	120	–1.9	–13.2
Al-2-C	Machined	240	–8.4	–58.1
Al-3-C	Machined	0	–8.1	–56.1
Al-3-C	Machined	120	–13.7	–94.7
Al-3-C	Machined	240	–6.1	–42.0
Al-8-B	MIC-4A	0	–33.1	–228.2
Al-8-B	MIC-4A	120	–35.4	–244.3
Al-8-B	MIC-4A	240	–33.7	–232.1
Al-42-B	MIC-4A	0	–36.9	–254.2
Al-42-B	MIC-4A	120	–34.4	–237.0
Al-42-B	MIC-4A	240	–38.6	–266.0
Al-30-B	MIC-10A	0	–28.3	–195.3
Al-30-B	MIC-10A	120	–28.1	–193.9
Al-30-B	MIC-10A	240	–26.5	–182.6
Al-34-B	MIC-10A	0	–29.8	–205.5
Al-34-B	MIC-10A	120	–28.1	–193.5
Al-34-B	MIC-10A	240	–29.4	–202.5
Al-36-B	MIC-12A	0	–24.9	–171.8
Al-36-B	MIC-12A	120	–21.3	–146.6
Al-36-B	MIC-12A	240	–22.6	–155.9
Al-70-B	MIC-12A	0	–25.6	–176.7
Al-70-B	MIC-12A	120	–25.1	–173.1
Al-70-B	MIC-12A	240	–24.9	–171.6
Al-48-B	MIC-14A	0	–23.8	–164.3
Al-48-B	MIC-14A	120	–21.7	–149.6
Al-48-B	MIC-14A	240	–19.7	–135.7
Al-53-B	MIC-14A	0	–23.7	–163.2
Al-53-B	MIC-14A	120	–23.5	–161.7
Al-53-B	MIC-14A	240	–20.6	–141.7
Al-57-B	CCAD-10A	0	–26.9	–185.4
Al-57-B	CCAD-10A	120	–27.3	–188.2
Al-57-B	CCAD-10A	240	–30.9	–212.8
Al-63-B	CCAD-10A	0	–31.4	–216.3
Al-63-B	CCAD-10A	120	–29.5	–203.2
Al-63-B	CCAD-10A	240	–26.8	–185.0
Al-79-B	CCAD-12A	0	–33.2	–229.2
Al-79-B	CCAD-12A	120	–35.2	–242.6
Al-79-B	CCAD-12A	240	–33.3	–229.6
Al-80-B	CCAD-12A	0	–32.8	–226.2
Al-80-B	CCAD-12A	120	–31.6	–217.7
Al-80-B	CCAD-12A	240	–30.1	–207.3

Table 29. The beta-STOA Ti-6-4 XRD-RSA fatigue specimen data.

Specimen	Surface Condition	Orientation (°)	Stress (ksi)	Stress (MPa)
Ti-18-C	Machined	0	–40.6	–279.9
Ti-18-C	Machined	120	–40.8	–281.6
Ti-18-C	Machined	240	–35.2	–242.5
Ti-19-C	Machined	0	–53.5	–369.0
Ti-19-C	Machined	120	–51.2	–352.8
Ti-19-C	Machined	240	–57.1	–393.8
Ti-15-C	MIC-4A	0	–79.2	–546.2
Ti-15-C	MIC-4A	120	–71.6	–493.8
Ti-15-C	MIC-4A	240	–87.3	–602.2
Ti-31-C	MIC-4A	0	–77.3	–532.7
Ti-31-C	MIC-4A	120	–62.7	–432.2
Ti-31-C	MIC-4A	240	–77.5	–534.5
Ti-36-C	MIC-8A	0	–66.8	–460.9
Ti-36-C	MIC-8A	120	–80.0	–551.7
Ti-36-C	MIC-8A	240	–80.4	–554.2
Ti-72-C	MIC-8A	0	–87.1	–600.9
Ti-72-C	MIC-8A	120	–84.0	–578.9
Ti-72-C	MIC-8A	240	–74.8	–515.7
Ti-24-C	MIC-11.5A	0	–81.5	–561.9
Ti-24-C	MIC-11.5A	120	–81.3	–560.4
Ti-24-C	MIC-11.5A	240	–84.5	–582.6
Ti-39-C	MIC-11.5A	0	–85.2	–587.6
Ti-39-C	MIC-11.5A	120	–75.4	–520.1
Ti-39-C	MIC-11.5A	240	–62.5	–430.6
Ti-63-B	CCAD-14A	0	–65.4	–450.8
Ti-63-B	CCAD -14A	120	–70.8	–488.5
Ti-63-B	CCAD -14A	240	–58.4	–402.4
Ti-68-B	CCAD -14A	0	–69.4	–478.2
Ti-68-B	CCAD -14A	120	–64.8	–446.7
Ti-68-B	CCAD -14A	240	–67.7	–466.5
Ti-53-C	MIC-3N	0	–82.2	–566.9
Ti-53-C	MIC-3N	120	–78.9	–544.0
Ti-53-C	MIC-3N	240	–81.8	–564.2
Ti-70-C	MIC-3N	0	–85.2	–587.3
Ti-70-C	MIC-3N	120	–84.7	–584.3
Ti-70-C	MIC-3N	240	–88.7	–611.6
Ti-4-C	MIC-5N	0	–81.3	–560.7
Ti-4-C	MIC-5N	120	–87.1	–600.5
Ti-4-C	MIC-5N	240	–88.8	–612.0
Ti-8-C	MIC-5N	0	–83.3	–574.2
Ti-8-C	MIC-5N	120	–89.7	–618.8
Ti-8-C	MIC-5N	240	–84.1	–580.0
Ti-27-C	MIC-14N	0	–85.3	–588.3
Ti-28-C	MIC-11N	0	–87.7	–604.8
Ti-28-C	MIC-11N	120	–91.2	–628.6
Ti-28-C	MIC-11N	240	–83.5	–575.7
Ti-59-C	MIC-11N	0	–89.9	–620.1
Ti-59-C	MIC-11N	120	–87.7	–604.8
Ti-59-C	MIC-11N	240	–82.1	–566.2
Ti-27-C	MIC-14N	120	–91.4	–630.1
Ti-27-C	MIC-14N	240	–81.4	–561.0
Ti-54-C	MIC-14N	0	–82.4	–568.3
Ti-54-C	MIC-14N	120	–78.6	–542.2
Ti-54-C	MIC-14N	240	–92.6	–638.7

Table 30. The 4340 steel XRD-RSA fatigue specimen data.

Specimen	Surface Condition	Orientation (°)	Stress (ksi)	Stress (MPa)
4-31-B	Machined	0	–13.2	–90.8
4-31-B	Machined	120	–10.3	–71.1
4-31-B	Machined	240	–12.5	–86.1
4-35-B	Machined	0	–42.3	–291.6
4-35-B	Machined	120	–39.8	–274.6
4-35-B	Machined	240	–43.0	–296.3
4-21-B	Machined	0	–21.3	–147.1
4-23-B	Machined	0	–19.0	–131.0
4-24-B	Machined	0	–15.1	–104.3
4-25-B	Machined	0	–42.7	–294.3
4-28-B	Machined	0	–16.7	–114.9
4-29-B	Machined	0	–15.5	–107.0
4-30-B	Machined	0	–36.8	–253.6
4-32-B	Machined	0	–16.5	–113.8
4-4-B	MIC-4A	0	–73.1	–504.0
4-4-B	MIC-4A	120	–73.6	–507.5
4-4-B	MIC-4A	240	–70.6	–487.1
4-12-B	MIC-4A	0	–72.0	–496.2
4-12-B	MIC-4A	120	–72.3	–498.6
4-12-B	MIC-4A	240	–77.3	–532.7
4-1-B	MIC-8A	0	–70.0	–482.3
4-1-B	MIC-8A	120	–69.1	–476.1
4-1-B	MIC-8A	240	–64.8	–447.1
4-17-B	MIC-8A	0	–71.4	–492.0
4-17-B	MIC-8A	120	–66.6	–459.1
4-17-B	MIC-8A	240	–68.7	–474.0
4-62-B	CCAD-4A	0	–71.3	–491.6
4-62-B	CCAD-4A	120	–72.4	–499.2
4-62-B	CCAD-4A	240	–69.7	–480.9
4-63-B	CCAD-4A	0	–74.8	–515.9
4-63-B	CCAD-4A	120	–73.6	–507.6
4-63-B	CCAD-4A	240	–66.1	–455.6
4-51-B	CCAD-8A	0	–72.8	–502.2
4-51-B	CCAD-8A	120	–75.8	–522.7
4-51-B	CCAD-8A	240	–73.1	–503.8
4-54-B	CCAD-8A	0	–70.8	–488.0
4-54-B	CCAD-8A	120	–67.8	–467.3
4-54-B	CCAD-8A	240	–72.7	–501.1
4-36-B	CCAD-12A	0	–69.8	–481.0
4-36-B	CCAD-12A	120	–72.8	–501.6
4-36-B	CCAD-12A	240	–72.1	–497.3
4-38-B	CCAD-12A	0	–70.4	–485.3
4-38-B	CCAD-12A	120	–73.4	–506.0
4-38-B	CCAD-12A	240	–70.6	–486.7

Table 31. The 9310 steel XRD-RSA fatigue specimen data.

Specimen	Surface Condition	Orientation (°)	Stress (ksi)	Stress (MPa)
9-16-B	Machined	0	–63.9	–440.9
9-16-B	Machined	120	–58.8	–405.7
9-16-B	Machined	240	–62.3	–429.3
9-17-B	Machined	0	–70.4	–485.7
9-17-B	Machined	120	–71.1	–490.1
9-17-B	Machined	240	–67.8	–467.3
9-53-B	MIC-4A	0	–78.0	–537.6
9-53-B	MIC-4A	120	–78.6	–542.1
9-53-B	MIC-4A	240	–83.0	–572.0
9-57-B	MIC-4A	0	–76.2	–525.3
9-57-B	MIC-4A	120	–78.9	–544.3
9-57-B	MIC-4A	240	–74.1	–511.2
9-51-C	MIC-8A	0	–76.1	–525.0
9-51-C	MIC-8A	120	–81.8	–564.1
9-51-C	MIC-8A	240	–71.3	–491.3
9-52-C	MIC-8A	0	–80.1	–552.4
9-52-C	MIC-8A	120	–74.2	–511.4
9-52-C	MIC-8A	240	–73.4	–506.2
9-61-B	MIC-8A	0	–80.6	–555.9
9-62-B	MIC-8A	0	–70.6	–486.5
9-63-B	MIC-8A	0	–68.6	–473.3
9-64-B	MIC-8A	0	–71.8	–494.7
9-65-B	MIC-8A	0	–74.4	–512.8
9-66-B	MIC-8A	0	–76.1	–524.9
9-67-B	MIC-8A	0	–77.7	–535.4
9-68-B	MIC-8A	0	–75.3	–519.3
9-69-B	MIC-8A	0	–79.1	–545.6
9-70-B	MIC-8A	0	–75.2	–518.5
9-32-B	CCAD-4A	0	–81.4	–561.1
9-32-B	CCAD-4A	120	–76.0	–524.1
9-32-B	CCAD-4A	240	–81.0	–558.5
9-35-B	CCAD-4A	0	–81.2	–560.1
9-35-B	CCAD-4A	120	–83.5	–575.9
9-35-B	CCAD-4A	240	–77.7	–535.8
9-33-A	CCAD-8A	0	–78.6	–542.1
9-33-A	CCAD-8A	120	–83.3	–574.4
9-33-A	CCAD-8A	240	–84.0	–578.8
9-35-A	CCAD-8A	0	–81.9	–564.9
9-35-A	CCAD-8A	120	–76.7	–529.1
9-35-A	CCAD-8A	240	–77.2	–532.0
9-30-A	CCAD-12A	0	–68.4	–471.6
9-30-A	CCAD-12A	120	–70.6	–486.6
9-30-A	CCAD-12A	240	–64.6	–445.2
9-22-A	CCAD-12A	0	–69.9	–481.8
9-22-A	CCAD-12A	120	–69.9	–482.0
9-22-A	CCAD-12A	240	–63.8	–440.2

Table 32. The 7075-T73 aluminum XRD-RSA disk specimen data.

Condition	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)
Baseline	Al 5 center	0.0000	–2.81	Al 41 center	0.0000	–0.72	Al 43 center	0.0000	–8.82
Baseline	Al 5 center	0.0010	–0.99	Al 41 center	0.0010	–0.87	Al 43 center	0.0010	–1.67
Baseline	Al 5 center	0.0020	–0.19	Al 41 center	0.0020	–1.35	Al 43 center	0.0020	–0.19
Baseline	Al 5 center	0.0050	–1.14	Al 41 center	0.0050	–1.03	Al 43 center	0.0051	–2.42
Baseline	Al 5 center	0.0071	–1.62	Al 41 center	0.0070	–1.68	Al 43 center	0.0071	–1.17
Baseline	Al 5 center	0.0102	–0.63	Al 41 center	0.0100	–0.34	Al 43 center	0.0100	0.54
Baseline	Al 5 edge	0.0000	–4.47	Al 41 edge	0.0000	–0.62	Al 43 edge	0.0000	–8.07
Baseline	Al 5 edge	0.0010	–1.59	Al 41 edge	0.0010	–0.57	Al 43 edge	0.0010	–5.92
Baseline	Al 5 edge	0.0021	0.52	Al 41 edge	0.0021	–1.36	Al 43 edge	0.0021	–1.62
Baseline	Al 5 edge	0.0051	–0.93	Al 41 edge	0.0051	1.34	Al 43 edge	0.0052	–1.85
Baseline	Al 5 edge	0.0071	–2.27	Al 41 edge	0.0071	–0.78	Al 43 edge	0.0072	–3.30
Baseline	Al 5 edge	0.0102	–1.46	Al 41 edge	0.0100	–1.22	Al 43 edge	0.0100	–1.23
MIC-4A	Al 10 center	0.0000	–38.64	Al 17 center	0.0000	–35.96	Al 33 center	0.0000	–36.52
MIC-4A	Al 10 center	0.0010	–40.09	Al 17 center	0.0010	–45.07	Al 33 center	0.0010	–42.82
MIC-4A	Al 10 center	0.0021	–52.00	Al 17 center	0.0020	–49.96	Al 33 center	0.0020	–48.30
MIC-4A	Al 10 center	0.0050	–34.67	Al 17 center	0.0050	–32.15	Al 33 center	0.0050	–32.66
MIC-4A	Al 10 center	0.0071	–15.22	Al 17 center	0.0069	–13.74	Al 33 center	0.0070	–13.32
MIC-4A	Al 10 center	0.0103	–0.99	Al 17 center	0.0101	–0.63	Al 33 center	0.0100	–3.34
MIC-4A	Al 10 edge	0.0000	–38.27	Al 17 edge	0.0000	–38.69	Al 33 edge	0.0000	–33.70
MIC-4A	Al 10 edge	0.0010	–44.68	Al 17 edge	0.0010	–46.45	Al 33 edge	0.0010	–41.06
MIC-4A	Al 10 edge	0.0022	–44.71	Al 17 edge	0.0022	–49.42	Al 33 edge	0.0020	–49.28
MIC-4A	Al 10 edge	0.0051	–30.71	Al 17 edge	0.0053	–36.82	Al 33 edge	0.0050	–32.56
MIC-4A	Al 10 edge	0.0072	–16.72	Al 17 edge	0.0072	–16.07	Al 33 edge	0.0070	–15.96
MIC-4A	Al 10 edge	0.0101	–4.03	Al 17 edge	0.0102	–3.57	Al 33 edge	0.0098	–5.45
MIC-10A	Al 19 center	0.0000	–33.44	Al 31 center	0.0000	–31.46	Al 38 center	0.0000	–34.60
MIC-10A	Al 19 center	0.0010	–37.51	Al 31 center	0.0010	–38.13	Al 38 center	0.0010	–39.28
MIC-10A	Al 19 center	0.0020	–42.40	Al 31 center	0.0021	–43.61	Al 38 center	0.0020	–43.08
MIC-10A	Al 19 center	0.0052	–44.65	Al 31 center	0.0050	–49.46	Al 38 center	0.0051	–47.51
MIC-10A	Al 19 center	0.0070	–43.18	Al 31 center	0.0071	–45.71	Al 38 center	0.0070	–47.14
MIC-10A	Al 19 center	0.0100	–28.18	Al 31 center	0.0100	–30.51	Al 38 center	0.0100	–31.86
MIC-10A	Al 19 edge	0.0000	–32.32	Al 31 edge	0.0000	–33.02	Al 38 edge	0.0000	–29.38
MIC-10A	Al 19 edge	0.0010	–36.93	Al 31 edge	0.0010	–36.53	Al 38 edge	0.0010	–38.52
MIC-10A	Al 19 edge	0.0020	–42.60	Al 31 edge	0.0020	–42.18	Al 38 edge	0.0020	–42.85
MIC-10A	Al 19 edge	0.0052	–46.75	Al 31 edge	0.0050	–47.26	Al 38 edge	0.0052	–47.59
MIC-10A	Al 19 edge	0.0070	–44.74	Al 31 edge	0.0070	–46.47	Al 38 edge	0.0071	–49.46
MIC-10A	Al 19 edge	0.0100	–30.59	Al 31 edge	0.0099	–34.26	Al 38 edge	0.0101	–34.56
MIC-12A	Al 16 center	0.0000	–31.70	Al 18 center	0.0000	–29.33	Al 44 center	0.0000	–30.48
MIC-12A	Al 16 center	0.0010	–35.77	Al 18 center	0.0010	–36.28	Al 44 center	0.0010	–34.46
MIC-12A	Al 16 center	0.0020	–41.76	Al 18 center	0.0020	–43.43	Al 44 center	0.0020	–38.98
MIC-12A	Al 16 center	0.0050	–45.13	Al 18 center	0.0050	–45.41	Al 44 center	0.0051	–46.83
MIC-12A	Al 16 center	0.0069	–47.57	Al 18 center	0.0071	–45.49	Al 44 center	0.0071	–53.53
MIC-12A	Al 16 center	0.0099	–31.93	Al 18 center	0.0100	–33.08	Al 44 center	0.0101	–36.02
MIC-12A	Al 16 edge	0.0000	–29.90	Al 18 edge	0.0000	–31.04	Al 44 edge	0.0000	–27.74
MIC-12A	Al 16 edge	0.0010	–35.66	Al 18 edge	0.0010	–35.75	Al 44 edge	0.0010	–34.34
MIC-12A	Al 16 edge	0.0020	–43.72	Al 18 edge	0.0020	–43.65	Al 44 edge	0.0020	–41.84
MIC-12A	Al 16 edge	0.0053	–49.41	Al 18 edge	0.0051	–49.70	Al 44 edge	0.0051	–44.71
MIC-12A	Al 16 edge	0.0072	–52.95	Al 18 edge	0.0071	–50.28	Al 44 edge	0.0072	–50.44
MIC-12A	Al 16 edge	0.0102	–36.60	Al 18 edge	0.0100	–37.24	Al 44 edge	0.0102	–40.50

Table 32. The 7075-T73 aluminum XRD-RSA disk specimen data (continued).

Condition	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)
MIC-14A	Al 12 center	0.0000	–26.43	Al 24 center	0.0000	–29.66	Al 39 center	0.0000	–23.19
MIC-14A	Al 12 center	0.0010	–34.48	Al 24 center	0.0010	–31.90	Al 39 center	0.0010	–33.67
MIC-14A	Al 12 center	0.0021	–38.31	Al 24 center	0.0021	–39.42	Al 39 center	0.0022	–40.74
MIC-14A	Al 12 center	0.0050	–48.00	Al 24 center	0.0050	–49.60	Al 39 center	0.0052	–47.36
MIC-14A	Al 12 center	0.0071	–49.66	Al 24 center	0.0071	–49.34	Al 39 center	0.0070	–50.02
MIC-14A	Al 12 center	0.0103	–44.06	Al 24 center	0.0101	–38.13	Al 39 center	0.0100	–42.87
MIC-14A	Al 12 edge	0.0000	–29.70	Al 24 edge	0.0000	–25.53	Al 39 edge	0.0000	–21.40
MIC-14A	Al 12 edge	0.0010	–30.66	Al 24 edge	0.0010	–33.91	Al 39 edge	0.0010	–36.38
MIC-14A	Al 12 edge	0.0020	–39.40	Al 24 edge	0.0020	–40.67	Al 39 edge	0.0022	–39.54
MIC-14A	Al 12 edge	0.0049	–49.48	Al 24 edge	0.0049	–48.42	Al 39 edge	0.0052	–48.05
MIC-14A	Al 12 edge	0.0069	–49.39	Al 24 edge	0.0070	–47.78	Al 39 edge	0.0070	–49.62
MIC-14A	Al 12 edge	0.0101	–43.00	Al 24 edge	0.0099	–43.63	Al 39 edge	0.0099	–45.72
CCAD-10A	Al 25 center	0.0000	–31.25	Al 30 center	0.0000	–33.55	Al 40 center	0.0000	–28.46
CCAD-10A	Al 25 center	0.0010	–38.47	Al 30 center	0.0010	–40.78	Al 40 center	0.0010	–36.25
CCAD-10A	Al 25 center	0.0020	–45.54	Al 30 center	0.0020	–44.83	Al 40 center	0.0020	–41.43
CCAD-10A	Al 25 center	0.0050	–49.94	Al 30 center	0.0050	–49.25	Al 40 center	0.0050	–45.99
CCAD-10A	Al 25 center	0.0070	–54.44	Al 30 center	0.0071	–49.78	Al 40 center	0.0070	–47.20
CCAD-10A	Al 25 center	0.0100	–31.28	Al 30 center	0.0101	–29.95	Al 40 center	0.0100	–30.43
CCAD-10A	Al 25 edge	0.0000	–30.78	Al 30 edge	0.0000	–35.14	Al 40 edge	0.0000	–30.06
CCAD-10A	Al 25 edge	0.0010	–39.78	Al 30 edge	0.0010	–41.79	Al 40 edge	0.0010	–37.57
CCAD-10A	Al 25 edge	0.0020	–42.85	Al 30 edge	0.0020	–45.71	Al 40 edge	0.0020	–42.01
CCAD-10A	Al 25 edge	0.0050	–48.71	Al 30 edge	0.0050	–49.94	Al 40 edge	0.0050	–46.23
CCAD-10A	Al 25 edge	0.0070	–53.18	Al 30 edge	0.0071	–53.68	Al 40 edge	0.0070	–51.71
CCAD-10A	Al 25 edge	0.0100	–36.95	Al 30 edge	0.0101	–38.35	Al 40 edge	0.0100	–37.97
CCAD-12A	Al 16 center	0.0000	–32.51	Al 21 center	0.0000	–29.95	Al 34 center	0.0000	–29.80
CCAD-12A	Al 16 center	0.0010	–39.56	Al 21 center	0.0011	–34.74	Al 34 center	0.0011	–35.85
CCAD-12A	Al 16 center	0.0020	–44.50	Al 21 center	0.0020	–41.27	Al 34 center	0.0021	–41.85
CCAD-12A	Al 16 center	0.0050	–48.46	Al 21 center	0.0050	–48.87	Al 34 center	0.0051	–48.63
CCAD-12A	Al 16 center	0.0070	–50.94	Al 21 center	0.0070	–48.38	Al 34 center	0.0073	–45.02
CCAD-12A	Al 16 center	0.0100	–35.88	Al 21 center	0.0102	–30.14	Al 34 center	0.0100	–31.17
CCAD-12A	Al 16 edge	0.0000	–32.52	Al 21 edge	0.0000	–30.11	Al 34 edge	0.0000	–29.43
CCAD-12A	Al 16 edge	0.0010	–39.95	Al 21 edge	0.0011	–36.00	Al 34 edge	0.0011	–36.16
CCAD-12A	Al 16 edge	0.0020	–44.53	Al 21 edge	0.0020	–42.27	Al 34 edge	0.0021	–42.33
CCAD-12A	Al 16 edge	0.0050	–47.74	Al 21 edge	0.0050	–48.87	Al 34 edge	0.0051	–48.51
CCAD-12A	Al 16 edge	0.0070	–50.92	Al 21 edge	0.0070	–50.81	Al 34 edge	0.0071	–48.98
CCAD-12A	Al 16 edge	0.0100	–38.23	Al 21 edge	0.0102	–30.76	Al 34 edge	0.0100	–36.90

Table 33. The beta-STOA Ti-6-4 XRD-RSA disk specimen data.

Condition	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)
Baseline	Ti 4 center	0.0000	25.58	Ti 7 center	0.0000	11.24	Ti 31 center	0.0000	36.48
Baseline	Ti 4 center	0.0010	29.12	Ti 7 center	0.0010	34.34	Ti 31 center	0.0010	35.57
Baseline	Ti 4 center	0.0020	13.49	Ti 7 center	0.0022	19.42	Ti 31 center	0.0020	21.68
Baseline	Ti 4 center	0.0050	–0.90	Ti 7 center	0.0052	–0.26	Ti 31 center	0.0050	1.56
Baseline	Ti 4 center	0.0072	–1.73	Ti 7 center	0.0070	–0.40	Ti 31 center	0.0072	2.96
Baseline	Ti 4 center	0.0102	–0.67	Ti 7 center	0.0100	0.57	Ti 31 center	0.0102	1.27
Baseline	Ti 4 edge	0.0000	33.08	Ti 7 edge	0.0000	20.47	Ti 31 edge	0.0000	23.95
Baseline	Ti 4 edge	0.0010	27.16	Ti 7 edge	0.0010	32.31	Ti 31 edge	0.0010	37.40
Baseline	Ti 4 edge	0.0020	19.69	Ti 7 edge	0.0022	13.25	Ti 31 edge	0.0020	26.41
Baseline	Ti 4 edge	0.0048	–7.68	Ti 7 edge	0.0052	–5.45	Ti 31 edge	0.0050	3.44
Baseline	Ti 4 edge	0.0070	–8.59	Ti 7 edge	0.0070	–6.96	Ti 31 edge	0.0071	–1.79
Baseline	Ti 4 edge	0.0101	–7.19	Ti 7 edge	0.0100	–3.42	Ti 31 edge	0.0100	–1.83
MIC-4A	Ti 12 center	0.0000	–99.87	Ti 21 center	0.0000	–91.50	Ti 26 center	0.0000	–97.62
MIC-4A	Ti 12 center	0.0010	–98.62	Ti 21 center	0.0010	–99.62	Ti 26 center	0.0010	–101.09
MIC-4A	Ti 12 center	0.0020	–83.63	Ti 21 center	0.0020	–98.65	Ti 26 center	0.0020	–92.65
MIC-4A	Ti 12 center	0.0050	31.83	Ti 21 center	0.0050	–4.06	Ti 26 center	0.0050	–10.68
MIC-4A	Ti 12 center	0.0070	55.86	Ti 21 center	0.0070	–2.43	Ti 26 center	0.0070	–1.10
MIC-4A	Ti 12 center	0.0100	51.94	Ti 21 center	0.0100	4.71	Ti 26 center	0.0100	–2.97
MIC-4A	Ti 12 edge	0.0000	–98.61	Ti 21 edge	0.0000	–97.52	Ti 26 edge	0.0000	–93.20
MIC-4A	Ti 12 edge	0.0010	–100.45	Ti 21 edge	0.0010	–102.45	Ti 26 edge	0.0012	–99.09
MIC-4A	Ti 12 edge	0.0020	–94.49	Ti 21 edge	0.0020	–106.23	Ti 26 edge	0.0022	–98.66
MIC-4A	Ti 12 edge	0.0049	12.06	Ti 21 edge	0.0052	–2.71	Ti 26 edge	0.0051	–12.70
MIC-4A	Ti 12 edge	0.0070	44.81	Ti 21 edge	0.0070	5.97	Ti 26 edge	0.0071	–4.29
MIC-4A	Ti 12 edge	0.0100	37.33	Ti 21 edge	0.0101	5.07	Ti 26 edge	0.0099	–8.18
MIC-8A	Ti 14 center	0.0000	–105.32	Ti 23 center	0.0000	–111.27	Ti 24 center	0.0000	–91.90
MIC-8A	Ti 14 center	0.0010	–115.44	Ti 23 center	0.0010	–117.03	Ti 24 center	0.0010	–109.60
MIC-8A	Ti 14 center	0.0020	–117.24	Ti 23 center	0.0020	–114.27	Ti 24 center	0.0020	–113.31
MIC-8A	Ti 14 center	0.0050	–45.73	Ti 23 center	0.0050	–49.64	Ti 24 center	0.0050	–46.96
MIC-8A	Ti 14 center	0.0070	–5.23	Ti 23 center	0.0070	0.46	Ti 24 center	0.0071	2.92
MIC-8A	Ti 14 center	0.0100	0.76	Ti 23 center	0.0100	6.60	Ti 24 center	0.0100	7.67
MIC-8A	Ti 14 edge	0.0000	–101.33	Ti 23 edge	0.0000	–103.13	Ti 24 edge	0.0000	–104.27
MIC-8A	Ti 14 edge	0.0010	–113.56	Ti 23 edge	0.0010	–112.76	Ti 24 edge	0.0010	–109.87
MIC-8A	Ti 14 edge	0.0020	–116.83	Ti 23 edge	0.0020	–117.63	Ti 24 edge	0.0020	–117.52
MIC-8A	Ti 14 edge	0.0049	–51.31	Ti 23 edge	0.0049	–80.55	Ti 24 edge	0.0050	–65.10
MIC-8A	Ti 14 edge	0.0069	–6.77	Ti 23 edge	0.0069	–9.70	Ti 24 edge	0.0070	–4.19
MIC-8A	Ti 14 edge	0.0099	–4.07	Ti 23 edge	0.0100	–0.93	Ti 24 edge	0.0100	–0.35
MIC-11.5A	Ti 9 center	0.0000	–101.43	Ti 11 center	0.0000	–87.82	Ti 29 center	0.0000	–89.11
MIC-11.5A	Ti 9 center	0.0010	–105.14	Ti 11 center	0.0010	–106.77	Ti 29 center	0.0010	–102.74
MIC-11.5A	Ti 9 center	0.0020	–113.46	Ti 11 center	0.0020	–111.19	Ti 29 center	0.0020	–119.32
MIC-11.5A	Ti 9 center	0.0050	–102.24	Ti 11 center	0.0050	–107.80	Ti 29 center	0.0050	–108.50
MIC-11.5A	Ti 9 center	0.0070	–42.10	Ti 11 center	0.0070	–69.97	Ti 29 center	0.0071	–63.01
MIC-11.5A	Ti 9 center	0.0100	–1.36	Ti 11 center	0.0100	5.84	Ti 29 center	0.0101	1.24
MIC-11.5A	Ti 9 edge	0.0000	–104.30	Ti 11 edge	0.0000	–97.42	Ti 29 edge	0.0000	–99.71
MIC-11.5A	Ti 9 edge	0.0010	–113.20	Ti 11 edge	0.0010	–104.47	Ti 29 edge	0.0010	–101.81
MIC-11.5A	Ti 9 edge	0.0020	–115.39	Ti 11 edge	0.0020	–107.60	Ti 29 edge	0.0020	–110.84
MIC-11.5A	Ti 9 edge	0.0050	–108.98	Ti 11 edge	0.0050	–108.31	Ti 29 edge	0.0050	–107.39
MIC-11.5A	Ti 9 edge	0.0070	–61.87	Ti 11 edge	0.0070	–72.03	Ti 29 edge	0.0071	–73.95
MIC-11.5A	Ti 9 edge	0.0101	–7.41	Ti 11 edge	0.0100	8.95	Ti 29 edge	0.0101	–3.30

Table 33. The beta-STOA Ti-6-4 XRD-RSA disk specimen data (continued).

Condition	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)
CCAD-14A	Ti 13 center	0.0000	–90.29	Ti 15 center	0.0000	–78.83	Ti 30 center	0.0000	–92.85
CCAD-14A	Ti 13 center	0.0014	–106.69	Ti 15 center	0.0010	–101.88	Ti 30 center	0.0010	–109.40
CCAD-14A	Ti 13 center	0.0020	–109.49	Ti 15 center	0.0020	–112.94	Ti 30 center	0.0020	–111.08
CCAD-14A	Ti 13 center	0.0050	–105.05	Ti 15 center	0.0051	–100.25	Ti 30 center	0.0050	–99.44
CCAD-14A	Ti 13 center	0.0070	–68.10	Ti 15 center	0.0071	–42.26	Ti 30 center	0.0070	–48.48
CCAD-14A	Ti 13 center	0.0100	–3.69	Ti 15 center	0.0101	46.38	Ti 30 center	0.0100	14.34
CCAD-14A	Ti 13 edge	0.0000	–101.16	Ti 15 edge	0.0000	–85.66	Ti 30 edge	0.0000	–92.63
CCAD-14A	Ti 13 edge	0.0014	–104.78	Ti 15 edge	0.0010	–99.47	Ti 30 edge	0.0010	–106.17
CCAD-14A	Ti 13 edge	0.0021	–106.01	Ti 15 edge	0.0021	–112.13	Ti 30 edge	0.0021	–107.08
CCAD-14A	Ti 13 edge	0.0053	–104.80	Ti 15 edge	0.0052	–95.30	Ti 30 edge	0.0051	–87.14
CCAD-14A	Ti 13 edge	0.0072	–76.27	Ti 15 edge	0.0071	–48.38	Ti 30 edge	0.0070	–27.36
CCAD-14A	Ti 13 edge	0.0102	–6.08	Ti 15 edge	0.0101	1.50	Ti 30 edge	0.0100	22.00
MIC-3N	Ti 1 center	0.0000	–108.75	Ti 5 center	0.0000	–112.34	Ti 22 center	0.0000	–111.05
MIC-3N	Ti 1 center	0.0010	–39.94	Ti 5 center	0.0010	–36.81	Ti 22 center	0.0010	–51.10
MIC-3N	Ti 1 center	0.0020	6.80	Ti 5 center	0.0020	–2.84	Ti 22 center	0.0020	13.27
MIC-3N	Ti 1 center	0.0050	4.86	Ti 5 center	0.0050	1.93	Ti 22 center	0.0052	9.50
MIC-3N	Ti 1 center	0.0070	3.03	Ti 5 center	0.0072	–0.34	Ti 22 center	0.0072	6.57
MIC-3N	Ti 1 center	0.0098	3.19	Ti 5 center	0.0101	0.42	Ti 22 center	0.0100	3.12
MIC-3N	Ti 1 edge	0.0000	–95.40	Ti 5 edge	0.0000	–110.06	Ti 22 edge	0.0000	–103.67
MIC-3N	Ti 1 edge	0.0010	–47.27	Ti 5 edge	0.0010	–53.92	Ti 22 edge	0.0010	–50.66
MIC-3N	Ti 1 edge	0.0020	–0.30	Ti 5 edge	0.0020	–8.39	Ti 22 edge	0.0021	5.92
MIC-3N	Ti 1 edge	0.0050	2.76	Ti 5 edge	0.0049	–2.81	Ti 22 edge	0.0054	–0.59
MIC-3N	Ti 1 edge	0.0069	–0.66	Ti 5 edge	0.0072	–9.25	Ti 22 edge	0.0074	–1.98
MIC-3N	Ti 1 edge	0.0101	–1.48	Ti 5 edge	0.0101	–4.00	Ti 22 edge	0.0100	–4.96
MIC-5N	Ti 2 center	0.0000	–92.65	Ti 27 center	0.0000	–89.27	Ti 28 center	0.0000	–96.31
MIC-5N	Ti 2 center	0.0010	–70.21	Ti 27 center	0.0010	–68.47	Ti 28 center	0.0010	–84.38
MIC-5N	Ti 2 center	0.0020	0.12	Ti 27 center	0.0020	0.32	Ti 28 center	0.0020	–19.73
MIC-5N	Ti 2 center	0.0050	57.08	Ti 27 center	0.0050	5.56	Ti 28 center	0.0050	0.86
MIC-5N	Ti 2 center	0.0070	53.86	Ti 27 center	0.0070	1.04	Ti 28 center	0.0070	2.84
MIC-5N	Ti 2 center	0.0100	46.58	Ti 27 center	0.0100	2.11	Ti 28 center	0.0100	2.02
MIC-5N	Ti 2 edge	0.0000	–101.62	Ti 27 edge	0.0000	–96.27	Ti 28 edge	0.0000	–90.66
MIC-5N	Ti 2 edge	0.0010	–69.29	Ti 27 edge	0.0010	–71.73	Ti 28 edge	0.0010	–90.08
MIC-5N	Ti 2 edge	0.0020	–1.25	Ti 27 edge	0.0020	–14.44	Ti 28 edge	0.0020	–31.17
MIC-5N	Ti 2 edge	0.0050	60.65	Ti 27 edge	0.0050	–3.77	Ti 28 edge	0.0050	5.29
MIC-5N	Ti 2 edge	0.0070	49.99	Ti 27 edge	0.0070	–5.95	Ti 28 edge	0.0070	0.93
MIC-5N	Ti 2 edge	0.0100	49.39	Ti 27 edge	0.0099	–4.18	Ti 28 edge	0.0100	2.12
MIC-11N	Ti 8 center	0.0000	–102.42	Ti 10 center	0.0000	–91.00	Ti 17 center	0.0000	–107.03
MIC-11N	Ti 8 center	0.0010	–111.84	Ti 10 center	0.0010	–109.06	Ti 17 center	0.0010	–105.36
MIC-11N	Ti 8 center	0.0021	–85.28	Ti 10 center	0.0020	–90.29	Ti 17 center	0.0020	–100.88
MIC-11N	Ti 8 center	0.0051	–1.09	Ti 10 center	0.0050	8.47	Ti 17 center	0.0050	–0.23
MIC-11N	Ti 8 center	0.0071	–0.40	Ti 10 center	0.0071	8.47	Ti 17 center	0.0070	4.04
MIC-11N	Ti 8 center	0.0100	1.30	Ti 10 center	0.0101	4.64	Ti 17 center	0.0100	4.77
MIC-11N	Ti 8 edge	0.0000	–107.06	Ti 10 edge	0.0000	–105.07	Ti 17 edge	0.0000	–108.03
MIC-11N	Ti 8 edge	0.0010	–107.66	Ti 10 edge	0.0010	–102.01	Ti 17 edge	0.0010	–109.20
MIC-11N	Ti 8 edge	0.0021	–95.88	Ti 10 edge	0.0020	–94.85	Ti 17 edge	0.0020	–101.07
MIC-11N	Ti 8 edge	0.0050	–5.23	Ti 10 edge	0.0046	15.55	Ti 17 edge	0.0046	4.49
MIC-11N	Ti 8 edge	0.0070	0.03	Ti 10 edge	0.0071	22.02	Ti 17 edge	0.0070	7.74
MIC-11N	Ti 8 edge	0.0100	0.85	Ti 10 edge	0.0101	13.97	Ti 17 edge	0.0100	9.76

Table 33. The beta-STOA Ti-6-4 XRD-RSA disk specimen data (continued).

Condition	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)
MIC-14N	Ti 32 center	0.0000	–105.78	Ti 16 center	0.0000	–108.94	—	—	—
MIC-14N	Ti 32 center	0.0010	–109.58	Ti 16 center	0.0010	–112.70	—	—	—
MIC-14N	Ti 32 center	0.0020	–96.80	Ti 16 center	0.0020	–108.20	—	—	—
MIC-14N	Ti 32 center	0.0050	51.82	Ti 16 center	0.0050	–4.26	—	—	—
MIC-14N	Ti 32 center	0.0070	55.40	Ti 16 center	0.0070	0.52	—	—	—
MIC-14N	Ti 32 center	0.0098	46.13	Ti 16 center	0.0100	1.90	—	—	—
MIC-14N	Ti 32 edge	0.0000	–103.74	Ti 16 edge	0.0000	–100.50	—	—	—
MIC-14N	Ti 32 edge	0.0010	–110.17	Ti 16 edge	0.0010	–109.67	—	—	—
MIC-14N	Ti 32 edge	0.0020	–105.94	Ti 16 edge	0.0020	–110.90	—	—	—
MIC-14N	Ti 32 edge	0.0050	33.02	Ti 16 edge	0.0050	–5.39	—	—	—
MIC-14N	Ti 32 edge	0.0070	34.36	Ti 16 edge	0.0070	0.07	—	—	—
MIC-14N	Ti 32 edge	0.0100	22.85	Ti 16 edge	0.0100	0.75	—	—	—

Table 34. The 4340 steel XRD-RSA disk specimen data.

Condition	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)
Baseline	4340 26 center	0.0000	–75.20	4340 27 center	0.0000	–72.43	4340 33 center	0.0000	–56.67
Baseline	4340 26 center	0.0011	61.18	4340 27 center	0.0010	34.28	4340 33 center	0.0010	47.47
Baseline	4340 26 center	0.0019	69.57	4340 27 center	0.0020	35.40	4340 33 center	0.0020	47.89
Baseline	4340 26 center	0.0050	48.79	4340 27 center	0.0050	9.40	4340 33 center	0.0050	14.62
Baseline	4340 26 center	0.0070	38.36	4340 27 center	0.0070	0.61	4340 33 center	0.0070	4.97
Baseline	4340 26 center	0.0100	21.78	4340 27 center	0.0100	-0.98	4340 33 center	0.0100	–0.41
Baseline	4340 26 edge	0.0000	–79.62	4340 27 edge	0.0000	–68.18	4340 33 edge	0.0000	–51.76
Baseline	4340 26 edge	0.0012	90.10	4340 27 edge	0.0011	17.18	4340 33 edge	0.0011	6.07
Baseline	4340 26 edge	0.0022	92.67	4340 27 edge	0.0022	13.79	4340 33 edge	0.0022	5.62
Baseline	4340 26 edge	0.0051	65.38	4340 27 edge	0.0052	0.15	4340 33 edge	0.0052	2.06
Baseline	4340 26 edge	0.0072	59.38	4340 27 edge	0.0071	0.34	4340 33 edge	0.0070	1.04
Baseline	4340 26 edge	0.0101	41.60	4340 27 edge	0.0100	–2.10	4340 33 edge	0.0100	0.78
MIC-4A	4340 37 center	0.0000	–84.55	4340 41 center	0.0000	–82.12	4340 46 center	0.0000	–87.21
MIC-4A	4340 37 center	0.0011	–81.61	4340 41 center	0.0010	–82.38	4340 46 center	0.0010	–86.45
MIC-4A	4340 37 center	0.0020	–87.52	4340 41 center	0.0020	–85.52	4340 46 center	0.0020	–88.85
MIC-4A	4340 37 center	0.0049	–8.97	4340 41 center	0.0049	–4.57	4340 46 center	0.0050	–5.77
MIC-4A	4340 37 center	0.0068	3.66	4340 41 center	0.0069	15.77	4340 46 center	0.0070	14.93
MIC-4A	4340 37 center	0.0099	6.08	4340 41 center	0.0100	7.11	4340 46 center	0.0100	7.39
MIC-4A	4340 37 edge	0.0000	–87.56	4340 41 edge	0.0000	–79.84	4340 46 edge	0.0000	–89.41
MIC-4A	4340 37 edge	0.0012	–85.47	4340 41 edge	0.0011	–85.98	4340 46 edge	0.0012	–84.44
MIC-4A	4340 37 edge	0.0022	–82.47	4340 41 edge	0.0022	–80.23	4340 46 edge	0.0023	–89.27
MIC-4A	4340 37 edge	0.0051	–0.01	4340 41 edge	0.0051	4.63	4340 46 edge	0.0051	–8.83
MIC-4A	4340 37 edge	0.0070	4.07	4340 41 edge	0.0070	8.02	4340 46 edge	0.0070	7.47
MIC-4A	4340 37 edge	0.0100	3.42	4340 41 edge	0.0100	2.38	4340 46 edge	0.0100	3.87
MIC-8A	4340 29 center	0.0000	–77.74	4340 35 center	0.0000	–76.80	4340 39 center	0.0000	–75.24
MIC-8A	4340 29 center	0.0011	–82.07	4340 35 center	0.0011	–85.40	4340 39 center	0.0010	–81.44
MIC-8A	4340 29 center	0.0020	–83.31	4340 35 center	0.0020	–84.25	4340 39 center	0.0021	–80.52
MIC-8A	4340 29 center	0.0050	–76.90	4340 35 center	0.0050	–73.22	4340 39 center	0.0051	–74.47
MIC-8A	4340 29 center	0.0068	–28.66	4340 35 center	0.0070	–18.60	4340 39 center	0.0068	–36.98
MIC-8A	4340 29 center	0.0100	5.96	4340 35 center	0.0100	6.19	4340 39 center	0.0099	3.83
MIC-8A	4340 29 edge	0.0000	–77.22	4340 35 edge	0.0000	–84.30	4340 39 edge	0.0000	–76.42
MIC-8A	4340 29 edge	0.0013	–82.36	4340 35 edge	0.0013	–87.20	4340 39 edge	0.0012	–85.27
MIC-8A	4340 29 edge	0.0022	–82.70	4340 35 edge	0.0022	–87.07	4340 39 edge	0.0023	–83.43
MIC-8A	4340 29 edge	0.0052	–68.72	4340 35 edge	0.0050	–79.65	4340 39 edge	0.0053	–74.12
MIC-8A	4340 29 edge	0.0070	–8.18	4340 35 edge	0.0070	–21.55	4340 39 edge	0.0070	–29.93
MIC-8A	4340 29 edge	0.0099	5.65	4340 35 edge	0.0101	4.67	4340 39 edge	0.0100	4.04
CCAD-4A	4340 1 center	0.0000	–87.50	4340 2 center	0.0000	–86.00	4340 28 center	0.0000	–82.26
CCAD-4A	4340 1 center	0.0010	–85.68	4340 2 center	0.0010	–84.26	4340 28 center	0.0010	–79.58
CCAD-4A	4340 1 center	0.0020	–83.27	4340 2 center	0.0020	–85.09	4340 28 center	0.0020	–82.54
CCAD-4A	4340 1 center	0.0050	–40.28	4340 2 center	0.0050	–38.25	4340 28 center	0.0050	–36.70
CCAD-4A	4340 1 center	0.0070	2.08	4340 2 center	0.0070	5.68	4340 28 center	0.0070	8.15
CCAD-4A	4340 1 center	0.0100	4.11	4340 2 center	0.0100	4.77	4340 28 center	0.0100	8.21
CCAD-4A	4340 1 edge	0.0000	–89.18	4340 2 edge	0.0000	–86.83	4340 28 edge	0.0000	–84.42
CCAD-4A	4340 1 edge	0.0010	–84.16	4340 2 edge	0.0010	–85.10	4340 28 edge	0.0010	–81.28
CCAD-4A	4340 1 edge	0.0020	–87.63	4340 2 edge	0.0020	–90.60	4340 28 edge	0.0020	–87.84
CCAD-4A	4340 1 edge	0.0050	–27.05	4340 2 edge	0.0050	–24.40	4340 28 edge	0.0050	–27.10
CCAD-4A	4340 1 edge	0.0070	0.84	4340 2 edge	0.0070	2.13	4340 28 edge	0.0070	4.12
CCAD-4A	4340 1 edge	0.0101	3.66	4340 2 edge	0.0100	1.30	4340 28 edge	0.0100	3.60

Table 34. The 4340 steel XRD-RSA disk specimen data (continued).

Condition	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)
CCAD-8A	4340 43 center	0.0000	–80.82	4340 44 center	0.0000	–85.28	4340 45 center	0.0000	–84.53
CCAD-8A	4340 43 center	0.0010	–82.67	4340 44 center	0.0011	–86.17	4340 45 center	0.0010	–81.99
CCAD-8A	4340 43 center	0.0020	–85.57	4340 44 center	0.0020	–87.34	4340 45 center	0.0020	–85.62
CCAD-8A	4340 43 center	0.0050	–61.88	4340 44 center	0.0050	–61.01	4340 45 center	0.0050	–56.13
CCAD-8A	4340 43 center	0.0070	–10.28	4340 44 center	0.0073	4.11	4340 45 center	0.0070	–3.73
CCAD-8A	4340 43 center	0.0100	6.47	4340 44 center	0.0100	9.96	4340 45 center	0.0100	8.00
CCAD-8A	4340 43 edge	0.0000	–83.58	4340 44 edge	0.0000	–84.84	4340 45 edge	0.0000	–86.86
CCAD-8A	4340 43 edge	0.0010	–88.11	4340 44 edge	0.0011	–92.07	4340 45 edge	0.0010	–89.47
CCAD-8A	4340 43 edge	0.0020	–89.92	4340 44 edge	0.0021	–90.25	4340 45 edge	0.0020	–92.25
CCAD-8A	4340 43 edge	0.0050	–58.74	4340 44 edge	0.0053	–56.80	4340 45 edge	0.0051	–33.84
CCAD-8A	4340 43 edge	0.0071	–6.94	4340 44 edge	0.0069	–18.23	4340 45 edge	0.0070	0.11
CCAD-8A	4340 43 edge	0.0100	5.80	4340 44 edge	0.0101	5.37	4340 45 edge	0.0101	7.03
CCAD-12A	4340 3 center	0.0000	–64.81	4340 40 center	0.0000	–70.03	4340 47 center	0.0000	–72.67
CCAD-12A	4340 3 center	0.0011	–78.73	4340 40 center	0.0010	–84.52	4340 47 center	0.0011	–85.36
CCAD-12A	4340 3 center	0.0021	–80.45	4340 40 center	0.0021	–81.58	4340 47 center	0.0021	–82.50
CCAD-12A	4340 3 center	0.0051	–74.67	4340 40 center	0.0050	–75.40	4340 47 center	0.0053	–76.83
CCAD-12A	4340 3 center	0.0070	–67.58	4340 40 center	0.0070	–71.16	4340 47 center	0.0070	–68.79
CCAD-12A	4340 3 center	0.0101	–7.41	4340 40 center	0.0100	–14.77	4340 47 center	0.0100	–10.70
CCAD-12A	4340 3 edge	0.0000	–68.69	4340 40 edge	0.0000	–74.84	4340 47 edge	0.0000	–73.91
CCAD-12A	4340 3 edge	0.0011	–81.62	4340 40 edge	0.0010	–85.99	4340 47 edge	0.0011	–85.13
CCAD-12A	4340 3 edge	0.0021	–83.65	4340 40 edge	0.0021	–87.61	4340 47 edge	0.0021	–84.77
CCAD-12A	4340 3 edge	0.0051	–80.04	4340 40 edge	0.0050	–81.14	4340 47 edge	0.0053	–80.62
CCAD-12A	4340 3 edge	0.0071	–62.18	4340 40 edge	0.0070	–68.18	4340 47 edge	0.0072	–58.46
CCAD-12A	4340 3 edge	0.0101	–5.74	4340 40 edge	0.0100	–5.96	4340 47 edge	0.0100	–5.03

Table 35. The 9310 steel XRD-RSA disk specimen data.

Condition	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)
Baseline	9310 10 center	0.0000	–81.69	9310 11 center	0.0000	–68.78	9310 12 center	0.0000	–88.28
Baseline	9310 10 center	0.0010	–10.87	9310 11 center	0.0010	–0.97	9310 12 center	0.0010	–13.57
Baseline	9310 10 center	0.0020	–6.90	9310 11 center	0.0021	–1.04	9310 12 center	0.0021	–6.35
Baseline	9310 10 center	0.0050	–7.68	9310 11 center	0.0050	1.39	9310 12 center	0.0050	–6.63
Baseline	9310 10 center	0.0070	–1.73	9310 11 center	0.0070	–0.28	9310 12 center	0.0071	–9.77
Baseline	9310 10 center	0.0100	–4.56	9310 11 center	0.0100	–1.17	9310 12 center	0.0101	–7.10
Baseline	9310 10 edge	0.0000	–93.12	9310 11 edge	0.0000	–77.94	9310 12 edge	0.0000	–111.86
Baseline	9310 10 edge	0.0008	3.85	9310 11 edge	0.0010	5.21	9310 12 edge	0.0010	–2.69
Baseline	9310 10 edge	0.0018	14.03	9310 11 edge	0.0021	7.37	9310 12 edge	0.0021	13.72
Baseline	9310 10 edge	0.0050	14.68	9310 11 edge	0.0050	12.52	9310 12 edge	0.0050	14.76
Baseline	9310 10 edge	0.0070	9.35	9310 11 edge	0.0070	10.44	9310 12 edge	0.0071	8.26
Baseline	9310 10 edge	0.0100	10.51	9310 11 edge	0.0100	10.05	9310 12 edge	0.0102	9.88
MIC-4A	9310 15 center	0.0000	–99.66	9310 16 center	0.0000	–100.20	9310 17 center	0.0000	–99.69
MIC-4A	9310 15 center	0.0010	–113.04	9310 16 center	0.0010	–109.90	9310 17 center	0.0011	–111.16
MIC-4A	9310 15 center	0.0020	–119.15	9310 16 center	0.0020	–115.84	9310 17 center	0.0020	–123.10
MIC-4A	9310 15 center	0.0050	–12.46	9310 16 center	0.0050	–10.48	9310 17 center	0.0051	–28.99
MIC-4A	9310 15 center	0.0071	0.82	9310 16 center	0.0070	–0.67	9310 17 center	0.0069	–8.50
MIC-4A	9310 15 center	0.0101	1.99	9310 16 center	0.0100	2.95	9310 17 center	0.0099	–3.51
MIC-4A	9310 15 edge	0.0000	–100.78	9310 16 edge	0.0000	–93.19	9310 17 edge	0.0000	–106.05
MIC-4A	9310 15 edge	0.0010	–117.97	9310 16 edge	0.0010	–112.46	9310 17 edge	0.0013	–117.85
MIC-4A	9310 15 edge	0.0020	–125.71	9310 16 edge	0.0020	–122.77	9310 17 edge	0.0021	–130.01
MIC-4A	9310 15 edge	0.0050	2.14	9310 16 edge	0.0050	3.98	9310 17 edge	0.0053	–1.55
MIC-4A	9310 15 edge	0.0071	19.40	9310 16 edge	0.0070	14.21	9310 17 edge	0.0071	16.81
MIC-4A	9310 15 edge	0.0100	18.05	9310 16 edge	0.0100	16.12	9310 17 edge	0.0101	18.52
MIC-8A	9310 13 center	0.0000	–88.85	9310 14 center	0.0000	–97.58	9310 18 center	0.0000	–92.10
MIC-8A	9310 13 center	0.0010	–101.82	9310 14 center	0.0010	–105.20	9310 18 center	0.0011	–100.93
MIC-8A	9310 13 center	0.0020	–109.31	9310 14 center	0.0020	–115.50	9310 18 center	0.0021	–114.79
MIC-8A	9310 13 center	0.0050	–98.00	9310 14 center	0.0050	–104.18	9310 18 center	0.0050	–103.85
MIC-8A	9310 13 center	0.0070	–39.67	9310 14 center	0.0070	–39.48	9310 18 center	0.0070	–47.34
MIC-8A	9310 13 center	0.0100	0.74	9310 14 center	0.0100	0.75	9310 18 center	0.0101	–3.08
MIC-8A	9310 13 edge	0.0000	–98.14	9310 14 edge	0.0000	–94.47	9310 18 edge	0.0000	–92.74
MIC-8A	9310 13 edge	0.0010	–103.58	9310 14 edge	0.0010	–110.35	9310 18 edge	0.0011	–103.00
MIC-8A	9310 13 edge	0.0020	–115.78	9310 14 edge	0.0020	–122.81	9310 18 edge	0.0021	–117.31
MIC-8A	9310 13 edge	0.0050	–92.40	9310 14 edge	0.0047	–97.03	9310 18 edge	0.0050	–97.66
MIC-8A	9310 13 edge	0.0070	–28.20	9310 14 edge	0.0069	–9.52	9310 18 edge	0.0070	–27.37
MIC-8A	9310 13 edge	0.0101	18.21	9310 14 edge	0.0101	22.49	9310 18 edge	0.0100	14.20
CCAD-4A	9310 2 center	0.0000	–101.37	9310 3 center	0.0000	–103.77	9310 4 center	0.0000	–104.48
CCAD-4A	9310 2 center	0.0010	–104.33	9310 3 center	0.0010	–108.46	9310 4 center	0.0010	–109.30
CCAD-4A	9310 2 center	0.0020	–117.01	9310 3 center	0.0020	–122.60	9310 4 center	0.0020	–120.86
CCAD-4A	9310 2 center	0.0050	–46.98	9310 3 center	0.0051	–42.75	9310 4 center	0.0050	–34.84
CCAD-4A	9310 2 center	0.0070	–7.81	9310 3 center	0.0070	–6.61	9310 4 center	0.0070	–2.10
CCAD-4A	9310 2 center	0.0100	–2.59	9310 3 center	0.0100	0.36	9310 4 center	0.0100	–2.53
CCAD-4A	9310 2 edge	0.0000	–100.70	9310 3 edge	0.0000	–111.57	9310 4 edge	0.0000	–106.25
CCAD-4A	9310 2 edge	0.0010	–110.44	9310 3 edge	0.0010	–116.44	9310 4 edge	0.0010	–119.70
CCAD-4A	9310 2 edge	0.0020	–123.78	9310 3 edge	0.0020	–130.04	9310 4 edge	0.0022	–131.43
CCAD-4A	9310 2 edge	0.0050	–22.78	9310 3 edge	0.0051	–24.47	9310 4 edge	0.0052	–1.42
CCAD-4A	9310 2 edge	0.0070	10.93	9310 3 edge	0.0070	13.46	9310 4 edge	0.0070	15.99
CCAD-4A	9310 2 edge	0.0100	12.85	9310 3 edge	0.0100	17.45	9310 4 edge	0.0100	16.91

Table 35. The 9310 steel XRD-RSA disk specimen data (continued).

Condition	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)	Specimen	Depth	Stress (ksi)
CCAD-8A	9310 5 center	0.0000	–98.32	9310 6 center	0.0000	-99.48	9310 9 center	0.0000	–92.75
CCAD-8A	9310 5 center	0.0010	–108.58	9310 6 center	0.0011	–113.08	9310 9 center	0.0010	–107.26
CCAD-8A	9310 5 center	0.0020	–116.30	9310 6 center	0.0020	–116.40	9310 9 center	0.0020	–115.17
CCAD-8A	9310 5 center	0.0050	–73.61	9310 6 center	0.0050	–73.57	9310 9 center	0.0050	–70.55
CCAD-8A	9310 5 center	0.0071	–16.37	9310 6 center	0.0070	–18.77	9310 9 center	0.0070	–16.96
CCAD-8A	9310 5 center	0.0100	–2.36	9310 6 center	0.0100	–2.09	9310 9 center	0.0100	1.72
CCAD-8A	9310 5 edge	0.0000	–102.82	9310 6 edge	0.0000	–106.02	9310 9 edge	0.0000	–93.72
CCAD-8A	9310 5 edge	0.0010	–114.06	9310 6 edge	0.0011	–116.93	9310 9 edge	0.0010	–107.31
CCAD-8A	9310 5 edge	0.0020	–121.62	9310 6 edge	0.0020	–122.74	9310 9 edge	0.0020	–119.91
CCAD-8A	9310 5 edge	0.0050	–47.99	9310 6 edge	0.0050	–79.87	9310 9 edge	0.0050	–74.06
CCAD-8A	9310 5 edge	0.0071	8.74	9310 6 edge	0.0070	–6.70	9310 9 edge	0.0070	–7.83
CCAD-8A	9310 5 edge	0.0100	17.13	9310 6 edge	0.0102	11.74	9310 9 edge	0.0100	15.19
CCAD-12A	9310 1 center	0.0000	–82.57	9310 7 center	0.0000	–91.72	9310 8 center	0.0000	–85.49
CCAD-12A	9310 1 center	0.0011	–110.40	9310 7 center	0.0011	–111.31	9310 8 center	0.0011	–109.16
CCAD-12A	9310 1 center	0.0020	–113.12	9310 7 center	0.0020	–109.50	9310 8 center	0.0020	–111.14
CCAD-12A	9310 1 center	0.0050	–114.97	9310 7 center	0.0050	–107.69	9310 8 center	0.0050	–111.10
CCAD-12A	9310 1 center	0.0070	–85.95	9310 7 center	0.0070	–84.44	9310 8 center	0.0070	–75.63
CCAD-12A	9310 1 center	0.0100	–18.51	9310 7 center	0.0101	–20.28	9310 8 center	0.0100	–11.62
CCAD-12A	9310 1 edge	0.0000	–89.86	9310 7 edge	0.0000	–93.04	9310 8 edge	0.0000	–90.96
CCAD-12A	9310 1 edge	0.0011	–112.27	9310 7 edge	0.0011	–114.95	9310 8 edge	0.0011	–111.66
CCAD-12A	9310 1 edge	0.0020	–116.90	9310 7 edge	0.0020	–119.73	9310 8 edge	0.0020	–115.78
CCAD-12A	9310 1 edge	0.0050	–116.97	9310 7 edge	0.0050	–119.70	9310 8 edge	0.0050	–119.23
CCAD-12A	9310 1 edge	0.0070	–72.34	9310 7 edge	0.0072	–67.14	9310 8 edge	0.0071	–66.58
CCAD-12A	9310 1 edge	0.0100	–5.46	9310 7 edge	0.0101	–1.22	9310 8 edge	0.0101	–8.16

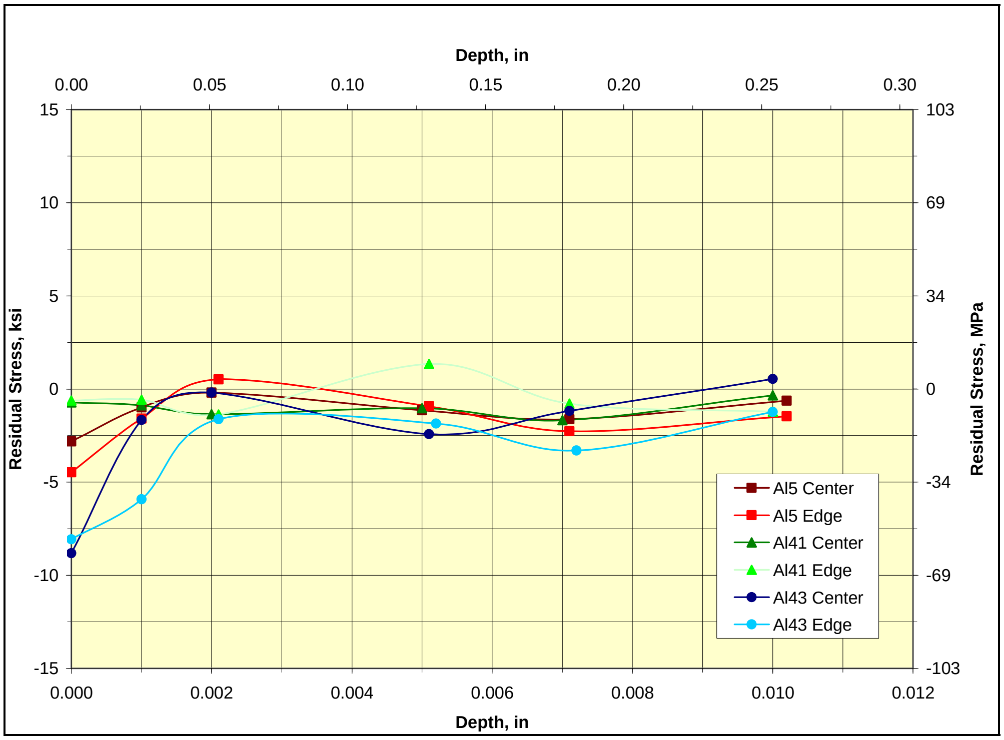


Figure 28. The XRD-RSA data for 7075-T73 aluminum baseline disks.

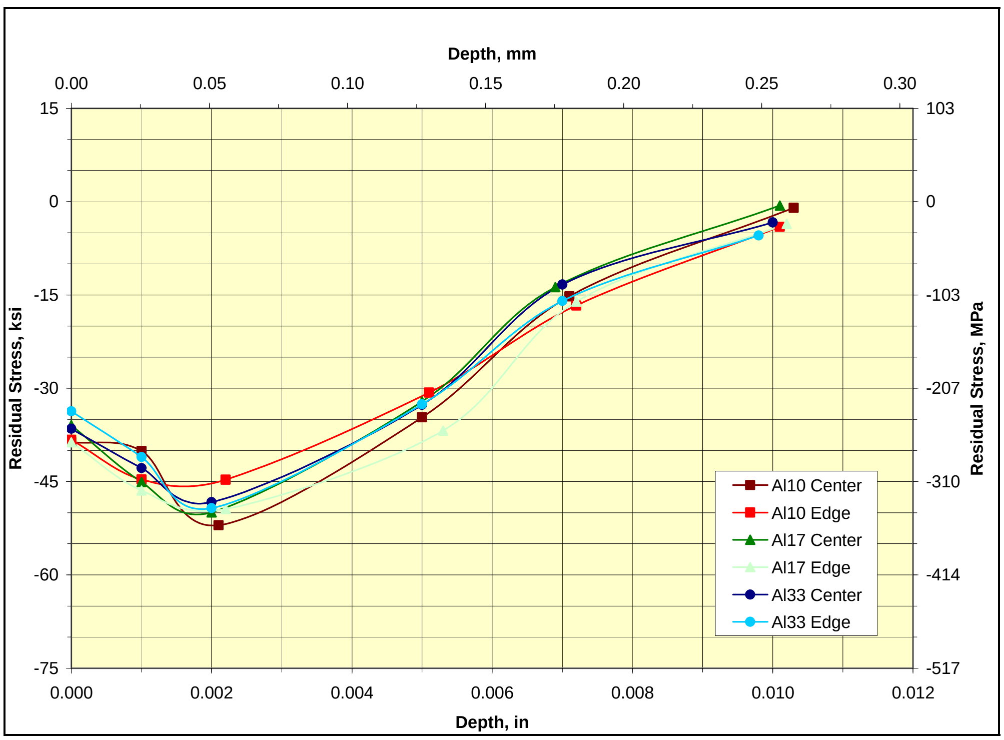


Figure 29. The XRD-RSA data for 7075-T73 aluminum MIC-4A disks.

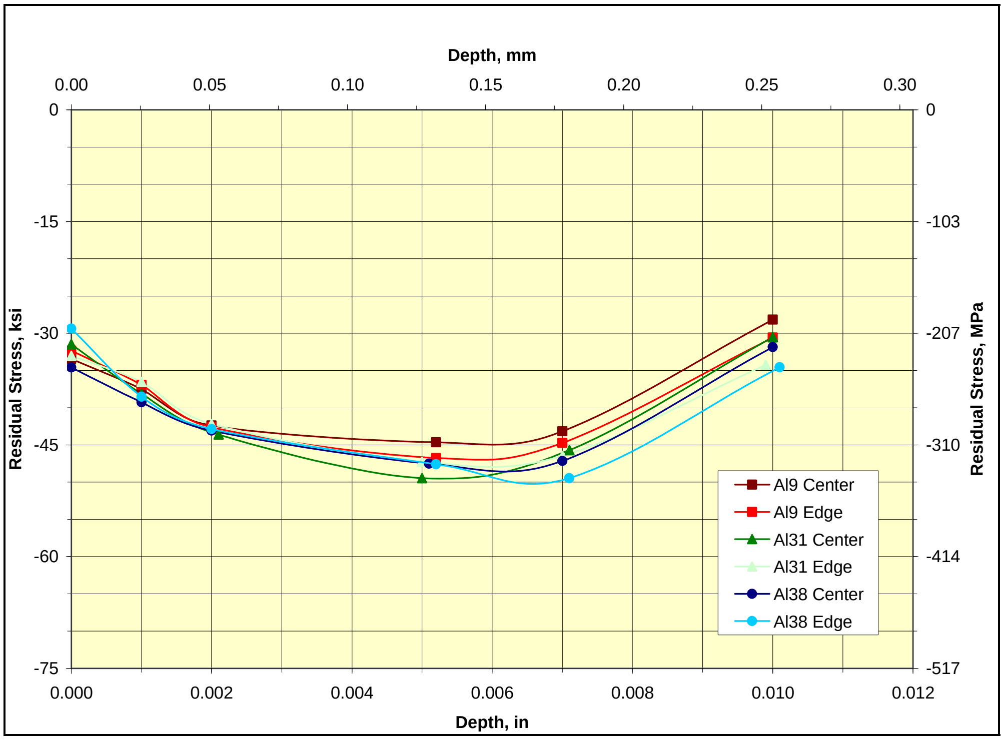


Figure 30. The XRD-RSA data for 7075-T73 aluminum MIC-10A disks.

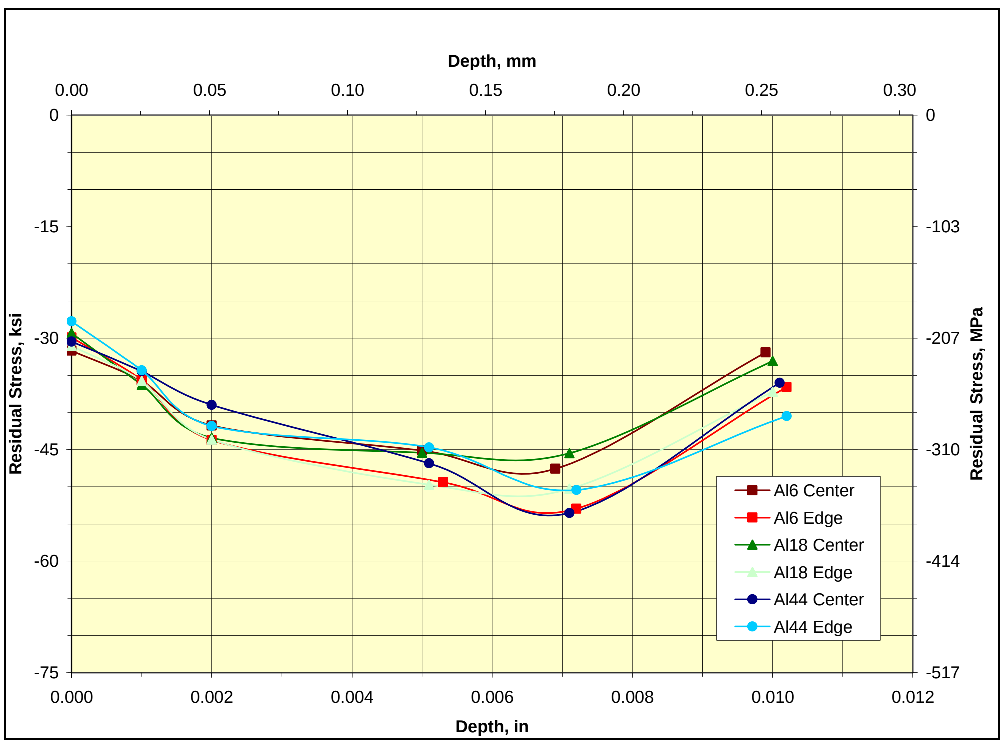


Figure 31. The XRD-RSA data for 7075-T73 aluminum MIC-12A disks.

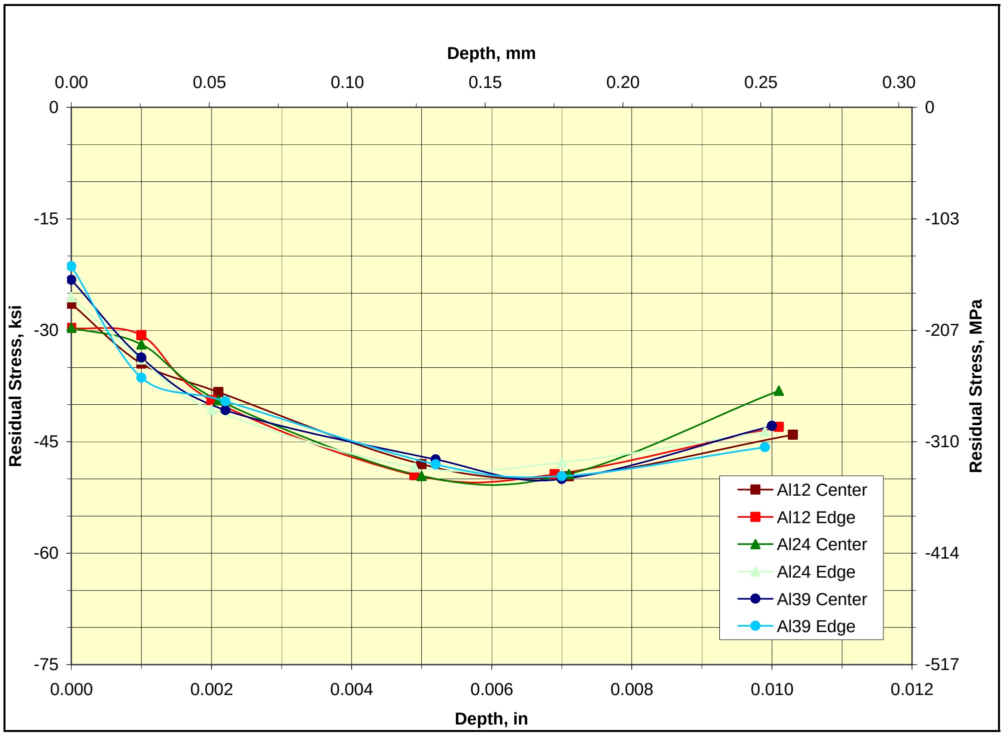


Figure 32. The XRD-RSA data for 7075-T73 aluminum MIC-14A disks.

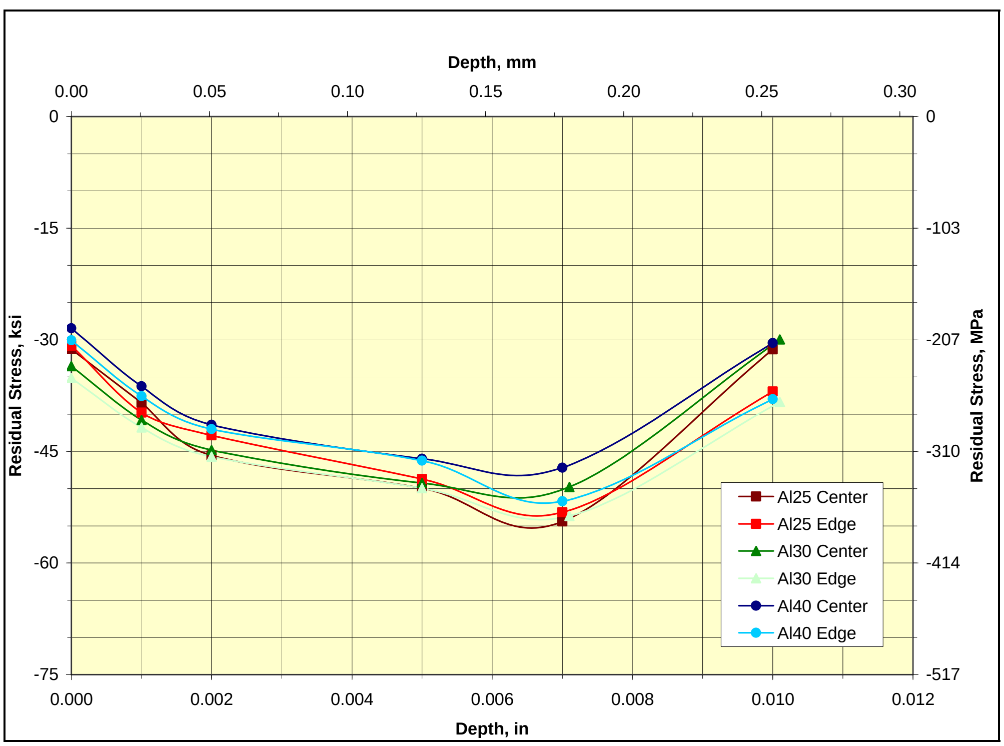


Figure 33. The XRD-RSA data for 7075-T73 aluminum CCAD-10A disks.

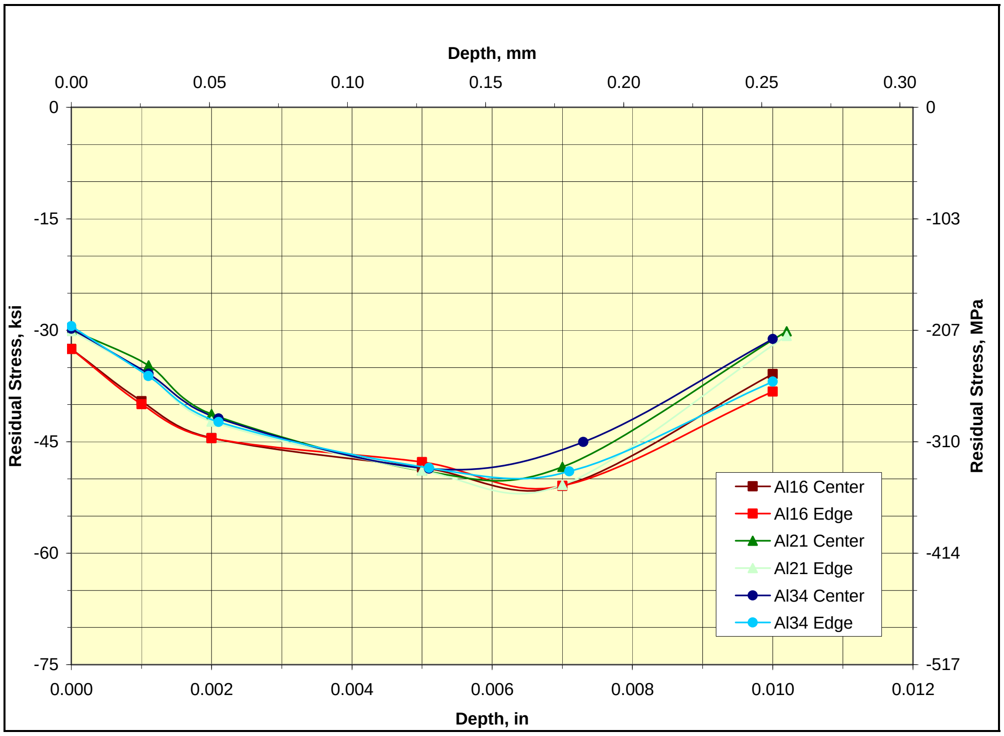


Figure 34. The XRD-RSA data for 7075-T73 aluminum CCAD-12A disks.

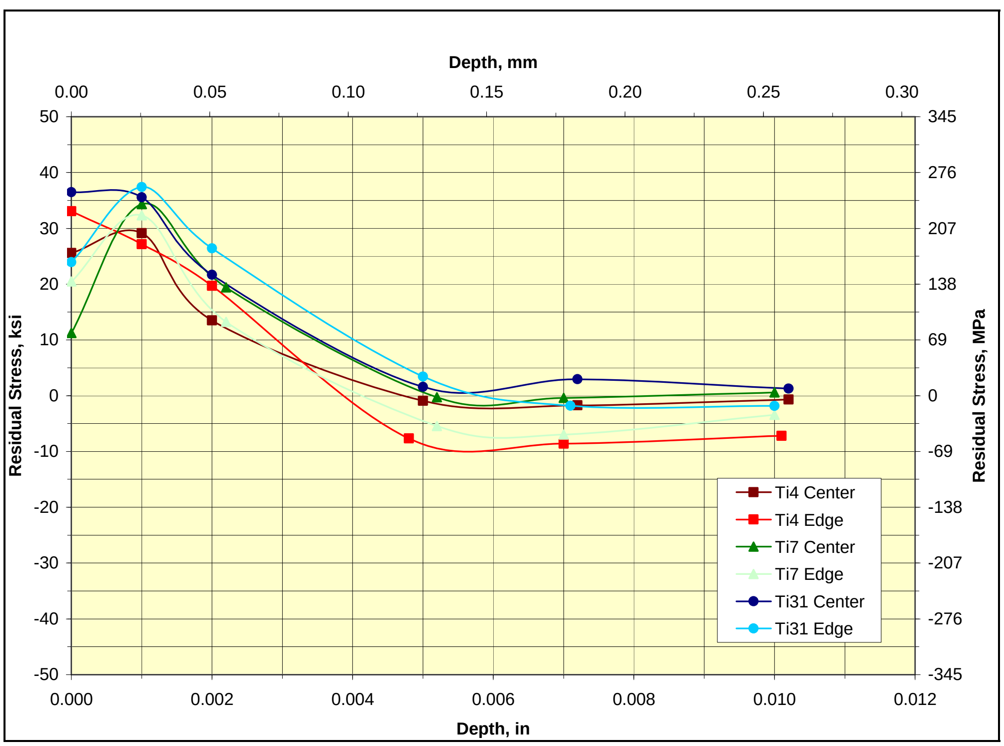


Figure 35. The XRD-RSA data for beta-STOA Ti-6-4 baseline disks.

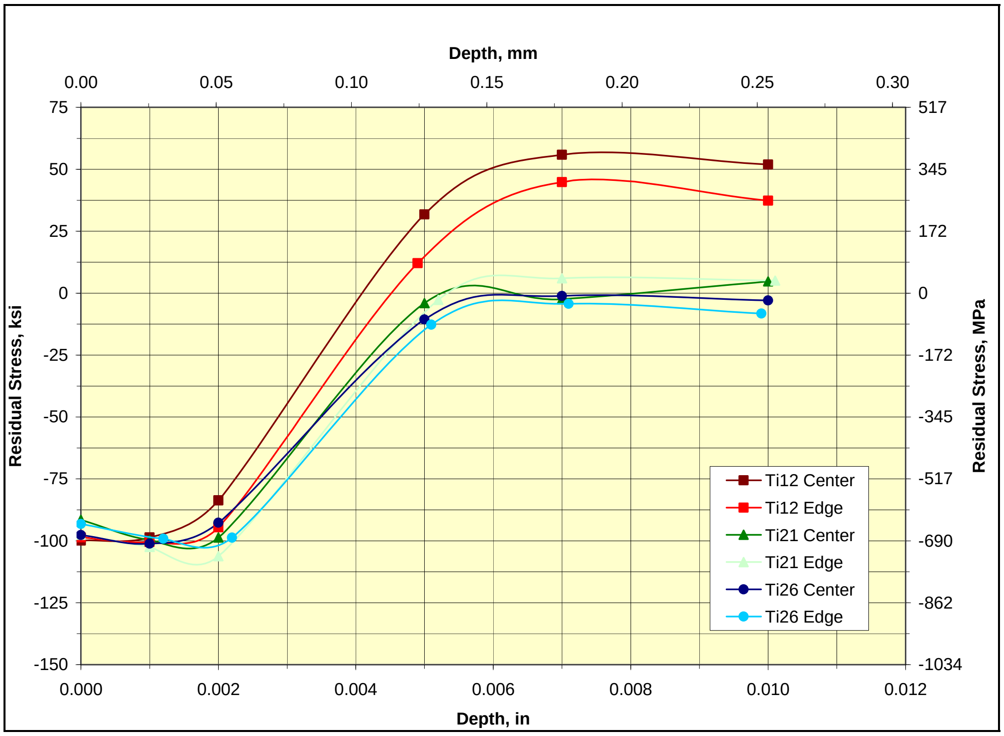


Figure 36. The XRD-RSA data for beta-STOA Ti-6-4 MIC-4A disks.

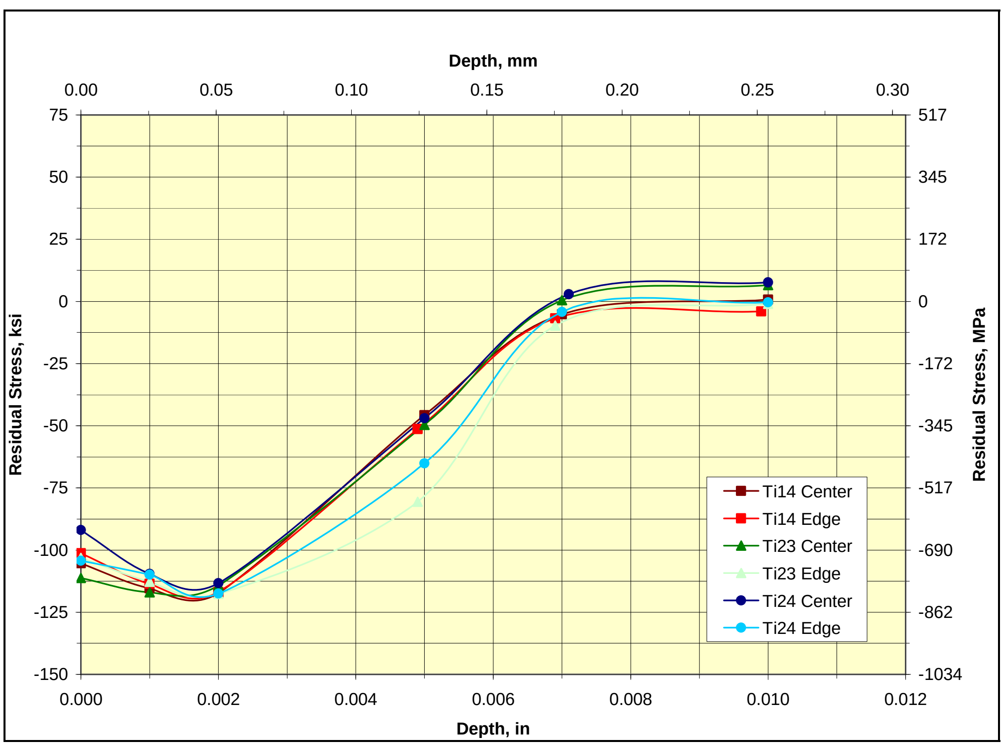


Figure 37. The XRD-RSA data for beta-STOA Ti-6-4 MIC-8A disks.

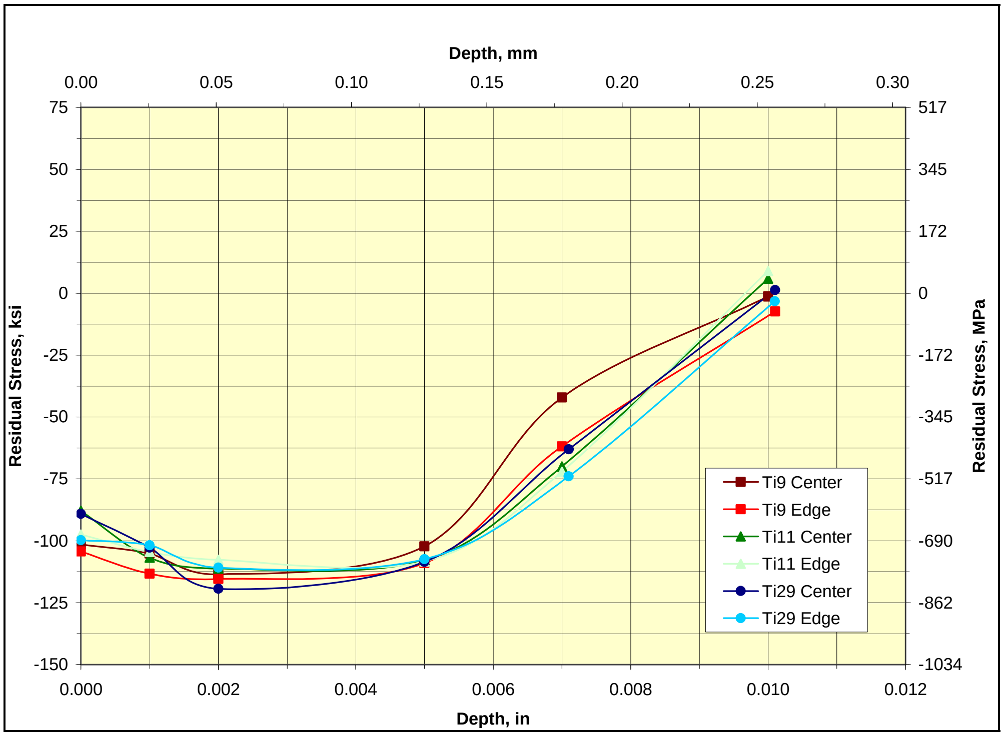


Figure 38. The XRD-RSA data for beta-STOA Ti-6-4 MIC-11.5A disks.

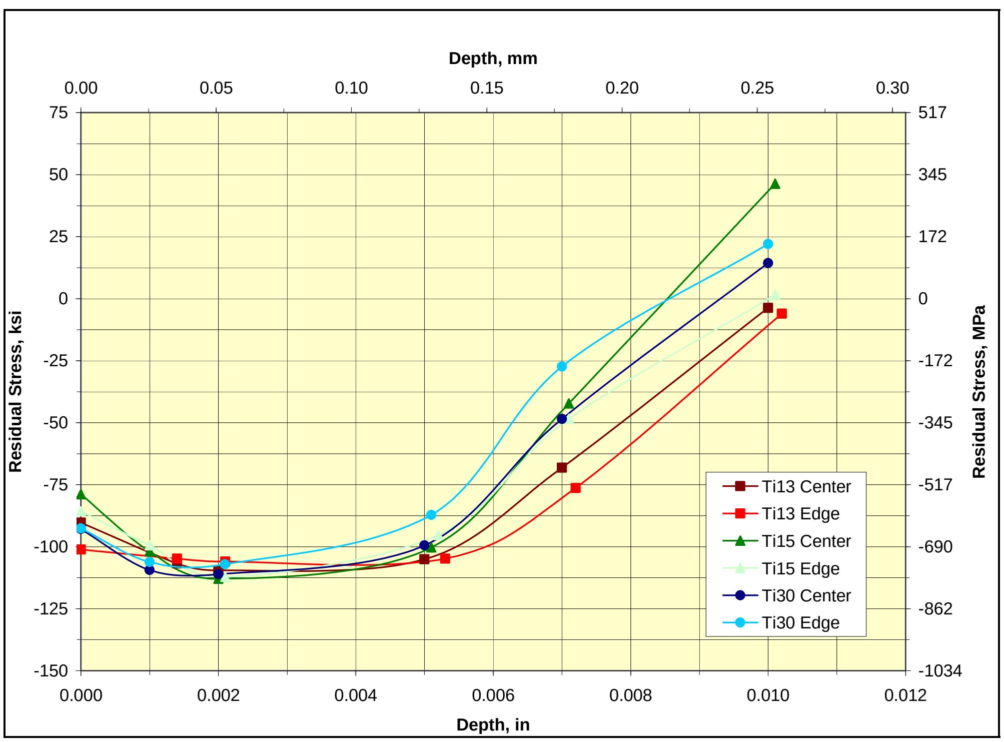


Figure 39. The XRD-RSA data for beta-STOA Ti-6-4 CCAD-14A disks.

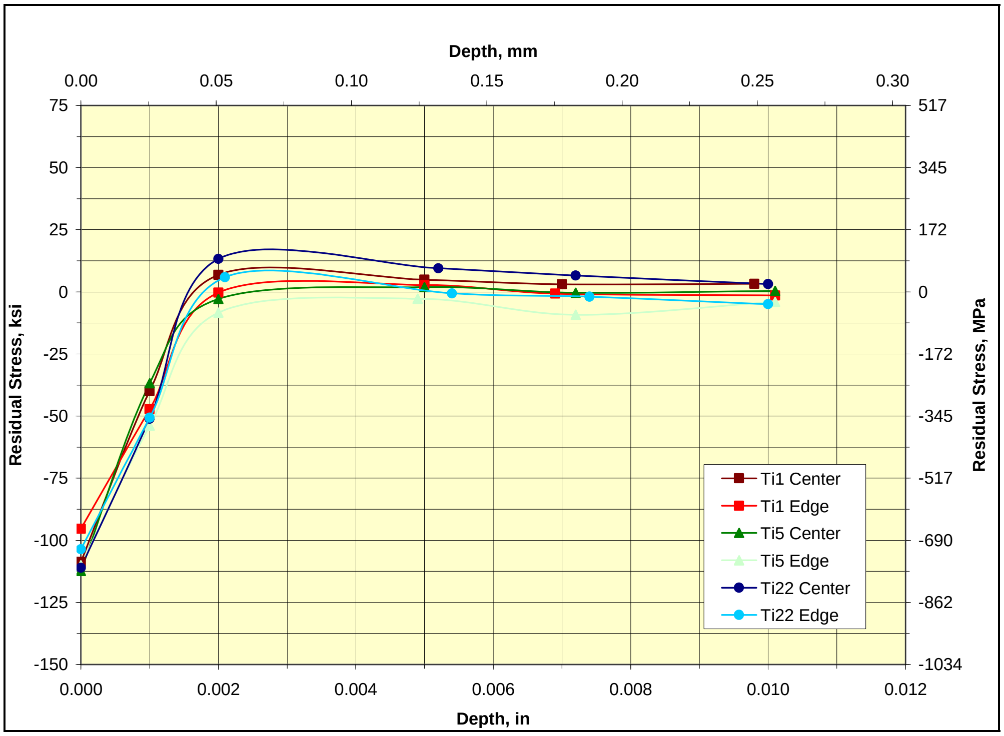


Figure 40. The XRD-RSA data for beta-STOA Ti-6-4 MIC-3N disks.

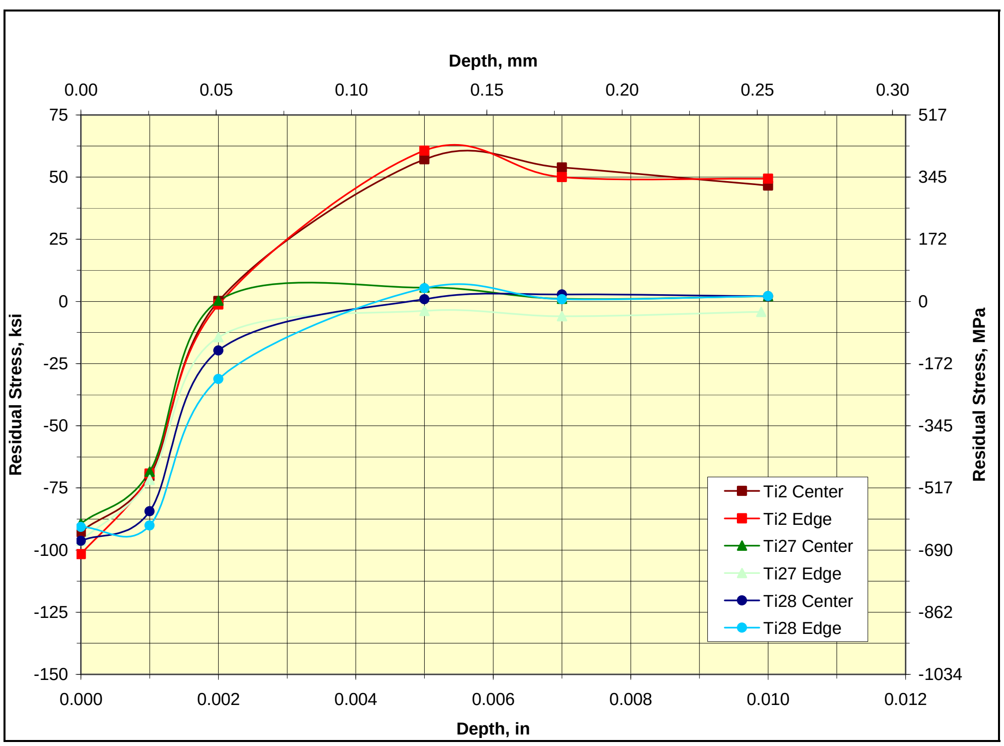


Figure 41. The XRD-RSA data for beta-STOA Ti-6-4 MIC-5N disks.

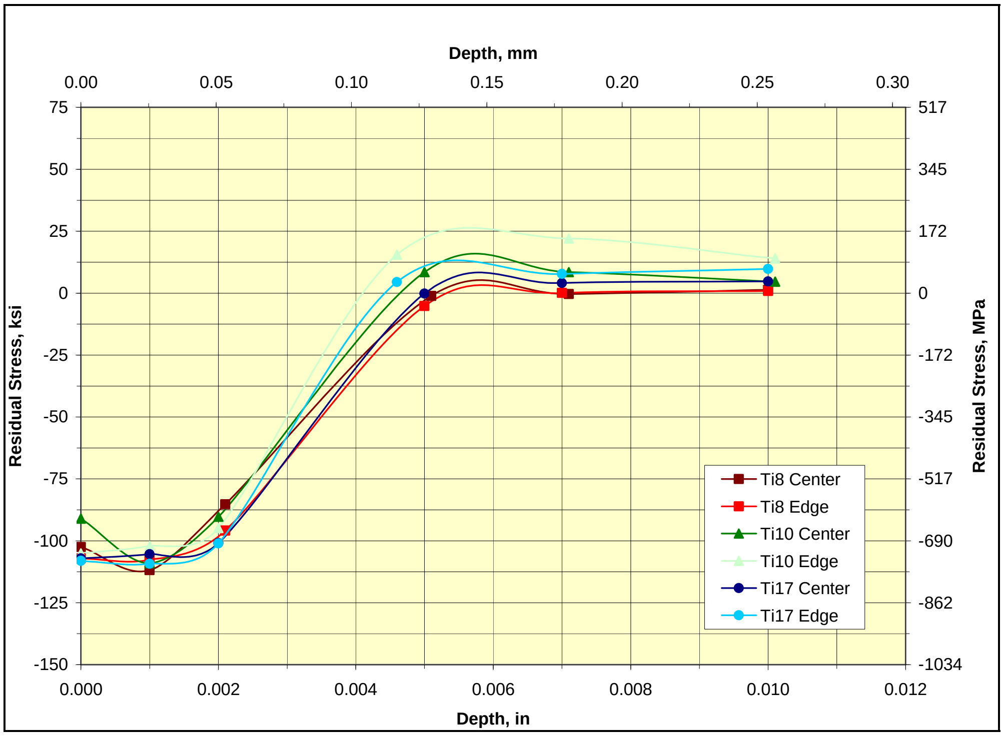


Figure 42. The XRD-RSA data for beta-STOA Ti-6-4 MIC-11N disks.

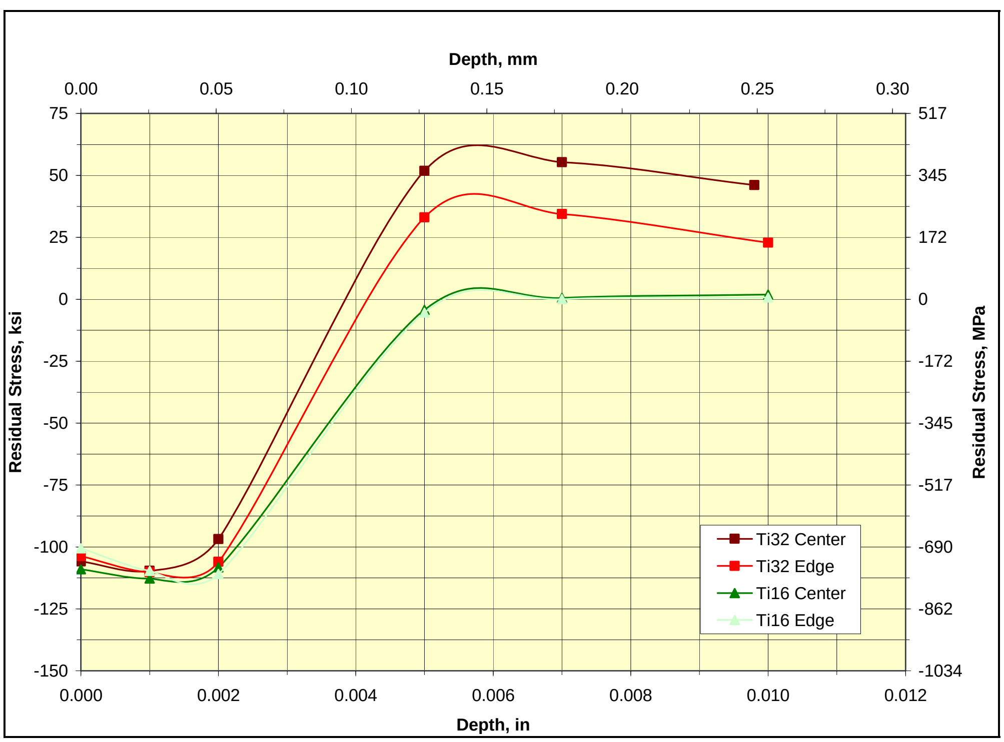


Figure 43. The XRD-RSA data for beta-STOA Ti-6-4 MIC-14N disks.

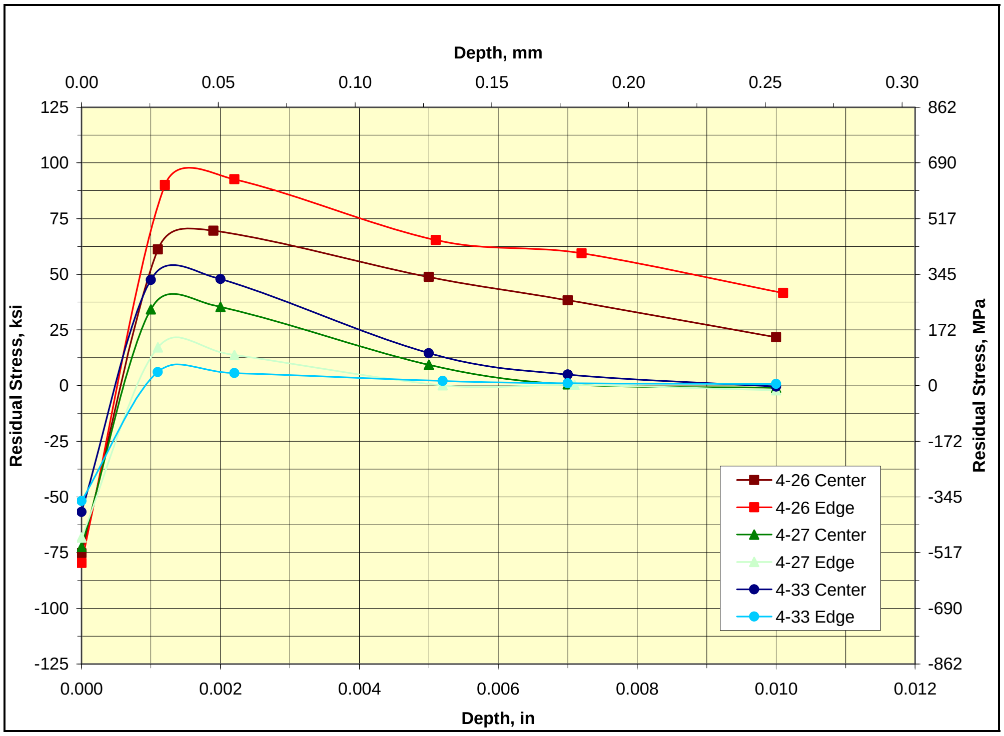


Figure 44. The XRD-RSA data for 4340 steel baseline disks.

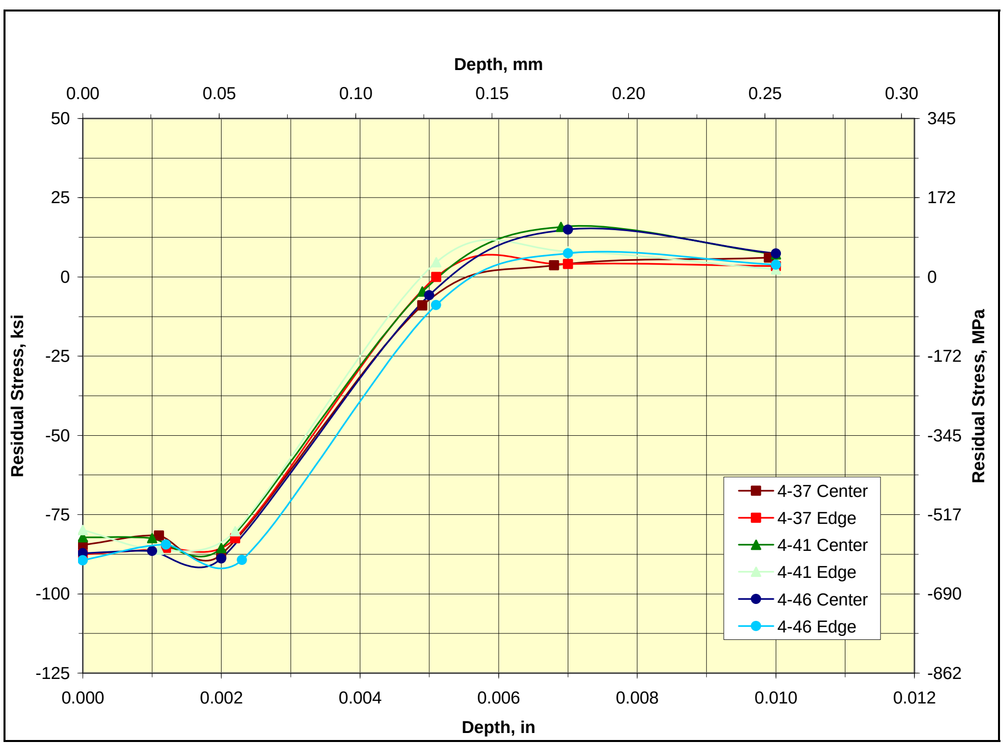


Figure 45. The XRD-RSA data for 4340 steel MIC-4A disks.

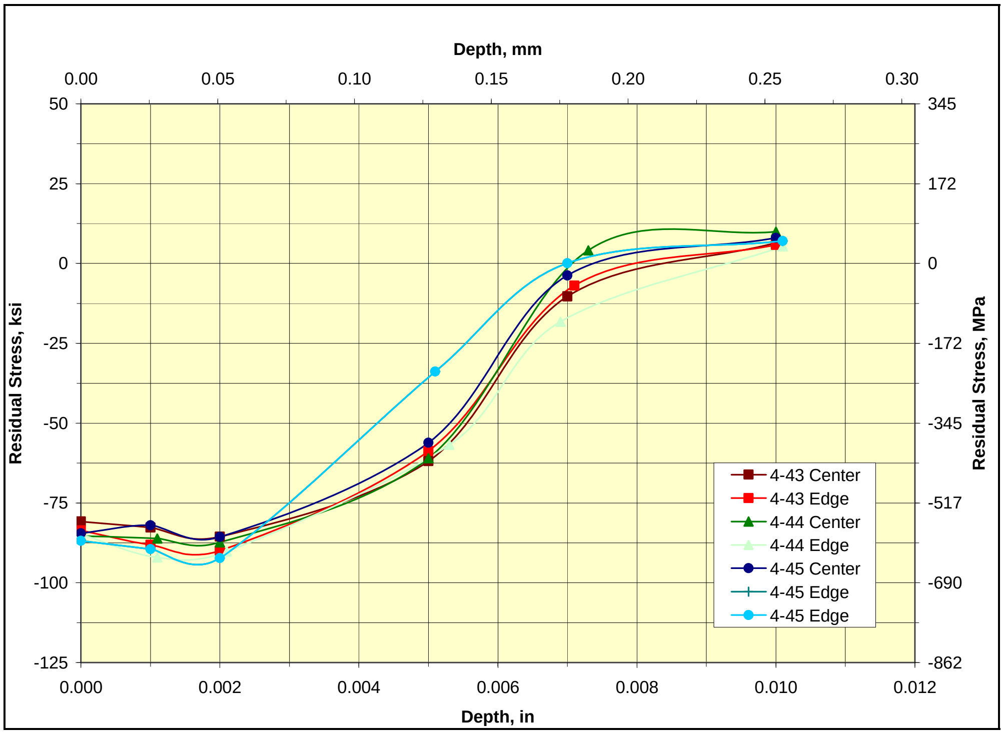


Figure 46. The XRD-RSA data for 4340 steel MIC-8A disks.

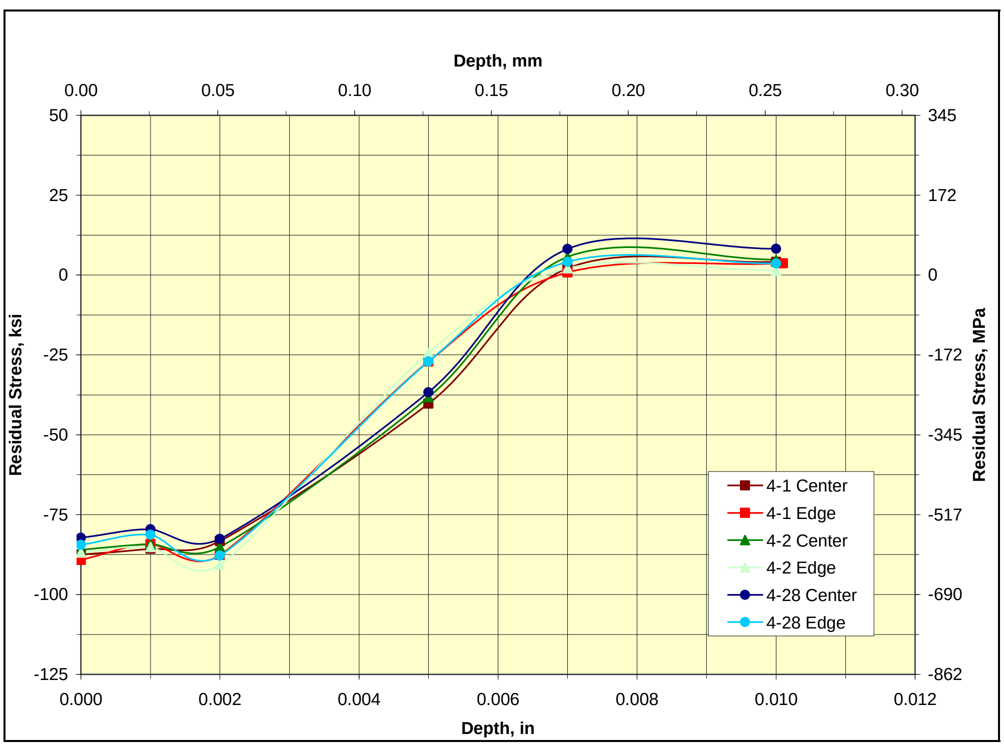


Figure 47. The XRD-RSA data for 4340 steel CCAD-4A disks.

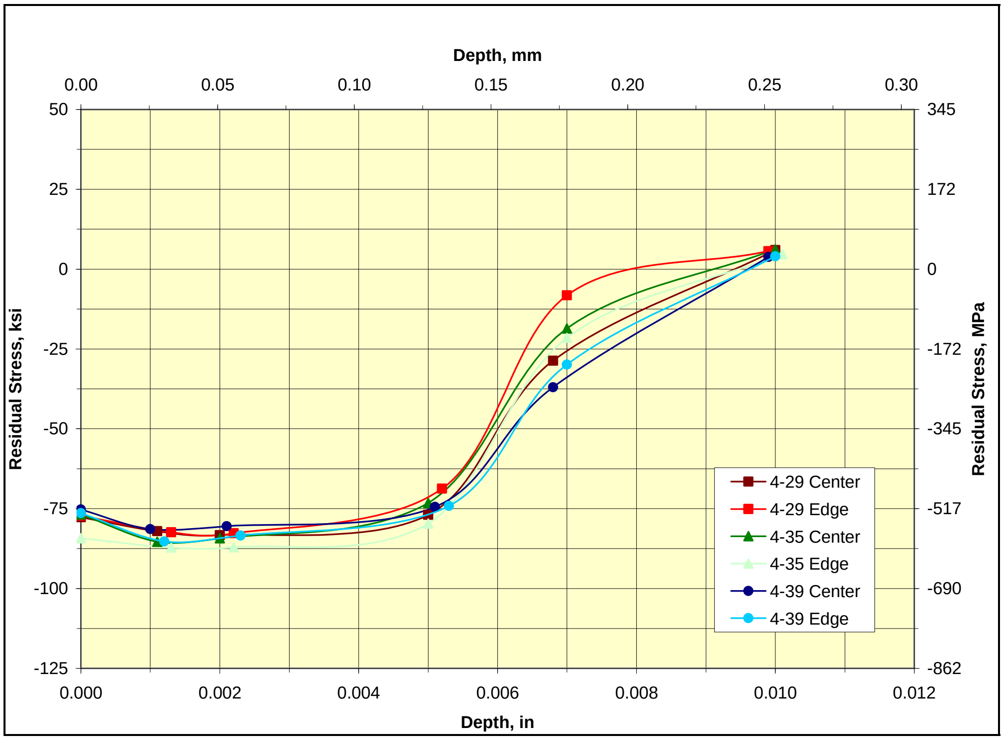


Figure 48. The XRD-RSA data for 4340 steel CCAD-8A disks.

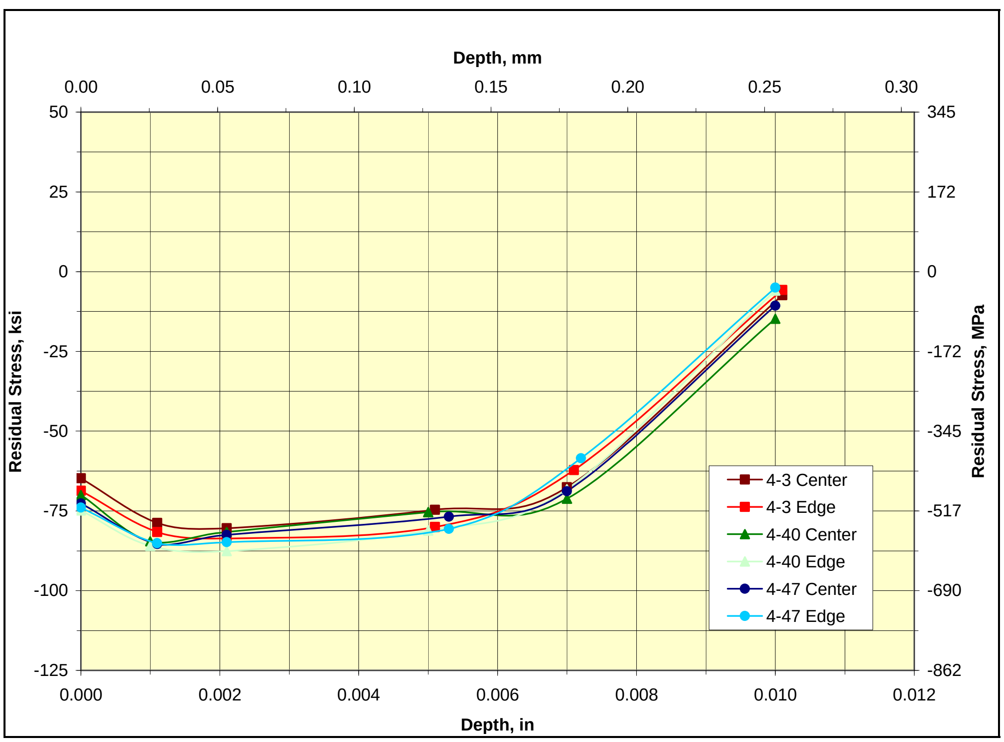


Figure 49. The XRD-RSA data for 4340 steel CCAD-12A disks.

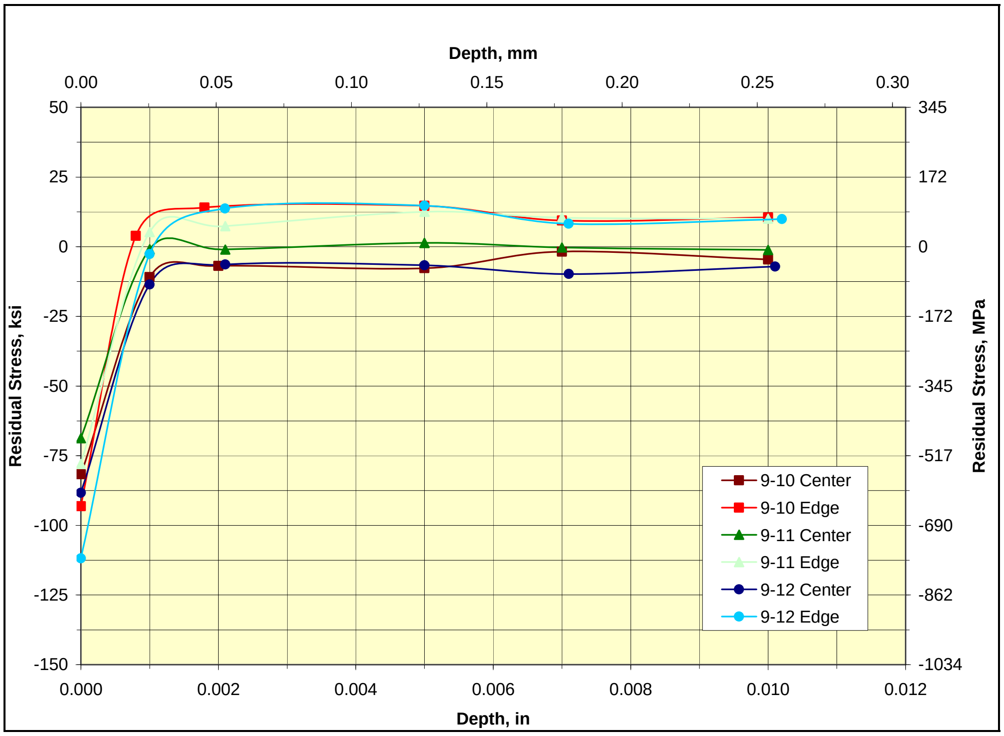


Figure 50. The XRD-RSA data for 9310 steel baseline disks.

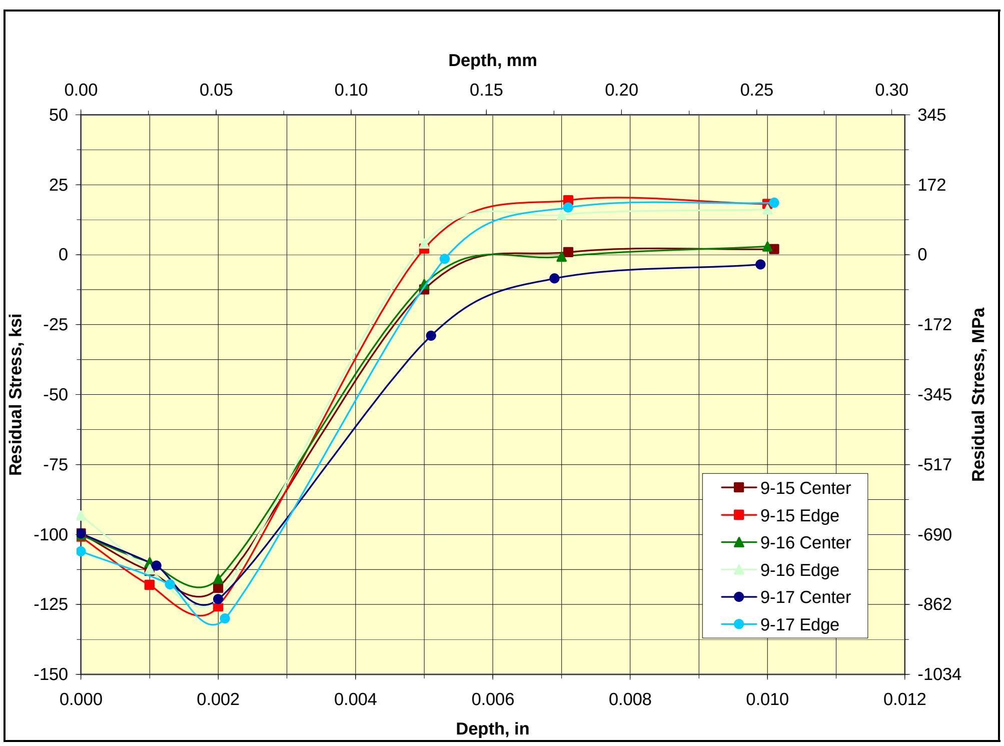


Figure 51. The XRD-RSA data for 9310 steel MIC-4A disks.

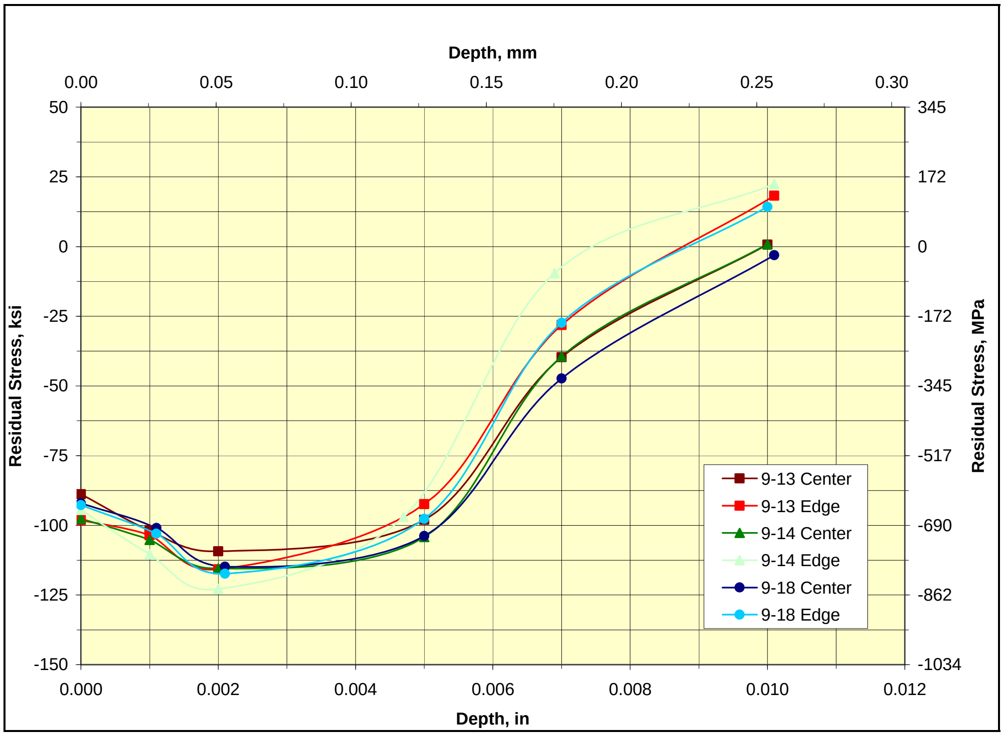


Figure 52. The XRD-RSA data for 9310 steel MIC-8A disks.

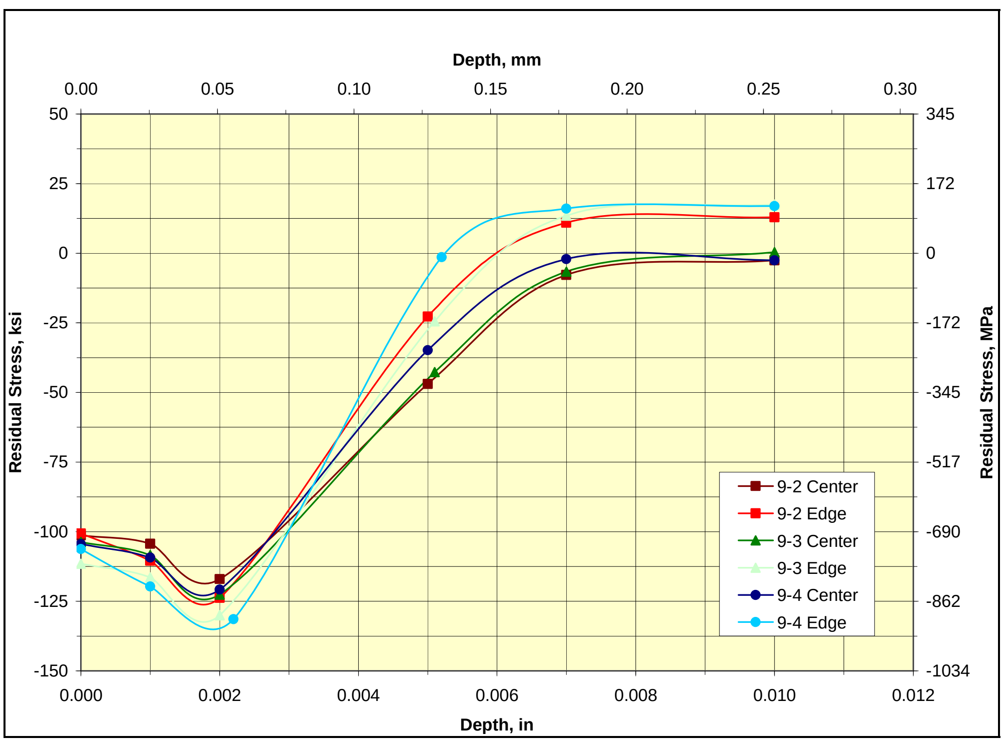


Figure 53. The XRD-RSA data for 9310 steel CCAD-4A disks.

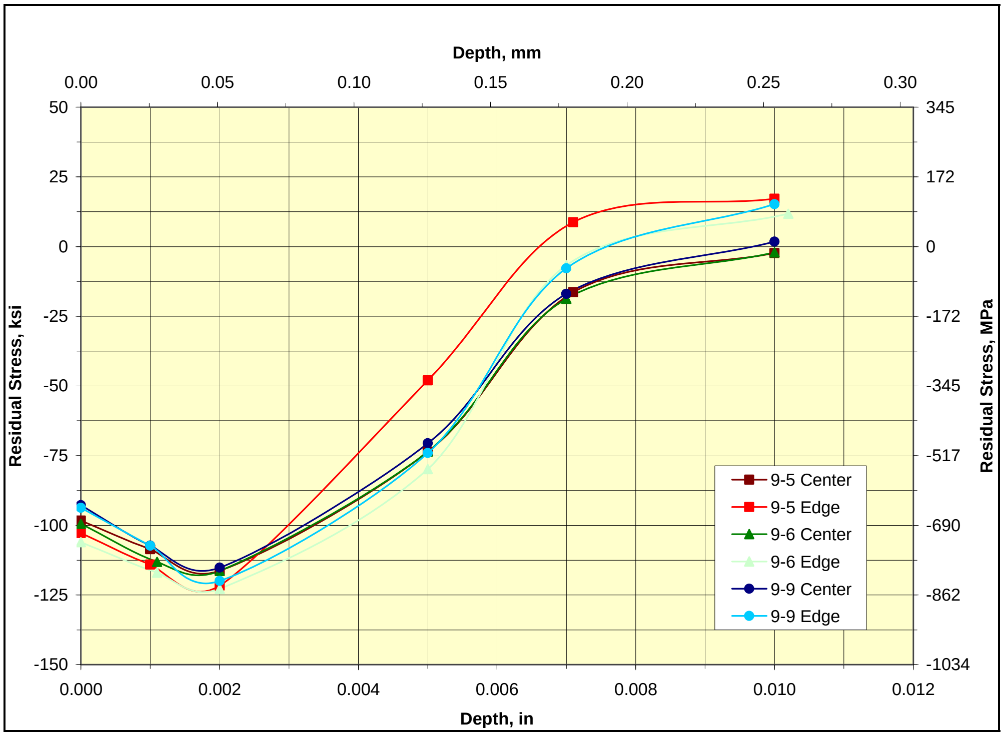


Figure 54. The XRD-RSA data for 9310 steel CCAD-8A disks.

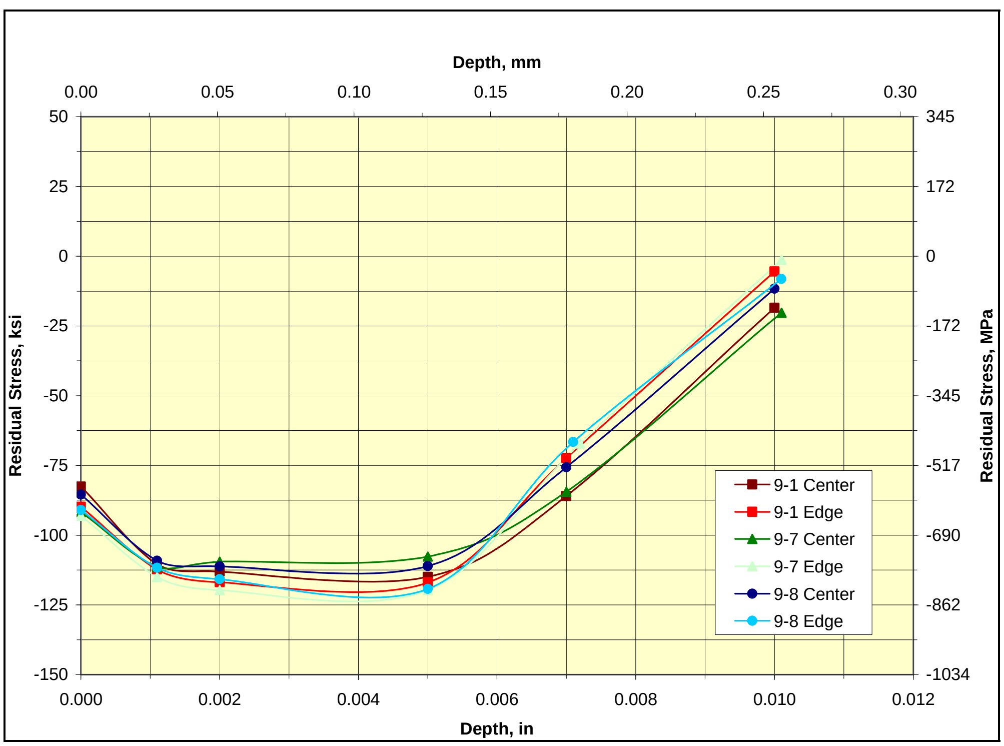


Figure 55. The XRD-RSA data for 9310 steel CCAD-12A disks.

5.3.3 Surface Roughness

The results of the surface roughness assessment of the study are presented in tables 36–44 for aluminum, titanium, 4340 steel, and 9310 steel, respectively. The entire group, MIC-L2-8A for 9310, was measured instead of just the required two specimens due to the apparent difference between the first two measured.

Table 36. Aluminum surface roughness data.

Group	Specimen No.	Ra (µin)	RMS (µin)	Specimen No.	Ra (µin)	RMS (µin)
Unpeened	3A	34.7	37.4	2C	24.0	28.8
Unpeened	3A	32.6	38.6	2C	25.4	30.1
Unpeened	3A	32.5	39.0	2C	24.9	29.7
Unpeened	4A	30.1	39.1	3C	28.7	34.7
Unpeened	4A	29.7	37.0	3C	28.8	35.0
Unpeened	4A	24.6	30.7	3C	29.5	35.9
MIC-L1-4A	38A	104.7	132.0	8B	106.3	132.0
MIC-L1-4A	38A	104.2	130.0	8B	104.8	129.8
MIC-L1-4A	38A	105.1	132.5	8B	95.1	121.9
MIC-L1-4A	66A	96.2	121.9	42B	97.3	123.8
MIC-L1-4A	66A	103.2	130.6	42B	98.7	121.1
MIC-L1-4A	66A	96.7	120.5	42B	97.9	122.9
MIC-L2-8A	73A	224.5	278.1	30B	192.5	240.8
MIC-L2-8A	73A	228.7	292.6	30B	234.8	298.9
MIC-L2-8A	73A	226.9	278.7	30B	232.5	293.7
MIC-L2-8A	76A	245.8	302.2	34B	237.0	290.0
MIC-L2-8A	76A	220.3	275.3	34B	199.0	251.6
MIC-L2-8A	76A	219.5	280.1	34B	206.3	256.8
CCAD-L2-8A	25A	279.4	347.2	57B	302.5	390.6
CCAD-L2-8A	25A	308.8	388.8	57B	266.2	335.0
CCAD-L2-8A	25A	286.9	361.2	57B	283.4	350.4
CCAD-L2-8A	41A	308.4	382.6	63B	289.3	362.2
CCAD-L2-8A	41A	298.1	372.2	63B	281.9	364.8
CCAD-L2-8A	41A	245.0	301.2	63B	287.8	344.6
CCAD-H1-12A	45A	303.4	381.3	79B	337.3	417.8
CCAD-H1-12A	45A	260.3	293.6	79B	256.1	318.9
CCAD-H1-12A	45A	307.7	399.9	79B	278.1	344.9
CCAD-H1-12A	50A	367.7	452.9	80B	333.1	416.0
CCAD-H1-12A	50A	281.3	341.2	80B	247.0	316.6
CCAD-H1-12A	50A	304.4	374.2	80B	283.6	359.7
MIC-H1-12A	34A	285.6	348.5	36B	296.5	360.1
MIC-H1-12A	34A	262.5	329.5	36B	256.2	317.1
MIC-H1-12A	34A	299.1	369.0	36B	247.9	304.7
MIC-H1-12A	71A	283.1	351.0	70B	280.2	361.6
MIC-H1-12A	71A	269.6	334.2	70B	285.5	348.3
MIC-H1-12A	71A	273.2	330.7	70B	285.9	357.3
MIC-H2-14A	52A	365.8	467.0	48B	307.6	389.8
MIC-H2-14A	52A	304.9	378.3	48B	337.9	421.4
MIC-H2-14A	52A	355.7	428.3	48B	310.8	378.8
MIC-H2-14A	51A	331.2	421.1	53B	324.1	388.8
MIC-H2-14A	51A	322.1	420.3	53B	271.7	351.8
MIC-H2-14A	51A	363.9	443.8	53B	334.0	414.7

Table 37. Aluminum surface roughness data, disks 1–3.

Group	Specimen No.	Disk 1		Specimen No.	Disk 2		Specimen No.	Disk 3	
		Ra	RMS		Ra	RMS		Ra	RMS
Unpeened	21a	3.7	7.6	25a	3.4	4.7	40a	3.4	4.5
Unpeened	21b	3.7	8.8	25b	3.1	4.5	40b	3.9	6.1
Unpeened	21c	3.7	6.0	25c	3.2	4.6	40c	4.7	9.8
MIC-L1-4A	17a	104.2	134.7	10a	109.6	133.9	33a	99.7	127.1
	17b	100.1	124.1	10b	94.8	117.5	33b	107.2	130.4
	17c	100.4	124.5	10c	98.4	120.6	33c	96.5	120.3
MIC-L2-10A	9a	189.9	239.8	31a	206.3	255.2	38a	210.6	262.8
	9b	215.1	264.6	31b	207.9	261.8	38b	209.2	259.3
	9c	187.1	235.3	31c	194.1	243.5	38c	199.8	249.9
CCAD-L2-10A	25a	240.8	302.4	30a	253.3	313.6	40a	270.5	334.7
	25b	267.1	327.7	30b	259.0	321.6	40b	270.6	336.3
	25c	228.8	285.8	30c	240.0	300.3	40c	255.5	318.6
CCAD-H1-12A	18a	250.1	309.1	6a	235.5	291.8	44a	271.7	330.8
	18b	289.2	354.2	6b	251.8	307.2	44b	258.7	325.6
	18c	234.5	297.5	6c	248.9	305.1	44c	255.7	323.8
CCAD-H1-12A	16a	247.4	306.1	21a	263.4	330.6	34a	274.4	342.0
	16b	275.4	343.7	21b	252.0	308.3	34b	297.1	373.8
	16c	295.4	372.1	21c	260.7	325.4	34c	283.3	357.4
MIC-H2-14A	24a	311.8	385.4	39a	315.3	388.0	12a	348.9	420.5
	24b	281.3	359.6	39b	313.6	381.9	12b	283.5	354.2
	24c	307.5	376.5	39c	279.5	341.6	12c	319.4	389.1

Table 38. Titanium surface roughness data.

Group	Specimen No.	Ra (µin)	RMS (µin)	Specimen No.	Ra (µin)	RS (µin)
Unpeened	2A	34.6	41.3	18C	17.8	22.5
Unpeened	2A	34.2	40.8	18C	16.5	21.1
Unpeened	2A	34.3	41.0	18C	18.6	23.2
Unpeened	54A	34.3	40.8	19C	14.9	18.7
Unpeened	54A	33.4	39.6	19C	15.7	19.7
Unpeened	54A	33.4	39.4	19C	16.4	20.1
MIC-L1-3N	75A	19.2	24.6	53C	18.3	22.8
MIC-L1-3N	75A	20.1	26.1	53C	18.8	23.4
MIC-L1-3N	75A	19.1	24.6	53C	18.6	23.5
MIC-L1-3N	73A	31.5	38.6	20C	20.2	25.3
MIC-L1-3N	73A	32.5	40.0	20C	22.6	27.8
MIC-L1-3N	73A	32.6	39.3	20C	22.1	27.7
MIC-L2-5N	42A	39.4	50.6	4C	28.9	36.9
MIC-L2-5N	42A	41.7	52.1	4C	38.9	44.2
MIC-L2-5N	42A	40.1	50.9	4C	34.9	44.4
MIC-L2-5N	66A	28.0	35.3	8C	29.0	36.3
MIC-L2-5N	66A	28.9	36.7	8C	29.0	37.3
MIC-L2-5N	66A	32.0	58.0	8C	29.0	36.5
MIC-H1-11N	28A	40.2	52.5	28C	42.6	53.1
MIC-H1-11N	28A	42.2	53.8	28C	41.2	51.7
MIC-H1-11N	28A	43.3	54.0	28C	43.7	55.0
MIC-H1-11N	32A	84.5	100.6	59C	39.5	50.1
MIC-H1-11N	32A	63.2	77.5	59C	36.8	46.9
MIC-H1-11N	32A	60.7	75.5	59C	38.6	49.4
MIC-H2-14N	20A	44.1	55.6	27C	58.7	81.1
MIC-H2-14N	20A	46.5	59.2	27C	40.5	52.5
MIC-H2-14N	20A	47.6	60.2	27C	42.6	53.9
MIC-H2-14N	25A	51.0	64.5	54C	45.4	57.5
MIC-H2-14N	25A	47.2	57.7	54C	46.8	58.8
MIC-H2-14N	25A	45.6	57.9	54C	48.9	61.9
MIC-L1-4A	49A	52.7	65.7	15C	48.3	63.8
MIC-L1-4A	49A	46.8	58.8	15C	47.7	60.5
MIC-L1-4A	49A	39.7	53.7	15C	44.2	54.5
MIC-L1-4A	53A	40.7	51.3	31C	44.1	56.7
MIC-L1-4A	53A	40.8	51.0	31C	45.1	56.2
MIC-L1-4A	53A	40.7	51.7	31C	41.2	51.9
MIC-L2-8A	9A	69.9	88.0	36C	66.2	84.3
MIC-L2-8A	9A	57.1	71.4	36C	66.6	85.8
MIC-L2-8A	9A	70.5	87.4	36C	59.8	74.9
MIC-L2-8A	17A	74.6	93.6	72C	61.3	80.1
MIC-L2-8A	17A	76.8	97.7	72C	56.6	71.8
MIC-L2-8A	17A	76.4	96.9	72C	64.0	81.3
MIC-H1-11.5A	35A	103.5	132.7	39C	110.2	145.8
MIC-H1-11.5A	35A	103.6	132.9	39C	116.2	146.3
MIC-H1-11.5A	35A	100.6	125.8	39C	88.1	113.1
MIC-H1-11.5A	62A	95.9	123.7	24C	118.6	147.3
MIC-H1-11.5A	62A	94.3	117.6	24C	118.8	147.9
MIC-H1-11.5A	62A	96.6	121.2	24C	107.2	137.1
CCAD-H2-14A	1A	110.4	138.2	63C	104.7	127.3
CCAD-H2-14A	1A	104.7	130.4	63C	97.1	127.5
CCAD-H2-14A	1A	115.5	141.3	63C	111.8	143.2
CCAD-H2-14A	57A	101.3	125.0	68C	97.3	122.4
CCAD-H2-14A	57A	102.4	130.4	68C	104.0	132.9
CCAD-H2-14A	57A	107.3	133.0	68C	93.1	115.5

Table 39. Titanium surface roughness data, disks 1–3.

Group	Specimen No.	Disk 1		Specimen No.	Disk 2		Specimen No.	Disk 3	
		Ra	RMS		Ra	RMS		Ra	RMS
Unpeened	13a	2.2	3.1	15a	2.6	3.7	30a	2.4	3.1
Unpeened	13b	2.3	3.1	15b	2.8	5.3	30b	2.5	3.1
Unpeened	13c	2.6	4.0	15c	2.7	3.6	30c	2.6	4.2
MIC-L1-3N	1A	11.5	15.1	5A	12.3	15.7	22A	11.8	15.1
	1B	11.5	14.7	5B	11.5	14.7	22B	11.6	15.1
	1C	11.5	14.6	5C	11.4	14.5	22C	11.3	14.4
MIC-L2-5N	2A	20.6	27.4	27A	19.7	26.1	28A	21.0	27.2
	2B	20.9	26.8	27B	25.9	34.5	28B	21.0	27.8
	2C	21.5	27.1	27C	21.5	27.1	28C	22.7	30.4
MIC-H1-11N	8A	40.4	50.8	10A	39.8	50.2	17A	41.0	51.4
	8B	39.2	50.2	10B	41.3	54.1	17B	40.8	51.8
	8C	42.1	54.5	10C	39.4	50.0	17C	43.0	54.1
MIC-H2-14N	16A	44.0	56.3	Bad Data			32A	43.6	55.5
	16B	44.8	56.4				32B	49.2	63.4
	16C	44.2	55.4				32C	40.8	52.1
MIC-L1-4A	12A	44.5	55.5	21A	47.2	59.4	26A	44.0	54.8
	12B	45.3	58.3	21B	45.9	59.0	26B	38.5	49.7
	12C	46.3	58.0	21C	44.1	56.6	26C	41.6	53.2
MIC-L2-8A	14A	65.6	82.3	23A	68.5	86.4	24A	63.8	81.2
	14B	75.0	93.7	23B	70.9	89.8	24B	70.6	88.8
	14C	73.6	91.8	23C	65.5	80.8	24C	69.7	86.9
MIC-H1-11.5A	9A	98.1	124.1	11A	104.4	132.3	29A	117.8	146.5
	9B	102.6	130.3	11B	97.2	124.5	29B	104.4	131.0
	9C	94.3	118.2	11C	104.4	131.6	29C	94.1	120.2
CCAD-H2-14A	13A	116.8	146.3	15A	120.7	156.6	30A	109.5	139.5
	13B	119.4	149.3	15B	107.9	141.8	30B	128.9	169.4
	13C	109.0	139.6	15C	105.4	135.6	30C	131.0	180.6

Table 40. The 4340 surface roughness data.

Group	Specimen No.	Ra (µin)	RMS (µin)	Specimen No.	Ra (µin)	RMS (µin)
Unpeened	23A	21.8	29.9	23B	7.4	9.8
Unpeened	23A	17.4	24.3	23B	7.8	10.1
Unpeened	23A	15.8	22.3	23B	7.7	10.3
Unpeened	30A	18.5	25.8	32B	8.2	17.5
Unpeened	30A	19.3	26.8	32B	5.9	9.1
Unpeened	30A	16.8	23.7	32B	7.9	15.1
MIC-L1	8A	50.1	61.9	4B	53.1	66.8
MIC-L1	8A	53.7	67.1	4B	49.6	62.2
MIC-L1	8A	51.6	63.8	4B	51.0	62.8
MIC-L1	20A	52.3	65.9	12B	49.2	61.3
MIC-L1	20A	53.7	67.7	12B	53.0	65.8
MIC-L1	20A	54.4	68.4	12B	54.9	70.7
MIC-L2	9A	130.0	168.7	1B	112.2	143.3
MIC-L2	9A	119.1	149.6	1B	107.8	134.4
MIC-L2	9A	121.0	153.6	1B	109.0	136.3
MIC-L2	16A	116.6	143.9	17B	111.2	136.4
MIC-L2	16A	108.9	137.6	17B	109.1	135.6
MIC-L2	16A	119.7	153.2	17B	109.2	138.0
CCAD-L2	31A	101.6	127.7	51B	87.0	105.5
CCAD-L2	31A	97.1	121.4	51B	96.6	121.7
CCAD-L2	31A	94.3	115.2	51B	97.2	122.2
CCAD-L2	32A	102.8	129.8	54B	103.2	128.6
CCAD-L2	32A	97.2	121.7	54B	88.2	109.6
CCAD-L2	32A	84.3	105.0	54B	94.9	118.8
CCAD-H1	51A	143.3	183.2	36B	174.3	216.1
CCAD-H1	51A	163.7	206.6	36B	154.3	198.2
CCAD-H1	51A	158.6	197.3	36B	154.4	195.9
CCAD-H1	56A	169.1	209.2	38B	162.4	200.9
CCAD-H1	56A	152.4	188.6	38B	166.8	211.2
CCAD-H1	56A	158.1	200.7	38B	171.1	213.2
CCAD-L1	64A	66.6	82.8	55B	67.1	84.0
CCAD-L1	64A	64.6	81.3	55B	64.4	80.8
CCAD-L1	64A	55.7	70.2	55B	64.0	80.0
CCAD-L1	69A	67.7	85.4	63B	63.6	78.1
CCAD-L1	69A	71.8	88.4	63B	63.4	79.5
CCAD-L1	69A	65.0	80.0	63B	71.1	91.3

Table 41. The 4340 surface roughness data, disks 1–3.

Group	Specimen No.	Disk 1		Specimen No.	Disk 2		Specimen No.	Disk 3	
		Ra	RMS		Ra	RMS		Ra	RMS
Unpeened	30A	1.4	4.2	34A	1.3	4.1	38A	0.5	1.0
Unpeened	30B	0.9	1.5	34B	0.8	2.2	38B	0.8	1.2
Unpeened	30C	1.1	1.8	34C	0.8	1.7	38C	0.5	0.8
MIC-L1-4A	37A	52.6	66.3	46A	52.5	67.6	41A	50.0	62.6
	37B	59.3	78.6	46B	49.8	61.8	41B	52.7	67.6
	37C	52.7	68.9	46C	50.5	64.0	41C	51.2	65.1
MIC-L2-8A	29A	100.3	124.3	39A	97.8	121.6	35A	99.8	127.1
	29B	98.0	122.1	39B	93.8	123.9	35B	97.3	122.3
	29C	96.1	118.1	39C	99.3	124.6	35C	91.3	113.1
CCAD-L2-8A	43A	89.9	115.2	44A	90.5	111.1	45A	86.7	110.7
	43B	85.7	106.0	44B	88.0	111.4	45B	85.1	108.5
	43C	93.6	118.1	44C	93.6	118.3	45C	89.3	113.6
CCAD-H1-12A	3A	158.1	202.3	40A	174.6	233.6	47A	158.0	208.1
	3B	162.5	208.8	40B	142.6	180.6	47B	137.4	173.1
	3C	152.6	190.0	40C	155.8	195.5	47C	150.7	191.4
CCAD-L1-4A	1A	70.0	87.4	2A	67.3	84.0	28A	70.4	87.6
	1B	70.8	88.7	2B	64.1	80.6	28B	63.6	78.4
	1C	73.6	92.0	2C	65.4	80.9	28C	62.0	76.9

Table 42. The 9310 surface roughness data.

Group	Specimen No.	Ra (µin)	RMS (µin)	Specimen No.	Ra (µin)	RMS (µin)
Unpeened	11A	21.1	38.3	16B	19.3	43.4
Unpeened	11A	34.0	50.2	16B	13.1	19.3
Unpeened	11A	22.3	36.5	16B	25.5	44.6
Unpeened	12A	15.5	22.0	17B	11.8	18.8
Unpeened	12A	18.3	30.3	17B	18.3	31.8
Unpeened	12A	17.2	25.4	17B	9.0	12.6
MIC L1	52A	40.6	51.4	53B	44.6	56.8
MIC L1	52A	47.3	59.6	53B	42.5	53.9
MIC L1	52A	40.6	51.4	53B	42.4	56.9
MIC L1	56A	46.7	60.3	57B	40.8	50.9
MIC L1	56A	51.9	69.7	57B	37.7	49.1
MIC L1	56A	51.1	64.6	57B	38.8	49.3
MIC L2	63A	91.2	119.0	61B	50.5	64.8
MIC L2	63A	97.1	119.7	61B	60.6	75.9
MIC L2	63A	113.4	142.6	61B	45.5	57.9
MIC L2	67A	81.6	101.5	65B	92.8	118.0
MIC L2	67A	92.6	118.8	65B	95.1	119.6
MIC L2	67A	86.1	89.5	65B	97.2	125.3
CCAD L2	33A	76.7	95.3	25B	75.4	93.3
CCAD L2	33A	82.7	104.7	25B	72.7	90.3
CCAD L2	33A	86.6	106.5	25B	71.4	90.1
CCAD L2	35A	75.9	94.3	28B	71.4	89.9
CCAD L2	35A	77.7	99.5	28B	79.9	98.9
CCAD L2	35A	86.7	107.7	28B	71.4	88.6
CCAD H1	22A	139.5	176.8	41B	119.7	149.5
CCAD H1	22A	145.4	181.3	41B	132.9	167.3
CCAD H1	22A	149.3	186.3	41B	128.4	161.7
CCAD H1	30A	127.6	161.9	50B	124.7	155.4
CCAD H1	30A	134.6	171.4	50B	133.7	169.3
CCAD H1	30A	139.4	176.3	50B	133.2	168.1
CCAD L1	47A	46.0	57.1	32B	47.6	59.9
CCAD L1	47A	51.1	64.7	32B	41.5	52.5
CCAD L1	47A	52.8	66.5	32B	53.2	65.0
CCAD L1	50A	51.6	65.5	35B	46.7	58.3
CCAD L1	50A	49.5	63.0	35B	50.9	66.1
CCAD L1	50A	47.8	60.7	36B	45.0	56.2

Note: [green box] = discrepancy noted. Expanded data for the group in table 40.

Table 43. The 9310 surface roughness data, disks 1–3.

Group	Specimen No.	Disk 1		Specimen No.	Disk 2		Specimen No.	Disk 3	
		Ra	RMS		Ra	RMS		Ra	RMS
Unpeened	10A	0.5	0.8	11A	0.4	0.7	12A	0.5	1.6
Unpeened	10B	0.6	1.0	11B	0.5	0.9	12B	0.4	1.8
Unpeened	10C	0.4	0.7	11C	1.1	0.5	12C	0.4	0.8
MIC-L1-4A	15A	36.1	44.3	16A	41.2	51.7	17A	36.2	47.2
	15B	36.5	45.9	16B	39.4	49.8	17B	38.1	47.2
	15C	37.6	47.2	16C	38.1	48.1	17C	37.2	46.4
MIC-L2-8A	13A	73.7	91.8	14A	84.6	106.8	18A	79.0	101.1
	13B	77.2	96.2	14B	80.5	106.2	18B	82.0	102.3
	13C	71.9	93.8	14C	92.9	113.5	18C	77.1	96.1
CCAD-L2-8A	5A	70.2	88.0	6A	72.3	91.4	9A	74.5	94.8
	5B	76.2	94.4	6B	74.6	93.3	9B	69.1	88.3
	5C	72.5	92.6	6C	72.5	92.8	9C	78.3	97.5
CCAD-H1-12A	1A	142.8	176.7	7A	130.2	164.6	8A	142.5	176.0
	1B	143.3	184.1	7B	131.8	161.1	8B	153.4	189.2
	1C	141.6	174.8	7C	140.3	174.4	8C	132.9	170.2
CCAD-L1-4A	2A	56.6	70.5	3A	53.6	67.0	4A	50.2	63.6
	2B	54.8	68.4	3B	57.5	72.3	4B	53.1	66.7
	2C	51.2	63.9	3C	54.4	69.0	4C	54.0	70.0

Table 44. Detailed surface roughness data for group MIC-L2.

Specimen No.	Ra (μin)	RMS (μin)	Specimen No.	Ra (μin)	RMS (μin)
MIC-L2 62A	46.0	57.6	MIC-L2 70A	84.6	104.9
MIC-L2 62B	52.3	66.1	MIC-L2 70B	92.9	116.7
MIC-L2 62C	45.7	58.7	MIC-L2 70C	81.6	108.9
MIC-L2 66A	54.4	68.4	MIC-L2 63A	83.3	105.8
MIC-L2 66B	57.4	72.8	MIC-L2 63B	83.8	104.0
MIC-L2 66C	53.1	66.9	MIC-L2 63C	89.4	110.1
MIC-L2 67A	62.8	78.8	MIC-L2 64A	87.3	111.1
MIC-L2 67B	57.9	74.1	MIC-L2 64B	98.3	118.2
MIC-L2 67C	51.1	65.0	MIC-L2 64C	83.5	107.7
MIC-L2 69A	61.2	75.6	MIC-L2 68A	87.9	109.8
MIC-L2 69B	64.7	83.6	MIC-L2 68B	74.5	93.2
MIC-L2 69C	58.6	73.2	MIC-L2 68C	88.7	110.9

6. Discussion

6.1 Phase 1. Almen Strip Intensity Study

Increasing the nozzle angle toward 90°, increasing the air pressure, decreasing the nozzle distance, and increasing the air jet size increased the resultant shot-peening intensity. Flow rate was only significantly dependent on air jet size. The combination of maximum and minimum intensity yielding parameters did provide the maximum and minimum intensities as planned. It was interesting to note that the ranges of intensities yielded by this phase of the study did not extend far beyond those stipulated on the component drawings that incorporate the materials used in this study (except for some extreme limits and the combined parameters yielding the maximum and minimum values). This would suggest that the intensity ranges on the component drawings are larger than those which could be expected from common errors encountered during shot-peening variation.

6.2 Phase 2. Fatigue Assessment

6.2.1 Aluminum 7075-T73

See figures 12, 16–18.

The fatigue performance of the various intensity groups varied significantly. MIC-4A performed nearly equivalent to the baseline and was the best performing shot-peened group for the smooth $K_t = 1$ specimens. MIC-14A had the lowest fatigue strength (well below the baseline). MIC- and CCAD-10A performed similarly, while at 12A, MIC outperformed CCAD by a substantial margin. It was interesting to note that the lowest shot-peening intensity was the best performer. It was expected that shot peening would show a benefit over the baseline at all intensities, but this was not the case. Only MIC-4A, the best performer, was similar to the baseline data. Possible explanations for this include surface imperfections from worn shot (although this is unlikely, since new shot was used) and processing differences of the shot-peened specimens (such as the acid cleaning treatment to remove the residual steel shot from the aluminum surfaces). A metallographic and surface analysis is planned.

Similar results were observed for the Kt = 1.75 groups. Again, the MIC-4A group outperformed the others; however, at this stress intensity, the baseline was still significantly higher. MIC-14A was again the poorest performer. MIC- and CCAD-10A and 12A were nearly equivalent at this stress intensity. All groups performed at a level lower than the baseline. This was unexpected, but similar results were found across all materials, and further study is planned.

At $K_t = 2.5$, all groups performed equal to or better than the baseline. However, at this stress intensity, MIC-14A performed the best. In a reversal from the previous stress intensities, MIC-4A was at the bottom. Similar to $K_t = 1$, MIC- and CCAD-10A performed at a nearly equivalent level, while at 12A, MIC outperformed CCAD by a significant amount.

6.2.2 Beta-STOA Titanium 6Al-4V

See figures 13, 19–21.

The fatigue performance varied significantly for titanium. At $K_t = 1$, the best performers were the MIC-5N and MIC-4A groups. It was interesting to note that the 5N and 14N groups performed similarly, as did the 3N and 12N groups. A direct or indirect relationship with intensity was not observed; rather, the peak appeared near the middle of the intensity range. For the A intensity scale, MIC-4A was clearly superior, and an indirect relationship with intensity was observed (the higher the intensity, the lower the fatigue performance). The two lower intensities, 4A and 8A, were clearly above the other groups and the baseline data.

For the K_t = 1.75 groups, superior performance was apparent at the lower intensities for the N and A scales. Indirect relationships with intensity were observed for both scales. The 8A, 11.5A, and 14A data all had endurance limits below the baseline, while all data above 100K cycles outperformed the baseline.

At K_t = 2.5, the 3N group performed the best on the N scale intensities. An indirect relationship with intensity was observed. At the A intensity scale, the MIC-11.5A group performed best and the CCAD-14A N group performed worst, although performance of this group was nearly equivalent to MIC-8A. It would appear that for this stress intensity, the best fatigue performance occurs near the 11.5A level. Beyond that, detrimental effects are observed. Similar to the K_t = 1.75 data, the A scale intensities (other than the optimum 11.5A) appear to be detrimental only above 100K cycles when compared with the baseline data.

6.2.3 The 4340 Steel

See figures 14, 22–24.

The fatigue performance varied significantly for 4340 steel. The best performers for K_t = 1, were the MIC- and CCAD-4A groups, which were essentially equal. The worst performer was the CCAD-H1-12A group, which approached baseline levels near the endurance limit. The MIC and CCAD performance at 8A was essentially the same. Fatigue performance demonstrated an indirect relationship with shot-peening intensity over the range studied. All shot-peened groups demonstrated at least slight improvements over the baseline data.

At K_t = 1.75, the 4A groups again demonstrated the top performance, while MIC slightly outperformed the specimens from CCAD. The lowest performance was observed for the CCAD-H1-12A group which fell well below the baseline data. Both groups at the 8A level performed worse than the baseline group, and the indirect relationship with shot-peening intensity was again observed.

For the K_t = 2.5 groups, the best performance was observed among the 4A groups from MIC and CCAD. The two had nearly equal performances. It appeared that the 8A group from CCAD had the lowest performance values, although the runout at 70 ksi for this group may be an outlier. The performance of CCAD-12A was lower for all other stress levels, and this group would be expected to be lower than 8A, based on the data for the other stress intensities of this material. It is likely that the small sample size for the group had prevented the true levels from being observed within CCAD-12A. The MIC-8A group appeared to have only slightly better performance than the CCAD-8A group, although the endurance limit for the group from MIC could not be fully explored because of the small sample size. All shot-peened data fell above the baseline data for this stress intensity. The indirect relationship of fatigue performance with shot-peening intensity, over the ranges studied, was readily apparent.

6.2.4 The 9310 Steel

See figures 15, 25–27.

The fatigue performance of the 9310 material varied widely for the ranges of shot-peening intensity and stress intensity studied. The $K_t = 1$ stress intensity saw the best performance from the MIC- and CCAD-4A groups. The two were essentially equivalent. The lowest performance came from the CCAD-12A group, which was dramatically below the baseline. This result was expected, based on the results at the other 9310 stress intensities and all data from 4340 steel. The indirect relationship between fatigue performance and shot-peening intensity was again revealed. The data from the MIC- and CCAD-8A groups were slightly different. The specimens from CCAD outperformed those from MIC at this stress intensity, and the group from MIC fared slightly worse than the baseline.

For the Kt = 1.75 data, the best performers among the shot-peened groups were those at 4A—the two groups from MIC and CCAD were essentially equivalent. The lowest performance was observed from the CCAD-12A group. The two groups at 8A, from MIC and CCAD, were essentially equal and fell in between the 4A and 12A results, demonstrating an indirect relationship of fatigue with shot-peening intensity. The most striking result from this stress intensity was the amount below the baseline that the shot-peened data fell. All shot-peened data above 100K cycles was below the baseline. This result was similar to the 4340 data for $K_t = 1.75$, which showed a dramatic decrease in fatigue strength for nearly all shot-peened groups. Certainly, the worst performance for shot-peened steel comes at the $K_t = 1.75$ level when compared with the baseline. This result even held true for the aluminum and the titanium materials.

At $K_t = 2.5$, the best performance was from the groups at 8A—the group from CCAD and MIC were essentially equal. The worst performance was again demonstrated by the CCAD-12A specimens. The two groups at 4A, from CCAD and MIC, showed equal performance. The group of 10 specimens from MIC was divided into two groups of five specimens. These two groups of five specimens appeared to have different surface characteristics. The color was slightly darker on one group, and this group demonstrated a rougher surface finish (discussed in section 6.4). MIC could not explain the disparity among the groups. No significant difference could be observed in the XRD-RSA data between these groups, although they appeared to have greatly different fatigue strength. The group with a rougher surface finish performed better than those with smoother finishes at equal shot-peening intensities and XRD-RSA values. All groups demonstrated better performance than the baseline data at this stress intensity.

6.3 Phase 2. XRD-RSA Assessment

6.3.1 Aluminum 7075-T73 Disks

See figures 28–34.

The residual stress distributions and magnitudes are approximately equivalent at the center and edge measurement locations for the three disk specimens in each shot-peened intensity group. The baseline surface and near surface (to the 1-mil depth) residual stresses varied somewhat, probably due to cutting and/or polishing irregularities. All intensities for both the MIC- and CCAD-peened disk specimens produced an average surface compressive stress of 31 ± 4 ksi (214 ± 28 MPa) and a maximum stress at depth of ~45–54 ksi (310–372 MPa). The maximum compressive residual stress value was at the 2-mil depth for the 4A intensity and at a 6- to 7-mil depth for the 10A, 12A, and 14A intensities. Except for the MIC-4A intensity specimen, which approached a tensive stress magnitude at the 10-mil depth, all residual stress profiles were in the compressive stress region for the entire subsurface analysis.

6.3.2 Beta-STOA Titanium 6Al-4V Disks

See figures 35–43.

The residual stress distributions and magnitudes are approximately equivalent at the center and edge measurement locations for the three disk specimens in the MIC-8A, 11.5A, 3N, and 11N shot-peened intensity groups. The CCAD-4A stress values are approximately equivalent at the surface and to the 5-mil depth, but then they deviate by as much as 50 ksi (345 MPa) at the 7- and 10-mil depths. The MIC-4A, 5N, and 14N profiles show that for one specimen in the group, the residual stress magnitudes were significantly more tensive after the 2-mil depth than for the other two specimens. Note that only two specimens were characterized for the MIC-14N shot-peened intensity. Since there was no accounting for this anomaly in the electropolishing method or the stress measuring technique, it is likely that the baseline preparation (cutting then polishing) or the shot-peening process was not consistent for all three specimens within these intensity groups. The baseline surface residual stresses varied between 11 ksi and 36 ksi (76 MPa and 248 MPa), but at depth they fall into about half that range. All intensities for the MIC- and CCAD-peened disk specimens produced an average surface compressive stress of 99 ± 8 ksi (683 ± 55 MPa) and a maximum stress of 105–119 ksi (724–821 MPa) at a depth of 1–2 mil, except for the MIC-3N and -5N intensity specimens, where the maximum compressive residual stress was at the surface. The residual stress profiles from the CCAD-4A and MIC-11.5A specimens did not approach or crossover to tensive values until the 10-mil depth. On all other disk specimens, the residual stress changed from compressive to tensive or compressive to 0 ksi at depths of 2–5 mil and then remained approximately uniform in magnitude at the additional depths.

6.3.3 The 4340 Steel Disks

See figures 44–49.

The residual stress distributions and magnitudes are approximately equivalent at the center and edge measurement locations for the three disk specimens in each shot-peened intensity group. Except for the outlying data point at the 5-mil depth on the CCAD-8A intensity plot, the residual stress profiles from the 4340 steel disk specimens were the most uniform in magnitude and distribution for the center and edge measurement locations of the four shot-peened materials characterized in this test program. The baseline residual stresses were approximately equivalent at the surface, averaging compressive 67 ksi (462 MPa) but changing to 0 ksi or becoming highly tensive within the 1-mil depth. Additionally, and as observed in some of the titanium 6Al-4V data, the residual stresses were significantly more tensive after the 2-mil depth on one of the baseline specimens than on the other two. All intensities for the MIC- and CCAD-peened disk specimens produced a surface compressive stress of 65–90 ksi (448–621 MPa) and a maximum stress at depths of 80–92 ksi (552–634 MPa). It is interesting to note that the surface compressive residual stresses induced from shot-peening are equivalent to or just slightly greater in magnitude than that of the baseline surface stresses. The maximum compressive residual stress value for all shot-peened intensities was at a depth of 1–2 mil. The residual stress profiles from the MIC-4A and CCAD-4A and 8A intensity specimens crossed over 0 ksi at a depth of 5–7 mil. They then remained at 0 ksi or became slightly tensive at the 10-mil depth. The MIC-8A intensity specimen residual stresses changed to tensive at the 10-mil depth, and the CCAD-12A specimen remained compressive at all depths.

6.3.4 The 9310 Steel Disks

See figures 50–55.

The residual stress distributions and magnitudes are approximately equivalent at the center and edge measurement locations for the three disk specimens in each shot-peened intensity group. The baseline surface residual stresses varied between –69 ksi and –112 ksi (–476 MPa and –112 MPa), probably due to cutting and/or polishing irregularities. At the 1-mil depth, the baseline stresses approached 0 ksi, then they remained at that magnitude ±10 ksi (±69 MPa) for the additional depths. A uniform surface compressive stress averaging 97 ± 7 ksi (669 ± 48 MPa) was measured at the disk specimen center and edge locations for all MIC- and CCAD-peened intensities. A maximum compressive residual stress of 110–131 ksi (758–903 MPa) was found at a 2-mil depth. All residual stress profiles became less compressive after the 2-mil depth except for the CCAD-12A intensity specimen, which remained at the maximum compressive stress until the 5-mil depth before trending tensive. The MIC- and CCAD-4A intensity specimens approached or crossed 0 ksi at a depth of 5–6 mil, and the 8A specimens did so at a depth of 7–8 mil. Similar to the 4340 steel CCAD-12A specimen, the measured residual stresses were compressive at all depths. The 4A and 8A intensity residual stress profiles from the 9310 steel showed the best uniformity between the MIC- and CCAD-peened specimens. They also better reflect the variation in residual stress with peeing intensity than the other materials investigated.

6.3.5 Fatigue Specimens

Table 45 shows a comparison of the average surface residual stress from the center and edge locations on the disk specimens and from the 0°, 120°, and 240° orientations on the fatigue specimens for all MIC and CCAD shot-peened intensities. For each material, the as-peened surface residual stress was more compressive on the disk specimens than on the fatigue specimens, however, the magnitude of the stress difference varied. Possible explanations for this difference are specimen geometry, prior processing of the material, and location of measurement. The disk specimens were sectioned from bar stock, ground, and then polished; the fatigue specimens were machined from round stock. Residual stress measurements were made on the flat cross sections of the disk specimens and on the curved OD surface on the fatigue specimens (outside the notch). Though an instrumental error due to specimen curvature may have biased the fatigue data somewhat (less than 5% has been estimated in published literature), it would have been consistent throughout the materials.

Table 45. Average surface residual stress for all shot-peened intensities.

Material	Disk Specimen Residual Stress		Fatigue Specimen Residual Stress		Δ Residual Stress	
	(ksi)	(MPa)	(ksi)	(MPa)	(ksi)	(MPa)
Aluminum 7075-T73	–31.3	–215.8	–28.6	–197.2	–2.7	18.6
Titanium 6Al-4V	–99.5	–686.1	–80.1	–552.3	–19.4	–133.8
4340 steel	–80.8	–557.1	–71.3	–491.6	–9.5	–65.5
9310 steel	–97.3	–670.9	–76.3	–526.1	–21	–144.8

6.4 Phase 2. Surface Roughness Assessment

The surface roughness of the shot-peened specimens agreed with the disk specimens across all materials. There existed slight differences among the baseline disk and fatigue data for all materials, based on the differences in the specimens' manufacture. All the fatigue specimens were turned, while the disk specimens were mechanically ground and polished. Once shot-peened, these initial surface roughness differences are alleviated or masked, depending on perspective. As expected, there existed a direct relationship between surface roughness and shot-peening intensity—the greater the peening intensity, the greater the resulting roughness. In some instances when comparing the resulting roughness at a given shot-peen intensity, the specimens from CCAD were rougher, while in other instances those from MIC were rougher. Clear trends were not noted when comparing this data to fatigue performance, either. In cases where direct comparisons between MIC and CCAD performance could be made, sometimes the rougher surface finish specimens performed better in fatigue resistance, while other times the lower surface roughness specimens fared better. For example, the 4340 steel L2-8A group from MIC has higher surface roughness. The resulting fatigue performance for the MIC-L2-8A specimens are equal to, better than, and equal to the CCAD-8A specimens' performance for $K_t = 1$, $K_t = 1.75$, and $K_t = 2.5$, respectively. The 9310 steel group MIC-L2-8A, also has higher surface roughness than the corresponding specimens from CCAD. The resulting fatigue performance for the specimens from MIC is worse than, equal to, and better than the corresponding CCAD-8A specimens for $K_t = 1$, $K_t = 1.75$, and $K_t = 2.5$, respectively. In the cases where the CCAD specimens had higher roughness, fatigue performance results were similarly scattered, in some cases higher, in some cases lower, and in some cases equal to the corresponding data resulting from the MIC specimens.

The data set from MIC-8A had apparent differences among the 10 specimens from $K_t = 2.5$. Five of the specimens from this group were noticeably darker in appearance than the others. Because of this discrepancy, the entire group of 10 specimens was characterized for surface roughness. The darker specimens were rougher. MIC could not explain this apparent discrepancy. The material supplier insists all material was from the same lot. Indeed, the hardness of this material is uniform, and there is no other reason to suspect that material differences exist. The fatigue performance of the darker, rougher group was higher than that from the lighter colored, smoother group. The data was also higher than the corresponding data set from CCAD-8A.

7. Conclusions

7.1 Phase 1. Almen Strip Intensity Study

1. Nozzle angle has a direct relationship with intensity. As the nozzle angle approaches 90°, the resultant shot-peening intensity increases.
2. Air pressure has a direct relationship with intensity. As the air pressure increases, the resultant shot-peening intensity increases.
3. Nozzle distance has an indirect relationship with intensity. As the nozzle increases, the resultant shot-peening intensity decreases.
4. Air jet size has a direct relationship with intensity As the air jet size increases, the resultant shot-peening intensity increases.

7.2 Phase 2. Fatigue Assessment

1. Fatigue performance of shot-peened specimens varied significantly with stress intensity and material.
2. In the majority of cases, the lowest shot-peening intensity exhibited the best fatigue performance. In almost all cases, an indirect relationship between fatigue strength and shot-peening intensity was observed—the lower the shot-peening intensity, the higher the fatigue strength.
3. For all materials, the K_t = 1.75 groups demonstrated the worst performance. For the steel materials, shot-peening appears to be detrimental at this stress intensity, especially at stress levels that yield above 100-K cycles.
4. There appeared to be no significant difference between CCAD specimens and MIC specimens, where direct comparisons could be made. In some cases, the groups performed equally. In some cases, CCAD performed better, and in other cases, MIC performed better.

7.3 Phase 2. XRD-RSA Assessment

1. The magnitude of the residual stresses measured at the center and edge locations on the shot-peened disk specimens were statistically equivalent.
2. The magnitude of the residual stresses measured at the 0°, 120°, and 240° orientations on the shot-peened fatigue specimens were approximately equivalent.
3. For a given intensity, the residual stress profiles from the MIC and CCAD shot-peened disk specimens were approximately uniform.

4. The maximum compressive residual stress was measured on the shot-peened disk specimens at a distinct depth below the surface.

7.4 Phase 2. Surface Roughness Assessment

1. There existed a direct relationship between shot-peening intensity and surface roughness—the greater the peening intensity, the greater the resultant surface roughness.

2. No clear trends were noted between the MIC and CCAD data when direct comparisons could be made. For some shot-peening intensities, the MIC specimens were rougher, and in others, the CCAD specimens were rougher. No trends were noted between surface roughness and fatigue performance between the two vendors when direct comparisons could be made—in some cases, the rougher MIC specimens outperformed the corresponding CCAD specimens, while in other cases, the smoother CCAD specimens outperformed the corresponding MIC specimens.

7.5 Implication on Flight Safety Critical Army Aviation Components

As shown herein, two separate entities shot-peening to the same prescribed parameters can yield different results. This information should be of the utmost importance to the U.S. Aviation and Missile Command in the maintenance of legacy systems and to designers of future systems.

8. References

1. AMS-QQ-A 225/9. *Aluminum Alloy 7075, Bar, Rod, Wire, and Special Shapes; Rolled Brawn, or Cold Finished* **1997**.
2. AMS 4928Q. *Titanium Alloy Bars, Wire, Forgings, and Rings* **2001**.
3. AISI/SAE E4340. *Steel, Chrome-Nickel-Molybdenum Bars and Reforging Stock* **1999**.
4. AMS 2759/1C. *Heat Treatment of Carbon and Low-Alloy Steel Parts Minimum Tensile Strength Below 220 Ksi (1517 MPa)* **2000**.
5. AMS-S-13165. *Shot-peening of Metal Parts* **1997**.
6. AMS 2432. *Shot-peening, Computer Monitored* **1996**.

Appendix A. Statement of Work for Determination of Shot-Peening Intensities to Be Used in Shot-Peening Qualification Sensitivity Test Plan*

*Received from AMRDEC-AED, 23 May 2005.

This appendix appears in its original form, without editorial change.

23-May-2005

Statement of Work for Determination of Shot Peening Intensities to be Used in Shot Peening Qualification Sensitivity Test Plan

1. Reference: Shot Peening Qualification Sensitivity Fatigue Test Plan, Undated.

2. Background Information:

This Statement Of Work (SOW) gives specific instructions regarding work pertaining to development/investigation of peening intensities that will be used on test specimens/coupons in Reference 1. The initial phase will consist of investigating the effects of varying specific shot peening parameters on Almen strips.

For this study, we have chosen to investigate the baseline peening specified in reference 1 for the titanium material (6Al-4V, Beta STOA condition) at two different primary intensity levels.

Final requirements for the peening intensities for all test specimens and material types in Reference 1 will be issued upon completion of all actions in this SOW and subsequent review by RDECOM Aviation Engineering Directorate (AED).

All parties (RDECOM AED, Army Research Laboratory (ARL), and MIC) shall concur with items specified in this SOW prior to implementation/initiation of effort performed In Accordance With (IAW) this SOW.

Scope of Work:

Metal Improvement Company (MIC) shall develop the peening processes that they intend to use on the test specimens specified in Reference 1. For the material mentioned above, Reference 1 requires shot peening at two different intensities IAW AMS-S-13165, the peening intensity of 8 to 12A requires use S170 cast steel shot and a coverage requirement of 200%. The second primary peening intensity is 5 to 11N using S70 cast steel shot, with a coverage requirement of 200%. This statement of work requires development of peening procedures that achieve nominal intensities of 10A ± 0.5A and 8N ± 0.5N for the applicable saturation curves. Upon successful completion of this requirement, MIC shall provide the process sheets (including all applicable production tolerances and settings for every peening parameter including those not mentioned in this SOW) used to achieve the nominal intensities to RDECOM AED for review. The peening parameters used to achieve the nominal peening intensities shall be varied as specified below on the same shot peening machine and the results recorded. Each parameter shall be changed separately (and not in combination with any other listed or unspecified peening parameter) and shall be performed on a minimum of 3 Almen strips. If the nominal peening parameter does not allow for the specified variation, advise RDECOM

Statement of Work for Determination of Shot Peening Intensities
to be Used in Shot Peening Qualification Sensitivity Test Plan

Scope of Work: (Continued)

upon development of the nominal peening procedure prior to proceeding. Our intent is to approximately double the standard production tolerance(s) for a given peening parameter for each of the specified incremental variations. MIC shall inform RDECOM AED if a doubling of their production tolerances differs from the incremental variations listed below for impingement angle, air pressure and media flow rate. All 3 Almen strips for each of the 4 listed parameters shall be peened consequently without further changes to the machine or other parameter settings.

Impingement Angle: Increase or decrease the peening angle from the nominal angle, in 10 degree increments (2 times production tolerance). For example, for a given impingement angle of 70 degrees (with a production tolerance of ± 5°), 3 each Almen strips would be peened at impingement angles of 80 and 90 degrees, as well as impingement angles of 60 and 50 degrees. If the nominal impingement angle used is 85 to 90 degrees, then the impingement angle shall be decreased only, in 10 degree increments to approximately 35 degrees.

Air Pressure: Increase and decrease the nominal air pressure, in two 20% increments. Example, 60 psi nominal pressure would be varied to pressures of 72 and 84 psi, as well as 48 and 36 psi.

Media Flow Rate: Increase the media flow rate to 120% and 140% of the nominal value. Then decrease the media flow rate to 80% and 60% of the nominal value.

Stand Off/ Nozzle Distance: Increase and decrease the nominal nozzle distances to 110% and 120% and 90%, and 80% respectively of the baseline value.
Note: Given the extremely precise requirements for nozzle positioning in the AMS shot peening spec (AMS 2432), of ±0.062", distance percentages were used rather than 0.125" increments since such small changes in nozzle distance would have a minimal effect on peening intensity.

Statement of Work for Determination of Shot Peening Intensities
to be Used in Shot Peening Qualification Sensitivity Test Plan

Scope of Work: (Continued)

The following table reflects previously provided information. Each of the listed parameter values are for illustrative purposes only and the tolerances shown are assumed to be representative of the production tolerances to be used by MIC in the peening of the test specimens/coupons in Reference 1. The parameters in each column are to be varied independently, **NOT** in combination with values in adjacent columns.

Table 1, Example Listing of Nominal and Modified Peening Parameters

Impingement angle (degree)	Air pressure (psi)	Media Flow Rate (lbs/minute)	Nozzle Distance (inches)
70 ± 5 (nom'l + tolerance)	**60± 6** (nominal + tol)	**10 ±1** (nominal + tol)	**10 ± 0.1**(nominal + tol)
80	72	12	11
90	84	14	12
60	48	8	9
50	36	6	8

Finally, there will be four more sets (two sets of two) of 3 Almen strips peened to determine the combined effect of the varying the four peening parameters characterized in this statement of work, with the goal of achieving the highest and lowest possible "production" Almen intensities for both the "A" and "N" intensity levels. These Almen strips will be peened using parameter settings based on the possible variations in the actual (not multipled) production tolerances. All parameter settings will be changed concurrently/simultaneously to the maximum specified/allowable production tolerance in an attempt to achieve both the highest and the lowest peening intensity for the Almen strips for the combined changes. For example, if increasing the impingement angle (i.e. 75°), increasing the air pressure (i.e. 66 psi), decreasing the media flow rate (i.e. 9 lbs/minute) and decreasing the nozzle distance (i.e 9.9"?) **EACH/ALL** resulted in higher Almen intensities above, then these parameters would be changed simultaneously to determine the resultant combined effect on peening intensity. These parameters would then be similarly reversed to determine the lowest peening intensity.

3. The point of contact for this action is Randy McFarland, tel. (256) 705-9645.

MARK S. SMITH
Chief, Structures and Materials Division

Appendix B. Statement of Work for Determination of Shot-Peening Intensities to Be Used in Shot-Peening Qualification*

*Received from AMRDEC-AED, 1 June 2005.

This appendix appears in its original form, without editorial change.

01-June-2005

Statement of Work for Determination of Shot Peening Intensities to be Used in Shot Peening Qualification Sensitivity Test Plan

1. Reference: Shot Peening Qualification Sensitivity Fatigue Test Plan, Undated.

2. Background Information:

This Statement Of Work (SOW) gives specific instructions regarding work pertaining to development/investigation of peening intensities that will be used on test specimens/coupons in Reference 1. The initial phase will consist of investigating the effects of varying specific shot peening parameters on Almen strips.

For this study, we have chosen to investigate the baseline peening specified in reference 1 for the titanium material (6Al-4V, Beta STOA condition) at two different primary intensity levels.

Final requirements for the peening intensities for all test specimens and material types in Reference 1 will be issued upon completion of all actions in this SOW and subsequent review by RDECOM Aviation Engineering Directorate (AED).

All parties (RDECOM AED, Army Research Laboratory (ARL), and MIC) shall concur with items specified in this SOW prior to implementation/initiation of effort performed In Accordance With (IAW) this SOW.

Scope of Work:

Metal Improvement Company (MIC) shall develop the peening processes that they intend to use on the test specimens specified in Reference 1. For the material mentioned above, Reference 1 requires shot peening at two different intensities IAW AMS-S-13165, the peening intensity of 8 to 12A requires use S170 cast steel shot and a coverage requirement of 200%. The second primary peening intensity is 5 to 11N using S70 cast steel shot, with a coverage requirement of 200%. This statement of work requires development of peening procedures that achieve nominal intensities of 10A ± 0.5A and 8N ± 0.5N for the applicable saturation curves. Upon successful completion of this requirement, MIC shall provide the process sheets (including all applicable production tolerances and settings for every peening parameter including those not mentioned in this SOW) used to achieve the nominal intensities to RDECOM AED for review. The peening parameters used to achieve the nominal peening intensities shall be varied as specified below on the same shot peening machine and the results recorded. Each parameter shall be changed separately (and not in combination with any other listed or unspecified peening parameter) and shall be performed on a minimum of 3 Almen strips. If the nominal peening parameter does not allow for the specified variation, advise RDECOM upon development of the nominal peening procedure prior to proceeding.

Scope of Work: (Continued)

Our intent is to approximately double the standard production tolerance(s) for a given peening parameter for each of the specified incremental variations. MIC shall inform RDECOM AED if a doubling of their production tolerances differs from the incremental variations listed below for impingement angle, air pressure and media flow rate. All 3 Almen strips for each of the 4 listed parameters shall be peened consequently without further changes to the machine (including the nozzle) or other parameter settings. The peening time used shall be held constant at the "2T" time as determined by the applicable saturation curve. The intensity verification strips per paragraph 4.2 of AMS-S-13165 shall be also be peened at the "2T" value prior to (and after) making the changes detailed below for each of the 4 parameters, however the minimum number of Almen strips peened shall be 3. Coverage on all Almen strips in this SOW shall be verified to be a minimum of 100% using either "Peenscan" or 10X visual inspection. All Almen strips in this SOW will be provided to ARL and will be made traceable to the peening parameters used for that particular Almen strip by labeling or other means.

Impingement Angle: Increase or decrease the peening angle from the nominal angle, in 10 degree increments (2 times production tolerance) to encompass a range of impingement angles from 20 to 90 °. For example, for a given impingement angle of 70 degrees (with a production tolerance of ± 5°), 3 each Almen strips would be peened at impingement angles of 80 and 90 degrees, as well as impingement angles from 60 to 20 degrees. If the nominal impingement angle used is 85 to 90 degrees, then the impingement angle shall be decreased only, in 10 degree increments to approximately 20 degrees.

Air Pressure: Increase and decrease the nominal air pressure, in two 20% increments. Example, 60 psi nominal pressure would be varied to pressures of 72 and 84 psi, as well as 48 and 36 psi.

Media Flow Rate: Increase the media flow rate to 120% and 140% of the nominal value. Then decrease the media flow rate to 80% and 60% of the nominal value.

Stand Off/ Nozzle Distance: Increase and decrease the nominal nozzle distances to 110% and 120% and 90%, and 80% respectively of the baseline value.
Note: Given the extremely precise requirements for nozzle positioning in the AMS shot peening spec (AMS 2432), of ±0.062", distance percentages were used rather than 0.125" increments since such small changes in nozzle distance would have a minimal effect on peening intensity.

The following table reflects previously provided information. Each of the listed parameter values are for illustrative purposes only and the tolerances shown are assumed to be representative of the production tolerances to be used by MIC in the peening of the test specimens/coupons in Reference 1.

Statement of Work for Determination of Shot Peening Intensities
to be Used in Shot Peening Qualification Sensitivity Test Plan

Scope of Work: (Continued)

The parameters in each column are to be varied independently, **NOT** in combination with values in adjacent columns and the sequence of varying a given parameter/column is at MIC's discretion.

Table 1, Example Listing of Nominal and Modified Peening Parameters

Impingement angle (degree)	Air pressure (psi)	Media Flow Rate (lbs/minute)	Nozzle Distance (inches)
70 ± 5 (nom'l + tolerance)	**60± 6** (nominal + tol)	**10 ±1** (nominal + tol)	**10 ± 0.1** (nominal + tol)
80	72	12	11
90	84	14	12
60	48	8	9
50	36	6	8
40			
30			
20			

Finally, there will be four more sets of Almen strips (3 strips per set) peened to determine the combined effect of the varying the four peening parameters specified in this statement of work, with the goal of achieving the highest and lowest possible "production" Almen intensities for both the "A" and "N" intensity levels. These Almen strips will be peened using parameter settings based on the possible variations in the actual (not multipled) production tolerances for a specific parameter. This will result in 2 Almen strip sets (one "high", the other "low") being associated with each of the two peening intensities. All parameter settings will be changed concurrently/simultaneously to the maximum specified/allowable production tolerance in an attempt to determine both the highest and the lowest peening intensity for the Almen strips from the combined changes. For example, if increasing the impingement angle (e.g. 75°), increasing the air pressure (e.g. 66 psi), decreasing the media flow rate (i.e. 9 lbs/minute) and decreasing the nozzle distance (e.g. 9.9") **EACH/ALL** resulted in higher Almen intensities above, then these parameters would be changed simultaneously to determine the resultant combined effect on peening intensity. These parameters would then be similarly reversed to determine the lowest peening intensity.

3. The point of contact for this action is Randy McFarland, tel. (256) 313-8729.

Mark S. Smith

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Chief, Structures and Materials Division

3

Appendix C. Shot-Peening Qualification Sensitivity Fatigue Test Plan*

*Received from AMRDEC-AED, 3 June 2005.
This appendix appears in its original form, without editorial change.

3-June-2005

Shot Peening Qualification Sensitivity Fatigue Test Plan

1.0 Background

Where shot peening is called out as a Critical Characteristic (CC) for critical safety items (CSI), it must be performed at an AMCOM approved source. The benefit to fatigue performance from shot peening is accounted for in the U.S. Army Helicopter safe-life design. Full scale component fatigue testing has been a qualification requirement for new shot peening sources. This work will result in a greater understanding of the effect of Almen intensity on the fatigue strength of the tested materials. Evaluation of this variability is essential to determine if new shot peening sources should be qualified by fatigue testing on a case-by-case basis. Results will be used to assess risk and to derive a safe life for discrepant parts.

2.0 Scope of Work

A. Materials and Shot Peening Vendor:

Army Research Lab (ARL) shall purchase the test materials and fabricate test samples. Metal Improvement Company (MIC) shall be used for shot peening. Materials and peening parameters to be used for the test program are as follows:

(1). Aluminum: Al7075-T73
Cast Steel Shot Size: S230
Intensity: 0.010 to 0.012 A
Coverage: 200 percent

(2). Titanium: Ti-6Al-4V Beta-solution and overaged
Cast Steel Shot Size: S170
Intensity: 0.008 to 0.012A
Coverage: 200 percent

(3). Titanium: Ti-6Al-4V Beta-solution and overaged
Cast Steel Shot Size: S70
Intensity: 0.005N to 0.011N
Coverage: 200 percent

(4). 9310 Steel (150-190 ksi)
Cast Steel Shot Size: S110
Intensity: 0.008 to 0.012 A
Coverage: 200 percent

(5). 4340 (150-170 ksi)
Cast Steel Shot Size: S110
Intensity: 0.008 to 0.012 A
Coverage: 200 percent

All material stock shall be from the same heat treat lots. Tensile properties shall be measured for all these materials. Test coupons and discs are to be machined to the same specifications from the same machining source. Shot peening shall be performed in accordance with AMS-S-13165. A shot peening plan shall be submitted and approved by AED prior to shot peening. After approval, the shot peening plan shall be frozen and followed for the peening of all test samples. Peening parameters (intensity, impingement angle, media flow, air pressure, etc.) shall be recorded for the peening of all specimen geometries, if possible.

B. Fatigue Testing:

ARL shall conduct axial fatigue tests (R=0.1, f = 20 Hz) at room temperature in air for each material listed in section 2A. Table 1 outlines the fatigue test matrix for Al7075-T73 alloy, 9310 steel, and 4340 steel. There are five shot peening intensity variables (include one unpeened condition) and three different test coupon geometries, one smooth ($K_t = 1$), and two notched ($K_t = 1.75$, $K_t = 2.5$). Ten fatigue tests are to be conducted for each of the 15 permutations for a total of 150 fatigue tests per material.

Table 1. Fatigue Test Matrix for Al7075-T73 Alloy, 9310 Steel, and 4340 Steel

Peening Variable (Intensity*)	$K_t = 1$	$K_t = 1.75$	$K_t = 2.5$
Not peened	10	10	10
Low 1	10	10	10
Low 2	10	10	10
High 1	10	10	10
High 2	10	10	10

Table 2 outlines the fatigue test matrix for Ti-6Al-4V Beta-solution and overaged alloy. Two different peening intensity levels (A and N) shall be evaluated. There are nine shot peening intensity variables (including one unpeened condition) and three different test coupon geometries, one smooth ($K_t = 1$), and two notched ($K_t = 1.75$, $K_t = 2.5$). A total of 240 fatigue test coupons shall be tested.

Note that for all fatigue tests, the cutoff (or stop point) is 10^7 cycles.

Table 2. Fatigue Test Matrix for Ti-6Al-4V Beta-Solution and Overaged Alloy

Peening Variable (Intensity*)	$K_t = 1$	$K_t = 1.75$	$K_t = 2.5$
Not peened	8	8	8
Low 1 (A intensity)	9	9	9
Low 2 (A intensity)	9	9	9
High 1 (A intensity)	9	9	9
High 2 (A intensity)	9	9	9
Low 1 (N intensity)	9	9	9
Low 2 (N intensity)	9	9	9
High 1 (N intensity)	9	9	9
High 2 (N intensity)	9	9	9

* Based on the Almen strip intensity study at MIC, ARL shall coordinate with AED and MIC to develop shot peening processing details affecting peening intensity for the intensity used on the fatigue coupons.

C. Residual Stress and Work Hardening Measurement

(1). In addition to fatigue coupons, disk samples, 1 inch in diameter and 0.375 inch in thickness, shall be sectioned from the round stock used for fatigue test coupons. For each test material item listed in section 2A, three of these disks shall be prepared for each peening variable (reference column one of Table 1 and Table 2). A total of 72 disks shall be manufactured. X-Ray diffraction shall be used to generate residual stress and work hardening profiles as a function of depth. These profiles shall be generated at two locations per disk. A profile consists of 6 measurements, one taken at the surface, and one each at depths of one (1), two (2), five (5), seven (7), and ten (10) mils.

(2). In addition, nine additional disks of 9310 steel shall be prepared and carburized. Three of the disks shall be peened to the nominal intensity for the intensity range specified for 9310 steel listed in section 2.A, three shall be peened to a low intensity (to be determined in the test plan), and the remaining three shall not be peened. As before, a profile shall be generated at two locations on each disk. A profile for these disks requires six measurements; one taken at the surface, and one each at depths of one (1), two (2), three (3), five (5), and seven (7) mils.

D. Surface Roughness Measurement

Surface roughness shall be measured by laser surface profilometry. Surface roughness shall be measured for each of the peening variable (reference column one of Table 1 and Table 2), for two peening geometries (the smooth fatigue coupon, ($K_t = 1$), and the disk sample described in section 2C), and at three different locations on each sample. Two samples shall be measured for each of the two peening geometries described above. A total of 288 surface roughness measurements shall be taken.

E. Post Test Metallurgical Evaluation

If the sample shows a significant drop in fatigue strength, ARL may need to perform metallurgical evaluation of the tested sample to identify the root cause of failure.

3.0 Deliverables

A. ARL shall develop a test plan detailing all activities, test parameters, and analyses. This test plan shall be developed in consultation with AMSRD-AMR -AE-P and AMSRD-AMR-AE-F. Technical points of contact are: for AMSRD-AMR-AE-F, George Liu (256-313-8762) or Jung-Hua Chang (256-313-8745), for AMSRD-AMR-AE-P, Glenn Sahrmann (256-319-5256).

B. ARL shall submit a report that includes all tensile and fatigue test results, residual stress profiles, work hardening measurements, surface roughness measurements, fatigue curve analyses (curve shape, mean, coefficient of variation, etc), and evaluations.

MARK S. SMITH
Chief, Structures and Materials Division
Aviation Engineering Directorate

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Appendix D. Statement of Work for Determination of Shot-Peening Intensities to Be Used in Shot-Peening Qualification Sensitivity Test Plan*

*Received from AMRDEC-AED, 13 July 2005.
This appendix appears in its original form, without editorial change.

13-July-2005

Statement of Work for Determination of Shot Peening Intensities to be Used in Shot Peening Qualification Sensitivity Test Plan

1. Reference: Shot Peening Qualification Sensitivity Fatigue Test Plan, 03-Jun-2005

2. Background Information:

This Statement Of Work (SOW) gives specific instructions regarding work pertaining to development/investigation of peening intensities that will be used on test specimens/coupons in Reference 1. The initial phase will consist of investigating the effects of varying specific shot peening parameters on Almen strips.

This study will investigate the 4 different media sizes and 3 different peening intensities specified in Reference 1 for shot peening performed In Accordance With (IAW) AMS-S-13165.

Final requirements for the peening intensities for all test specimens and material types in Reference 1 will be issued upon completion of all actions in this SOW and subsequent review by RDECOM Aviation Engineering Directorate (AED).

All parties (RDECOM AED, Army Research Laboratory (ARL), and Metal Improvement Corporation (MIC)) shall concur with items specified in this SOW prior to implementation/initiation of effort performed IAW this SOW.

Scope of Work:

Metal Improvement Company (MIC) shall **CONFIRM** that the MIC Bensalem, PA provided peening processes/parameters that will be used on the test specimens specified in Reference 1 are valid/correct. The provided peening parameters shall be verified via saturation curves and be capable of achieving the 200% coverage requirement specified for the test specimens in Reference 1. MIC shall inform ARL and RDECOM AED if changes to their predicted process are required to achieve the nominal peening intensities specified in Table 1. Tables 2, 3, 4 and 5 of this SOW are based upon information provided by MIC and may require modification if the parameters change from the MIC provided values. The peening parameters used to achieve the nominal peening intensities shall be varied as specified below in Tables 2 through 5 on the same shot peening machine and the results recorded. Each parameter in each table column shall be changed separately (and not in combination with any other listed or unspecified peening parameter) and shall be performed on a minimum of 3 Almen strips. When a specific parameter is changed or varied, the other 3 parameters shall be at the setting used to achieve the nominal intensity. Examples for Table 2, the 75° impingement Almen strips shall be peened at 45 psi, media flow rate of MIC TBD1 (MIC provided value), SOD of 7". For the air pressure column, the 36 psi Almen strip shall be peened at a 65° impingement angle, media flow of (MIC $TBD1_{70}$ lbs/min), Stand Off Distance (SOD) of 7". The modified media flow rate (MIC $TBD2_{70}$) Almen strips shall be peened at an impingement angle of 65°, air pressure of 45 psi, SOD 7". For the SOD column, the 9" SOD Almen strips shall be peened at impingement angle of 65°, air pressure of 45 psi, media flow rate of MIC $TBD1_{70}$. The sequence shall be repeated in this manner for each value in a column and for Tables 3 through 5 of this SOW.

Table 1, Shot Media Sizes and Intensities

Shot Media Size	Associated Intensity	Nominal Intensity Requirement
S70	**5 to 11N**	**8N ± 0.5N**
S110	**8 to 12A**	**10A ± 0.5A**
S170	**8 to 12A**	**10A ± 0.5A**
S230	**10 to 12A**	**11A ± 0.5A**

Our intent is to approximately double the standard production tolerance(s) for a given peening parameter for each of the specified incremental variations. All 3 Almen strips for each of the 4 listed parameters shall be peened sequentially without further changes to the machine (including the nozzle) or other parameter settings. The peening time used shall be held constant at the "2T" time as determined by the applicable saturation curve. The intensity verification strips per paragraph 4.2 of AMS-S-13165 shall also be peened at the "2T" value prior to (and after) making the changes detailed below for each of the 4 parameters, however the minimum number of Almen strips peened shall be 3. Coverage on all Almen strips in this SOW shall be verified to be a minimum of 100% using either "Peenscan" or 10X visual inspection. All Almen strips in this SOW will be provided to ARL and will be made traceable to the peening parameters used for that particular Almen strip by labeling or other means. Record and report results from all testing performed. Appendix A of this SOW has data record sheets suggested for use for recording results from peening performed IAW Tables 2 through 5 of this SOW.

Table 2, S70 Media At 8N Nominal Intensity

Impingement angle (degree)	Air pressure (psi)	Media Flow Rate (lbs/minute)	Nozzle Distance (inches)
65 ± 5 (nom'l + tolerance)	**45± 5** (nominal + tol)	**MIC $TBD1_{70}$**	**7** (nominal + tol)
75 ± 2°	36 ± 2	MIC $TBD2_{70}$	9 ± 0.25
85 ± 2°	30 ± 1.5	MIC $TBD3_{70}$	11 ± 0.25
90* ± 0.5°	54 ± 2.5		5 ± 0.25
55 ± 2°	63 ± 3		3 ± 0.25
45 ± 2°			
35 ± 2°			
25 ± 2°			

Table 3, S110 Media At 10A Nominal Intensity

Impingement angle (degree)	Air pressure (psi)	Media Flow Rate (lbs/minute)	Nozzle Distance (inches)
65 ± 5 (nom'l + tolerance)	**80, -5** (nominal & tol)	**MIC TBD1$_{110}$**	**7** (nominal + tol)
75 ± 2°	64 ± 3	MIC TBD2$_{110}$	9 ± 0.25
85 ± 2°	48 ± 2.5	MIC TBD3$_{110}$	11 ± 0.25
90* ± 0.5°			5 ± 0.25
55 ± 2°			3 ± 0.25
45 ± 2°			
35 ± 2°			
25 ± 2°			

Table 4, S170 Media At 10A Nominal Intensity

Impingement angle (degree)	Air pressure (psi)	Media Flow Rate (lbs/minute)	Nozzle Distance (inches)
65 ± 5 (nom'l + tolerance)	**75 ±5** (nominal & tol)	**MIC TBD1$_{170}$**	**7** (nominal + tol)
75 ± 2°	80 ± 4	MIC TBD2$_{170}$	9 ± 0.25
85 ± 2°	60 ± 3	MIC TBD3$_{170}$	11 ± 0.25
90* ± 0.5°	45 ± 2.5		5 ± 0.25
55 ± 2°			3 ± 0.25
45 ± 2°			
35 ± 2°			
25 ± 2°			

Table 5, S230 Media At 11A Nominal Intensity

Impingement angle (degree)	Air pressure (psi)	Media Flow Rate (lbs/minute)	Nozzle Distance (inches)
65 ± 5 (nom'l + tolerance)	**55 ±5** (nominal & tol)	**MIC TBD1$_{230}$**	7 (nominal + tol)
75 ± 2°	66 ± 3.5	MIC TBD2$_{230}$	9 ± 0.25
85 ± 2°	77 ± 4	MIC TBD3$_{230}$	11 ± 0.25
90* ± 0.5°	44 ± 2.5		5 ± 0.25
55 ± 2°	33 ± 2		3 ± 0.25
45 ± 2°			
35 ± 2°			
25 ± 2°			

Notes for Tables 2 through 5:
General: Row with parameters shown in **BOLD** are settings used to achieve nominal peening intensity.
* Special emphasis on this impingement angle to determine the effect of shot "ricochet".

For Tables 2 through 5, there will be two more sets of Almen strips (3 strips per set) peened to determine the combined effect of the varying the four peening parameters specified in this statement of work, with the goal of achieving the highest and lowest possible "**production**" Almen intensities for each Table's specified intensity level. These Almen strips will be peened using parameter settings based on the possible variations in the actual (not multipled) production tolerances for a specific parameter. All parameter settings will be changed concurrently/simultaneously to the maximum specified/allowable production tolerance in an attempt to determine both the highest and the lowest peening intensity for the Almen strips from the combined changes. Previously performed testing per this SOW will be used to determine how the peening parameters are changed to achieve the high or low peening intensities. For the Table 2 example, if increasing the impingement angle (e.g. 70°), increasing the air pressure (e.g. 50 psi), decreasing the media flow rate (i.e. MIC TBD_{70} lbs/minute) and decreasing the nozzle distance (e.g. 6.75") **EACH/ALL** resulted in higher Almen intensities above, then these parameters would be changed simultaneously in that combination to determine the resultant effect on peening intensity. These parameters would then be similarly reversed to determine the lowest peening intensity.

Finally, for Tables 2 through 5, develop peening saturation curves that utilize the lowest impingement angles coupled with the "worst case" production parameters evaluated for each table to determine lowest achievable peening intensities when the worst case parameters are combined simultaneously. For example, again for Table 2, if combining the lowest impingement angle (25°), with the lowest production air pressure (nominal setting less the 10% tolerance (40 psi), with the highest media flow rate ("MIC TBD_{70}") and the highest production SOD (7.25") is expected to produce the lowest intensity, then that is how the parameters shall be combined.

3. The point of contact for this action is Randy McFarland, tel. (256) 313-8729.

Mark S. Smith 7-13-05
MARK S. SMITH
Chief, Structures and Materials Division

Test Record
S230 Media
10A to 12A Intensity

Test No. 51 Total Tests* 3 Min. Per Row	Impingement Angle (degree) Nom. 65+/-5	Air Pressure (psi) Nom. 55+/-5	Media Flow Rate (lbs/min) Nom. MIC TBD1$_{230}$	Nozzle Distance (inches) Nom. 7 +/-0.25	Measured Intensity Nom. 11A+/-.5A	Measured Intensity Nom. 11A+/-.5A	Measured Intensity Nom. 11A+/-.5A	Measured Intensity Nom. 11A+/-.5A	Average Intensity (N,A)
	A	B	C	D	Record Results	Record Results	Record Results	Record Results, If Needed	Record Results, Optional
Base Line **	**65 +/-5 Nom.**	**55+/-5 Nom.**	**MIC TBD1$_{230}$**	**7 Nom.**					
A1	**90+/-0.5**	55+/-5 Nom.	MIC TBD1$_{230}$	7 Nom.					
A2	**85+/-2**	55+/-5 Nom.	MIC TBD1$_{230}$	7 Nom.					
A3	**75+/-2**	55+/-5 Nom.	MIC TBD1$_{230}$	7 Nom.					
A4	**55+/-2**	55+/-5 Nom.	MIC TBD1$_{230}$	7 Nom.					
A5	**45+/-2**	55+/-5 Nom.	MIC TBD1$_{230}$	7 Nom.					
A6	**35+/-2**	55+/-5 Nom.	MIC TBD1$_{230}$	7 Nom.					
A7	**25+/-2**	55+/-5 Nom.	MIC TBD1$_{230}$	7 Nom.					
B1	65 +/-5 Nom.	**77+/-4**	MIC TBD1$_{230}$	7 Nom.					
B2	65 +/-5 Nom.	**66+/-3.5**	MIC TBD1$_{230}$	7 Nom.					
B3	65 +/-5 Nom.	**44+/-2.5**	MIC TBD1$_{230}$	7 Nom.					
B4	65 +/-5 Nom.	**33+/-2**	MIC TBD1$_{230}$	7 Nom.					
C1	65 +/-5 Nom.	55+/-5 Nom.	**MIC TBD2$_{230}$**	7 Nom.					
C2	65 +/-5 Nom.	55+/-5 Nom.	**MIC TBD3$_{230}$**	7 Nom.					
D1	65 +/-5 Nom.	55+/-5 Nom.	MIC TBD1$_{230}$	**3+/-0.25**					
D2	65 +/-5 Nom.	55+/-5 Nom.	MIC TBD1$_{230}$	**5+/-0.25**					
D3	65 +/-5 Nom.	55+/-5 Nom.	MIC TBD1$_{230}$	**9+/-0.25**					
D4	65 +/-5 Nom.	55+/-5 Nom.	MIC TBD1$_{230}$	**11+/-0.25**					
Base Line **	**65 +/-5 Nom.**	**55+/-5 Nom.**	**MIC TBD1$_{230}$**	**7 Nom.**					

* Base Lines Not Included in Total Tests Count
** Either Saturation Curve or Intensity Verification Strips

Intensity Study, Table 5

IntensityStudy.xls

Test Record
S170 Media
8A to 12A Intensity

Test No. 48 Total Tests* 3 Min. Per Row	Impingement Angle (degree) Nom. 65+/-5	Air Pressure (psi) Nom. 75+/-5	Media Flow Rate (lbs/min) Nom. MIC TBD1$_{170}$	Nozzle Distance (inches) Nom. 7 +/-0.25	Measured Intensity Nom. 10A+/-.5A	Measured Intensity Nom. 10A+/-.5A	Measured Intensity Nom. 10A+/-.5A	Measured Intensity Nom. 10A+/-.5A	Average Intensity (N,A)
	A	B	C	D	Record Results	Record Results	Record Results	Record Results, If Needed	Record Results, Optional
Base Line **	**65 +/-5 Nom.**	**75+/-5 Nom.**	**MIC TBD1$_{170}$**	**7 Nom.**					
A1	**90+/-0.5**	**75+/-5 Nom.**	MIC TBD1$_{170}$	7 Nom.					
A2	**85+/-2**	**75+/-5 Nom.**	MIC TBD1$_{170}$	7 Nom.					
A3	**75+/-2**	**75+/-5 Nom.**	MIC TBD1$_{170}$	7 Nom.					
A4	**55+/-2**	**75+/-5 Nom.**	MIC TBD1$_{170}$	7 Nom.					
A5	**45+/-2**	**75+/-5 Nom.**	MIC TBD1$_{170}$	7 Nom.					
A6	**35+/-2**	**75+/-5 Nom.**	MIC TBD1$_{170}$	7 Nom.					
A7	**25+/-2**	**75+/-5 Nom.**	MIC TBD1$_{170}$	7 Nom.					
B1	65 +/-5 Nom.	**80+/-4**	MIC TBD1$_{170}$	7 Nom.					
B2	65 +/-5 Nom.	**60+/-3**	MIC TBD1$_{170}$	7 Nom.					
B3	65 +/-5 Nom.	**45+/-2.5**	MIC TBD1$_{170}$	7 Nom.					
C1	65 +/-5 Nom.	**75+/-5 Nom.**	**MIC TBD2$_{170}$**	7 Nom.					
C2	65 +/-5 Nom.	**75+/-5 Nom.**	**MIC TBD3$_{170}$**	7 Nom.					
D1	65 +/-5 Nom.	**75+/-5 Nom.**	MIC TBD1$_{170}$	**3+/-0.25**					
D2	65 +/-5 Nom.	**75+/-5 Nom.**	MIC TBD1$_{170}$	**5+/-0.25**					
D3	65 +/-5 Nom.	**75+/-5 Nom.**	MIC TBD1$_{170}$	**9+/-0.25**					
D4	65 +/-5 Nom.	**75+/-5 Nom.**	MIC TBD1$_{170}$	**11+/-0.25**					
Base Line **	**65 +/-5 Nom.**	**75+/-5 Nom.**	**MIC TBD1$_{170}$**	**7 Nom.**					

* Base Lines Not Included in Total Tests Count
** Either Saturation Curve or Intensity Verification Strips

Intensity Study, Table 4.

IntensityStudy.xls

Test Record
S110 Media
8A to 12A Intensity

Test No. 45 Total Tests* 3 Min. Per Row	Impingement Angle (degree) Nom. 65+/-5	Air Pressure (psi) Nom. 80+0/-5	Media Flow Rate (lbs/min) Nom. MIC TBD1$_{110}$	Nozzle Distance (inches) Nom. 7 +/-0.25	Measured Intensity Nom. 10A+/-.5A	Measured Intensity Nom. 10A+/-.5A	Measured Intensity Nom. 10A+/-.5A	Measured Intensity Nom. 10A+/-.5A	Average Intensity (N,A)
	A	B	C	D	Record Results	Record Results	Record Results	Record Results, If Needed	Record Results, Optional
Base Line **	**65 +/-5 Nom.**	**80+0/-5 Nom.**	**MIC TBD1$_{110}$**	**7 Nom.**					
A1	**90+/-0.5**	80+0/-5 Nom.	MIC TBD1$_{110}$	7 Nom.					
A2	**85+/-2**	80+0/-5 Nom.	MIC TBD1$_{110}$	7 Nom.					
A3	**75+/-2**	80+0/-5 Nom.	MIC TBD1$_{110}$	7 Nom.					
A4	**55+/-2**	80+0/-5 Nom.	MIC TBD1$_{110}$	7 Nom.					
A5	**45+/-2**	80+0/-5 Nom.	MIC TBD1$_{110}$	7 Nom.					
A6	**35+/-2**	80+0/-5 Nom.	MIC TBD1$_{110}$	7 Nom.					
A7	**25+/-2**	80+0/-5 Nom.	MIC TBD1$_{110}$	7 Nom.					
B1	65 +/-5 Nom.	**64+/-3**	MIC TBD1$_{110}$	7 Nom.					
B2	65 +/-5 Nom.	**48+/-2.5**	MIC TBD1$_{110}$	7 Nom.					
C1	65 +/-5 Nom.	80+0/-5 Nom.	**MIC TBD2$_{110}$**	7 Nom.					
C2	65 +/-5 Nom.	80+0/-5 Nom.	**MIC TBD3$_{110}$**	7 Nom.					
D1	65 +/-5 Nom.	80+0/-5 Nom.	MIC TBD1$_{110}$	**3+/-0.25**					
D2	65 +/-5 Nom.	80+0/-5 Nom.	MIC TBD1$_{110}$	**5+/-0.25**					
D3	65 +/-5 Nom.	80+0/-5 Nom.	MIC TBD1$_{110}$	**9+/-0.25**					
D4	65 +/-5 Nom.	80+0/-5 Nom.	MIC TBD1$_{110}$	**11+/-0.25**					
Base Line **	**65 +/-5 Nom.**	**80+0/-5 Nom.**	**MIC TBD1$_{110}$**	**7 Nom.**					

* Base Lines Not Included in Total Tests Count
** Saturation Curve or Intensity Verification Strips

Intensity Study, Table 3.

IntensityStudy.xls

Test Record
S70 Media
5N to 11N Intensity

Test No. 51 Total Tests* 3 Min. Per Row	Impingement Angle (degree) Nom. 65+/-5	Air Pressure (psi) Nom. 45+/-5	Media Flow Rate (lbs/min) Nom. MIC TBD1$_{70}$	Nozzle Distance (inches) Nom. 7 +/-0.25	Measured Intensity Nom. 8N+/-.5N	Measured Intensity Nom. 8N+/-.5N	Measured Intensity Nom. 8N+/-.5N	Measured Intensity Nom. 8N+/-.5N	Average Intensity (N,A)
	A	B	C	D	Record Results	Record Results	Record Results	Record Results, If Needed	Record Results, Optional
Base Line **	**65 +/-5 Nom.**	**45+/-5 Nom.**	**MIC TBD1$_{70}$**	**7 Nom.**					
A1	**90+/-0.5**	45+/-5 Nom.	MIC TBD1$_{70}$	7 Nom.					
A2	**85+/-2**	45+/-5 Nom.	MIC TBD1$_{70}$	7 Nom.					
A3	**75+/-2**	45+/-5 Nom.	MIC TBD1$_{70}$	7 Nom.					
A4	**55+/-2**	45+/-5 Nom.	MIC TBD1$_{70}$	7 Nom.					
A5	**45+/-2**	45+/-5 Nom.	MIC TBD1$_{70}$	7 Nom.					
A6	**35+/-2**	45+/-5 Nom.	MIC TBD1$_{70}$	7 Nom.					
A7	**25+/-2**	45+/-5 Nom.	MIC TBD1$_{70}$	7 Nom.					
B1	65 +/-5 Nom.	**63+/-3**	MIC TBD1$_{70}$	7 Nom.					
B2	65 +/-5 Nom.	**54+/-2.5**	MIC TBD1$_{70}$	7 Nom.					
B3	65 +/-5 Nom.	**36+/-2**	MIC TBD1$_{70}$	7 Nom.					
B4	65 +/-5 Nom.	**30+/-1.5**	MIC TBD1$_{70}$	7 Nom.					
C1	65 +/-5 Nom.	45+/-5 Nom.	**MIC TBD2$_{70}$**	7 Nom.					
C2	65 +/-5 Nom.	45+/-5 Nom.	**MIC TBD3$_{70}$**	7 Nom.					
D1	65 +/-5 Nom.	45+/-5 Nom.	MIC TBD1$_{70}$	**3+/-0.25**					
D2	65 +/-5 Nom.	45+/-5 Nom.	MIC TBD1$_{70}$	**5+/-0.25**					
D3	65 +/-5 Nom.	45+/-5 Nom.	MIC TBD1$_{70}$	**9+/-0.25**					
D4	65 +/-5 Nom.	45+/-5 Nom.	MIC TBD1$_{70}$	**11+/-0.25**					
Base Line **	**65 +/-5 Nom.**	**45+/-5 Nom.**	**MIC TBD1$_{70}$**	**7 Nom.**					

* Base Lines Not Included in Total Tests Count
** Either Saturation Curve or Intensity Verification Strips

Intensity Study, Table 2

IntensityStudy.xls

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Appendix E. Modifications to Shot-Peening Qualification Sensitivity Fatigue Test Plan*

*Received from AMRDEC-AED, 06 September 2005.
This appendix appears in its original form, without editorial change.

AMSRD-AMR-AE-F-M

MEMORANDUM FOR RECORD

Subject: Modifications to Shot-peening Qualification Sensitivity Fatigue Test Plan

1. Reference: AMSRD-AMR-AE-F Shot-peening Qualification Sensitivity Fatigue Test Plan, dated 3-June-05

2. This memorandum revises reference 1 to the extent specified herein. It provides the specific shot-peening intensities to be used on the fatigue coupons and disk samples in Reference 1. This memorandum also adds the requirement to shot-peen **additional** fatigue coupons **and disks** as detailed herein. The additional specimens are to be tested/evaluated in the same manner as specified in Ref. 1 for the baseline coupons/samples, but each sources results shall be reported separately. The intensity values herein were determined from the completed SOW for Determination of Shot-peening Intensities to be Used in Shot-peening Qualification Sensitivity Test Plan, dated 13-July-05.

Table 1, Fatigue Test Matrix for 4340 Alloy

Peening Intensity	Shot peen Source(s)	$K_t = 1$	$K_t = 1.75$	$K_t = 2.5$
Unpeened	NA	10	10	10
Low 1, 4A	MIC	10	10	10
Low 2, 8A	MIC & CCAD	10	10	10
High 1, 12A	CCAD	10	10	10
High 2, 14A (-0, +0.5)	CCAD	10	10	10

Note: For the 8A peening intensity (Low 2), Metal Improvement Corp. (MIC) will shot-peen a total of 30 coupons (10 at each Kt value) and 3 disk samples and Corpus Christi Army Depot (CCAD) will also shot-peen a total of 30 coupons (10 at each Kt value) and 3 disk coupons. This criteria also applies for 9310 alloy table below.

Table 2, Fatigue Test Matrix for 9310 Alloy

Peening Intensity	Shot peen Source(s)	$K_t = 1$	$K_t = 1.75$	$K_t = 2.5$
Unpeened	NA	10	10	10
Low 1, 4A	MIC	10	10	10
Low 2, 8A	MIC & CCAD	10	10	10
High 1, 12A	CCAD	10	10	10
High 2, 14A (-0, +0.5)	CCAD	10	10	10

Subject: Modifications to Shot-peening Qualification Sensitivity Fatigue Test Plan

Table 3, Fatigue Test Matrix for 7075-T73 Aluminum Alloy

Peening Intensity	Shot-peen Source(s)	$K_t = 1$	$K_t = 1.75$	$K_t = 2.5$
Unpeened	NA	10	10	10
Low 1, 4A	MIC	10	10	10
Low 2, 10A	MIC & CCAD	10	10	10
High 1, 12A	MIC & CCAD	10	10	10
High 2, 14A (-0, +0.5A)	MIC	10	10	10

Note for Al 7075-T73 Table: If a row indicates two shot-peen sources, then 10 specimens for each Kt value shall be shot-peened at each source at the specified intensities, e.g. for the 10A peening intensity, MIC shall shot-peen a total of 30 specimens at that intensity (and 3 disk samples), and CCAD shall shot-peen a total of 30 specimens at that intensity (10 at each Kt level and as well as 3 disks). Repeat for the 12A intensity.

Table 4, Fatigue Test Matrix for Ti-6Al-4V Beta-Solution and Overaged Alloy

Peening Intensity	Shot-peen Source	$K_t = 1$	$K_t = 1.75$	$K_t = 2.5$
Unpeened	NA	8	8	8
Low 1, 3N	MIC	9	9	9
Low 2, 5N	MIC	9	9	9
High 1, 11N	MIC	9	9	9
High 2, 14N	MIC	9	9	9
Low 1, 4A	MIC	9	9	9
Low 2, 8A	MIC	9	9	9
High 1, 11.5A, (-0, +0.5A)	MIC	9	9	9
High 2, 14A (-0, +0.5A)	CCAD	9	9	9

Note for All Tables: All intensity values in the tables above are ± 0.5 of the base N or A intensity value, unless otherwise specified. Additional tables were used in this memorandum since it was impractical to synchronize these tables with those originally specified in Reference 1.

3. The points of contact for this action are Randy McFarland, tel. 313-8729 or George Liu, tel. 313-8762.

Mark S. Smith
Chief, Structures and Materials Division
Aviation Engineering Directorate

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Appendix F. MIC Almen Strip Processing Data Reports for S070, S110, S170 and S230 Shot, and Including Saturation Curve Development Data*

*Received from MIC, November 2005.
This appendix appears in its original form, without editorial change.

Metal Improvement Company
3434 State Road • Bensalem, PA. 19020

Customer: US ARMY RESEARCH LAB	Part No.: MI-070R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6309	Rev.: 0	Date: 8/4/2005	Page 1 of 4

Specification: **AMS-S-13165**

Material Type: STEEL Material Hardness: N/A

Approximate Dimensions: Length: --- Width: --- Dia.: --- Height: ---

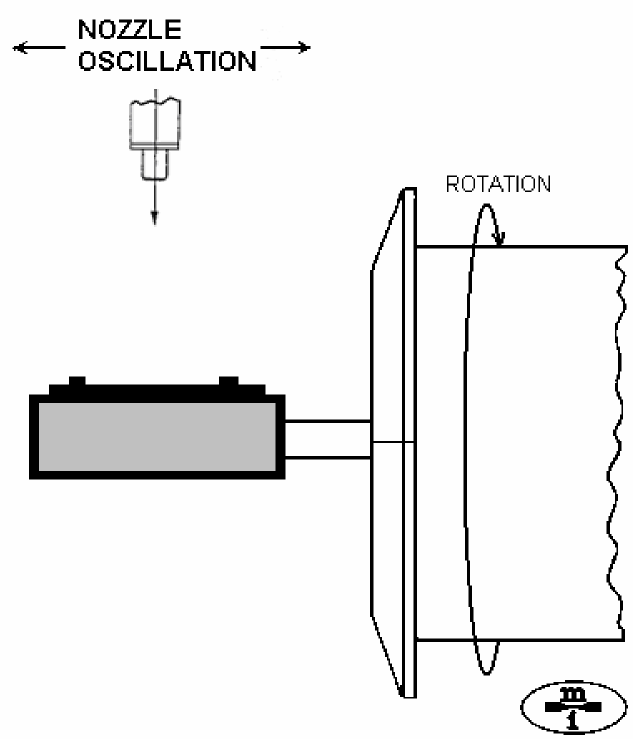
Shot Size: MI-070R Shot Hardness: RC 45-52 Intensity: VARIOUS Coverage: 200%

Machine No.: 54, 55 Tooling No.: N/A Almen Fixture No.: AB-028, 29

MACHINE SETUP AND PROCESS PARAMETERS – O.D. OPERATION

AIR PRESSURE / PSI:	SEE CHART	NUMBER OF NOZZLES:	1
ROLLER SPEED (RPM):	N/A	NOZZLE DIAMETER (IN):	3/8
SPINDLE SPEED (RPM):	55-60	AIR JET DIAMETER (IN):	SEE CHART
OSCILLATION SPEED (IN/MIN):	20-25	NOZZLE TO PART DISTANCE (IN):	SEE CHART
LENGTH OF STROKE (IN):	3.5 – 4.5	NOZZLE ANGLES (DEG):	SEE CHART
PEENING TIME:	2 MINUTES = T2	NUMBER OF PARTS PER RUN:	1
ADDITIONAL INFORMATION:	NOTE: ALL ALMEN STRIPS MUST BE CHECKED WITH 10X FOR MINIMUM 100% COVERAGE.		

BLUE PRINT NOTES AND APPLICABLE SKETCH



Metal Improvement Company
3434 State Road • Bensalem, PA. 19020

Customer: US ARMY RESEARCH LAB	Part No.: MI-070R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6309	Rev.: 0	Date: 8/4/2005	Page 2 of 4

S070 INTENSITY STUDY TABLE 3

BASELINE#	SHOT SIZE	AIR PRESSURE	NOZZLE ANGLE	AIR JET SIZE	NOZZLE DISTANCE	INTENSITY 1	INTENSITY 2	INTENSITY 3	AVERAGE INTENSITY	COMMENTS
BASELINE	MI-070R	10	65	1/4	7	.0097	.0094	.0093	.0095	
2B1	MI-070R	25	65	1/4	7	.0142	.0144	.0142	.0143	
2B2	MI-070R	20	65	1/4	7	.0140	.0140	.0142	.0141	
2B3	MI-070R	15	65	1/4	7	.0108	.0107	.0106	.0107	
2C1	MI-070R	10	65	1/8	7	.0029	.0025	.0028	.0027	
2C2	MI-070R	10	65	3/16	7	.0064	.0065	.0066	.0065	
2D1	MI-070R	10	65	1/4	3	.0104	.0102	.0102	.0103	
2D2	MI-070R	10	65	1/4	5	.0095	.0098	.0098	.0097	
2D3	MI-070R	10	65	1/4	9	.0091	.0089	.0091	.0090	
2D4	MI-070R	10	65	1/4	11	.0090	.0090	.0091	.0090	
2A1	MI-070R	10	90	1/4	7	.0103	.0103	.0103	.0103	
2A2	MI-070R	10	85	1/4	7	.0102	.0100	.0101	.0101	
2A3	MI-070R	10	75	1/4	7	.0096	.0095	.0098	.0096	
2A4	MI-070R	10	55	1/4	7	.0092	.0090	.0092	.0091	
2A5	MI-070R	10	45	1/4	7	.0087	.0085	.0082	.0085	
2A6	MI-070R	10	35	1/4	7	.0080	.0079	.0079	.0079	
2A7	MI-070R	10	25	1/4	7	.0070	.0066	.0068	.0068	
LOW 2A8	MI-070R	10	25	1/4	11	.0059	.0053	.0058	.0057	
HIGH 2A9	MI-070R	25	90	1/4	3	.0156	.0161	.0160	.0159	

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Customer: US ARMY RESEARCH LAB	Part No.: MI-070R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6309	Rev.: 0	Date: 8/4/2005	Page 3 of 4

ALMEN FIXTURE # AB-028

PROTRACTOR USED TO SET NOZZLE ANGLES

CALIBRATED DIGITAL ALMEN GAGE

SPINDLE PEENING MACHINE

Metal Improvement Company
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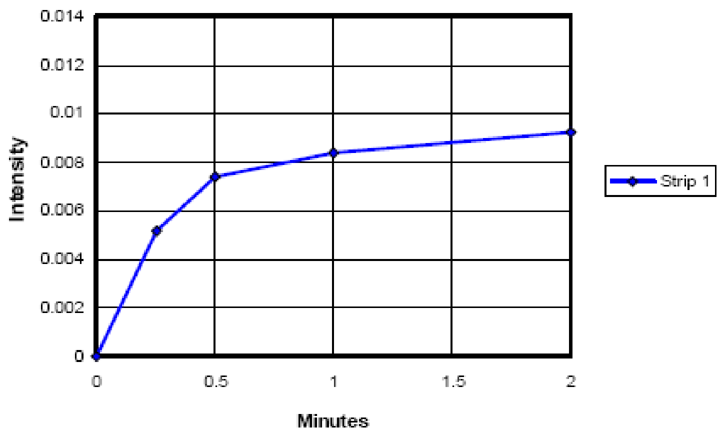
Customer: US ARMY RESEARCH LAB	Part No.: MI-070R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6309	Rev.: 0	Date: 8/4/2005	Page 4 of 4

SHOT SIZE: 070, AIR PRESSURE: 10 PSI, NOZZLE ANGLE: 65 DEG, AIR JET: 1/4", NOZZLE DISTANCE: 7"

INITIAL SATURATION CURVE

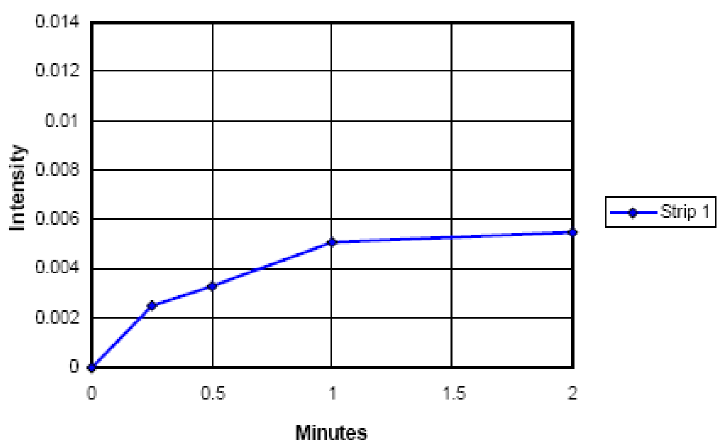
Minutes	Strip 1
0	0.0000
0.25	0.0052
0.5	0.0074
1 T1	0.0084
2 T2	0.0092



SHOT SIZE: 070, AIR PRESSURE: 8 PSI, NOZZLE ANGLE: 25 DEG, AIR JET: 1/4", NOZZLE DISTANCE: 7.25"

WORST CASE SATURATION CURVE

Minutes	Strip 1
0	0.0000
0.25	0.0025
0.5	0.0033
1 T1	0.0051
2 T2	0.0055



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Customer: US ARMY RESEARCH LAB	Part No.: MI-110R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6310	Rev.: 0	Date: 8/4/2005	Page 1 of 4

Specification: **AMS-S-13165**

Material Type: STEEL Material Hardness: N/A

Approximate Dimensions: Length: --- Width: --- Dia.: --- Height: ---

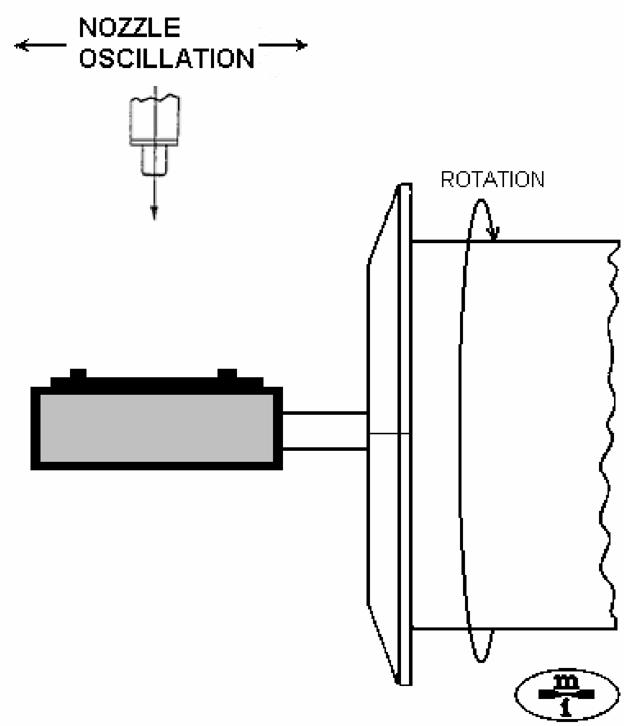
Shot Size: MI-110R Shot Hardness: RC 45-52 Intensity: VARIOUS Coverage: 200%

Machine No.: 54, 55 Tooling No.: N/A Almen Fixture No.: AB-028, 29

MACHINE SETUP AND PROCESS PARAMETERS – O.D. OPERATION

AIR PRESSURE / PSI:	SEE CHART	NUMBER OF NOZZLES:	1
ROLLER SPEED (RPM):	N/A	NOZZLE DIAMETER (IN):	3/8
SPINDLE SPEED (RPM):	55-60	AIR JET DIAMETER (IN):	SEE CHART
OSCILLATION SPEED (IN/MIN):	20-25	NOZZLE TO PART DISTANCE (IN):	SEE CHART
LENGTH OF STROKE (IN):	3.5 – 4.5	NOZZLE ANGLES (DEG):	SEE CHART
PEENING TIME:	2 MINUTES = T2	NUMBER OF PARTS PER RUN:	1
ADDITIONAL INFORMATION:	NOTE: ALL ALMEN STRIPS MUST BE CHECKED WITH 10X FOR MINIMUM 100% COVERAGE.		

BLUE PRINT NOTES AND APPLICABLE SKETCH



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Customer: US ARMY RESEARCH LAB	Part No.: MI-110R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6310	Rev.: 0	Date: 8/4/2005	Page 2 of 4

S110 INTENSITY STUDY TABLE 3

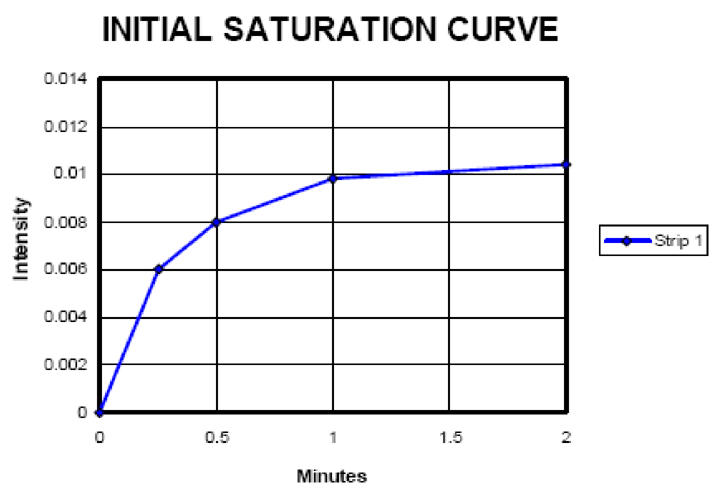
BASELINE#	SHOT SIZE	AIR PRESSURE	NOZZLE ANGLE	AIR JET SIZE	NOZZLE DISTANCE	INTENSITY 1	INTENSITY 2	INTENSITY 3	AVERAGE INTENSITY	COMMENTS
BASELINE	MI-110R	75	65	1/4	7	.0099	.0096	.0097	.0097	
3D1	MI-110R	75	65	1/4	3	.0103	.0103	.0101	.0102	
3D2	MI-110R	75	65	1/4	5	.0097	.0094	.0095	.0095	
3D3	MI-110R	75	65	1/4	9	.0081	.0084	.0084	.0083	
3D4	MI-110R	75	65	1/4	11	.0078	.0077	.0080	.0078	
3B1	MI-110R	60	65	1/4	7	.0078	.0078	.0079	.0078	
3B2	MI-110R	45	65	1/4	7	.0069	.0068	.0069	.0069	
3B3	**MI-110R**	**80**	**65**	**1/4**	**7**	**.0096**	**.0095**	**.0096**	**.0096**	**REVISED 8-11-02**
3C1	MI-110R	75	65	1/8	7	.0036	.0036	.0036	.0036	
3C2	MI-110R	75	65	3/16	7	.0069	.0066	.0065	.0066	
3A1	MI-110R	75	90	1/4	7	.0096	.0098	.0099	.0098	
3A2	MI-110R	75	85	1/4	7	.0097	.0098	.0096	.0097	
3A3	MI-110R	75	75	1/4	7	.0098	.0099	.0099	.0099	
3A4	MI-110R	75	55	1/4	7	.0086	.0082	.0084	.0084	
3A5	MI-110R	75	45	1/4	7	.0080	.0081	.0082	.0081	
3A6	MI-110R	75	35	1/4	7	.0074	.0070	.0072	.0072	
3A7	MI-110R	75	25	1/4	7	.0061	.0062	.0060	.0061	
HIGH 3A8	MI-110R	80	90	1/4	3	.010	.0101	.0101	.0101	
LOW 3A9	**MI-110R**	**45**	**25**	**1/4**	**11**	**.0042**	**.0042**	**.0043**	**.0042**	**REVISED 8-11-02**

ALMEN FIXTURE # AB-028	PROTRACTOR USED TO SET NOZZLE ANGLES
	
CALIBRATED DIGITAL ALMEN GAGE	SPINDLE PEENING MACHINE
	

Customer: US ARMY RESEARCH LAB	Part No.: MI-110R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6310	Rev.: 0	Date: 8/4/2005	Page 4 of 4

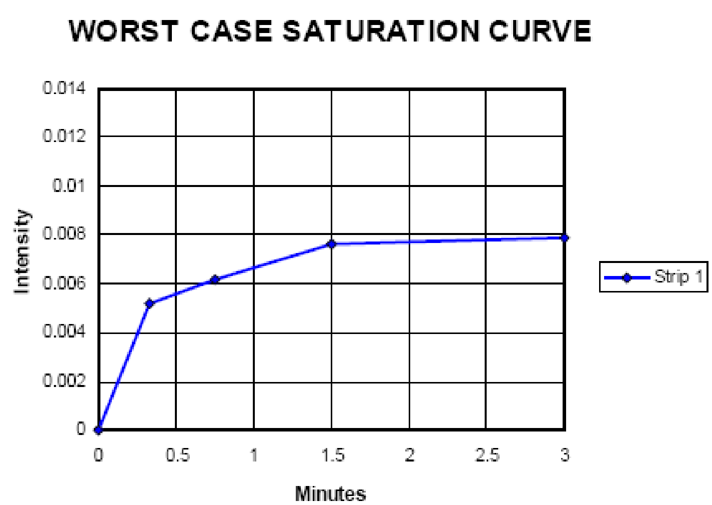
SHOT SIZE: 110, AIR PRESSURE: 75 PSI, NOZZLE ANGLE: 65 DEG, AIR JET: 1/4", NOZZLE DISTANCE: 7"

Minutes		Strip 1
0		0.0000
0.25		0.0060
0.5		0.0080
1	T1	0.0098
2	T2	0.0104



SHOT SIZE: 110, AIR PRESSURE: 70 PSI, NOZZLE ANGLE: 25 DEG, AIR JET: 1/4", NOZZLE DISTANCE: 7.25"

Minutes		Strip 1
0		0.0000
0.33		0.0052
0.75		0.0062
1.5	T1	0.0076
3	T2	0.0079



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Customer: US ARMY RESEARCH LAB	Part No.: MI-170R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6311	Rev.: 0	Date: 8/9/2005	Page 1 of 4

Specification: **AMS-S-13165**

Material Type: STEEL   Material Hardness: N/A

Approximate Dimensions: Length: ---   Width: ---   Dia.: ---   Height: ---

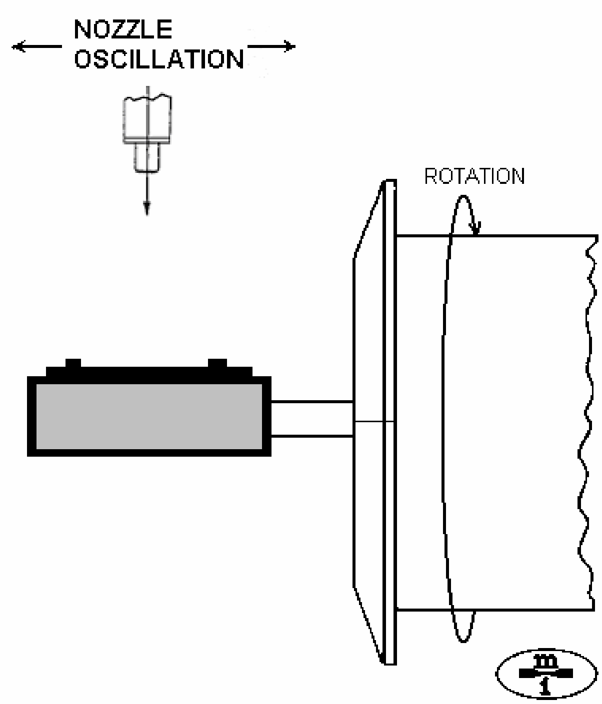
Shot Size: MI-170R   Shot Hardness: RC 45-52   Intensity: VARIOUS   Coverage: 200%

Machine No.: 54, 55   Tooling No.: N/A   Almen Fixture No.: AB-028, 29

MACHINE SETUP AND PROCESS PARAMETERS – O.D. OPERATION

AIR PRESSURE / PSI:	**SEE CHART**	**NUMBER OF NOZZLES:**	**1**
ROLLER SPEED (RPM):	**N/A**	**NOZZLE DIAMETER (IN):**	**3/8**
SPINDLE SPEED (RPM):	**55-60**	**AIR JET DIAMETER (IN):**	**SEE CHART**
OSCILLATION SPEED (IN/MIN):	**20-25**	**NOZZLE TO PART DISTANCE (IN):**	**SEE CHART**
LENGTH OF STROKE (IN):	**3.5 – 4.5**	**NOZZLE ANGLES (DEG):**	**SEE CHART**
PEENING TIME:	**2 MINUTES = T2**	**NUMBER OF PARTS PER RUN:**	**1**
ADDITIONAL INFORMATION:	**NOTE: ALL ALMEN STRIPS MUST BE CHECKED WITH 10X FOR MINIMUM 100% COVERAGE.**		

BLUE PRINT NOTES AND APPLICABLE SKETCH



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Customer: US ARMY RESEARCH LAB	Part No.: MI-170R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6311	Rev.: 0	Date: 8/9/2005	Page 2 of 4

S170 INTENSITY STUDY TABLE 3

BASELINE#	SHOT SIZE	AIR PRESSURE	NOZZLE ANGLE	AIR JET SIZE	NOZZLE DISTANCE	INTENSITY 1	INTENSITY 2	INTENSITY 3	AVERAGE INTENSITY	COMMENTS
BASELINE	MI-170R	75	65	1/4	7	.0100	.0101	.0101	.0101	
4B1	MI-170R	80	65	1/4	7	.0109	.0109	.0108	.0109	
4B2	MI-170R	60	65	1/4	7	.0094	.0094	.0096	.0095	
4B3	MI-170R	45	65	1/4	7	.0087	.0090	.0087	.0088	
4C1	MI-170R	75	65	1/8	7	.0038	.0040	.0039	.0039	
4C2	MI-170R	75	65	3/16	7	.0083	.0080	.0083	.0082	
4D1	MI-170R	75	65	1/4	3	.0105	.0104	.0103	.0104	
4D2	MI-170R	75	65	1/4	5	.0102	.0102	.0100	.0101	
4D3	MI-170R	75	65	1/4	9	.0099	.0102	.0100	.0100	
4D4	MI-170R	75	65	1/4	11	.0096	.0094	.0096	.0095	
4A1	MI-170R	75	90	1/4	7	.0105	.0105	.0104	.0105	
4A2	MI-170R	75	85	1/4	7	.0102	.0103	.0104	.0103	
4A3	MI-170R	75	75	1/4	7	.0104	.0102	.0104	.0103	
4A4	MI-170R	75	55	1/4	7	.0098	.0097	.0098	.0098	
4A5	MI-170R	75	45	1/4	7	.0092	.0091	.0092	.0092	
4A6	MI-170R	75	35	1/4	7	.0088	.0090	.0090	.0089	
4A7	MI-170R	75	25	1/4	7	.0083	.0083	.0084	.0083	
HIGH 4A8	MI-170R	80	90	1/4	3	.0114	.0116	.0114	.0115	
LOW 4A9	MI-170R	45	25	1/4	11	.0070	.0074	.0072	.0072	

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Customer: US ARMY RESEARCH LAB	Part No.: MI-170R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6311	Rev.: 0	Date: 8/9/2005	Page 3 of 4

ALMEN FIXTURE # AB-028

PROTRACTOR USED TO SET NOZZLE ANGLES

CALIBRATED DIGITAL ALMEN GAGE

SPINDLE PEENING MACHINE

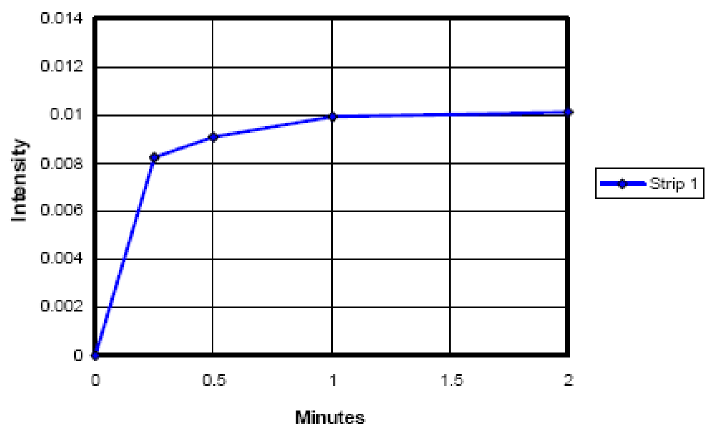
Metal Improvement Company
3434 State Road • Bensalem, PA. 19020

Customer: US ARMY RESEARCH LAB	Part No.: MI-170R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6311	Rev.: 0	Date: 8/9/2005	Page 4 of 4

SHOT SIZE: 170, AIR PRESSURE: 75 PSI, NOZZLE ANGLE: 65 DEG, AIR JET: 1/4", NOZZLE DISTANCE: 7"

INITIAL SATURATION CURVE

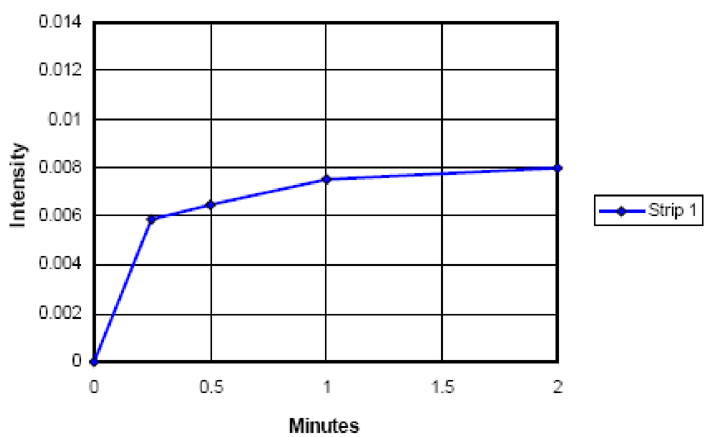
Minutes		Strip 1
0		0.0000
0.25		0.0082
0.5		0.0091
1	T1	0.0099
2	T2	0.0101



SHOT SIZE: 170, AIR PRESSURE: 70 PSI, NOZZLE ANGLE: 25 DEG, AIR JET: 1/4", NOZZLE DISTANCE: 7.25"

WORST CASE SATURATION CURVE

Minutes		Strip 1
0		0.0000
0.25		0.0059
0.5		0.0065
1	T1	0.0075
2	T2	0.0080



Metal Improvement Company
3434 State Road • Bensalem, PA. 19020

Customer: US ARMY RESEARCH LAB	Part No.: MI-230R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6312	Rev.: 0	Date: 8/4/2005	Page 1 of 4

Specification: **AMS-S-13165**

Material Type: STEEL Material Hardness: N/A

Approximate Dimensions: Length: --- Width: --- Dia.: --- Height: ---

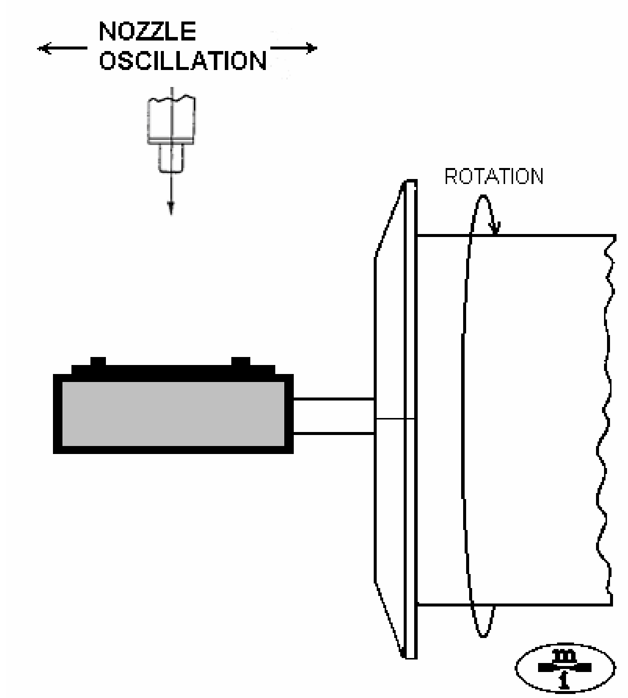
Shot Size: MI-230R Shot Hardness: RC 45-52 Intensity: VARIOUS Coverage: 200%

Machine No.: 54, 55 Tooling No.: N/A Almen Fixture No.: AB-028, 29

MACHINE SETUP AND PROCESS PARAMETERS – O.D. OPERATION

AIR PRESSURE / PSI:	SEE CHART	NUMBER OF NOZZLES:	1
ROLLER SPEED (RPM):	N/A	NOZZLE DIAMETER (IN):	3/8
SPINDLE SPEED (RPM):	55-60	AIR JET DIAMETER (IN):	SEE CHART
OSCILLATION SPEED (IN/MIN):	20-25	NOZZLE TO PART DISTANCE (IN):	SEE CHART
LENGTH OF STROKE (IN):	3.5 – 4.5	NOZZLE ANGLES (DEG):	SEE CHART
PEENING TIME:	2 MINUTES = T2	NUMBER OF PARTS PER RUN:	1
ADDITIONAL INFORMATION:	NOTE: ALL ALMEN STRIPS MUST BE CHECKED WITH 10X FOR MINIMUM 100% COVERAGE.		

BLUE PRINT NOTES AND APPLICABLE SKETCH



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Customer: US ARMY RESEARCH LAB	Part No.: MI-230R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6312	Rev.: 0	Date: 8/4/2005	Page 2 of 4

S230 INTENSITY STUDY TABLE 3

BASELINE#	SHOT SIZE	AIR PRESSURE	NOZZLE ANGLE	AIR JET SIZE	NOZZLE DISTANCE	INTENSITY 1	INTENSITY 2	INTENSITY 3	AVERAGE INTENSITY	COMMENTS
BASELINE	230R	60	65	1/4	7	.0111	.0111	.0110	.0111	
5B1	230R	80	65	1/4	7	.0132	.0134	.0130	.0132	
5B2	230R	72	65	1/4	7	.0117	.0120	.0116	.0118	
5B3	230R	48	65	1/4	7	.0101	.0101	.0099	.0100	
5B4	230R	36	65	1/4	7	.0089	.0085	.0089	.0088	
5C1	230R	60	65	1/8	7	.0044	.0043	.0043	.0043	
5C2	230R	60	65	3/16	7	.0087	.0087	.0089	.0088	
5A1	230R	60	90	1/4	7	.0112	.0113	.0113	.0113	
5A2	230R	60	85	1/4	7	.0112	.0111	.0110	.0111	
5A3	230R	60	75	1/4	7	.0110	.0110	.0108	.0109	
5A4	230R	60	55	1/4	7	.0102	.0103	.0101	.0102	
5A5	230R	60	45	1/4	7	.0097	.0096	.0094	.0096	
5A6	230R	60	38	1/4	7	.0095	.0096	.0091	.0094	
5A7	230R	60	25	1/4	7	.0078	.0077	.0080	.0078	
5D1	230R	60	65	1/4	3	.0114	.0116	.0119	.0116	
5D2	230R	60	65	1/4	5	.0108	.0108	.0112	.0109	
5D3	230R	60	65	1/4	9	.0109	.0107	.0110	.0109	
5D4	230R	60	65	1/4	11	.0100	.0102	.0102	.0101	
LOW	230R	36	25	1/4	11	.0063	.0061	.0064	.0063	
HIGH	230R	80	90	1/4	3	.0145	.0141	.0144	.0143	

ALMEN FIXTURE # AB-028 	**PROTRACTOR USED TO SET NOZZLE ANGLES** 
CALIBRATED DIGITAL ALMEN GAGE 	**SPINDLE PEENING MACHINE** 

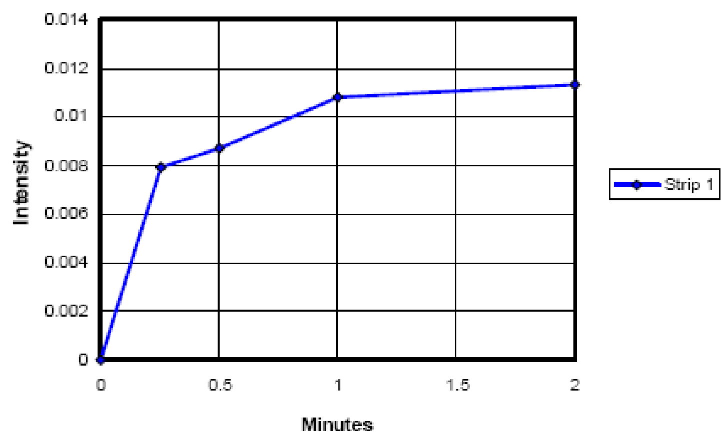
Metal Improvement Company
3434 State Road • Bensalem, PA. 19020

Customer: US ARMY RESEARCH LAB	Part No.: MI-230R MEDIA	Part Name: PEENING RESEARCH PROJECT	
Process No.: 32-6312	Rev.: 0	Date: 8/4/2005	Page 4 of 4

SHOT SIZE: 230, AIR PRESSURE: 60 PSI, NOZZLE ANGLE: 65 DEG, AIR JET: 1/4", NOZZLE DISTANCE: 7"

INITIAL SATURATION CURVE

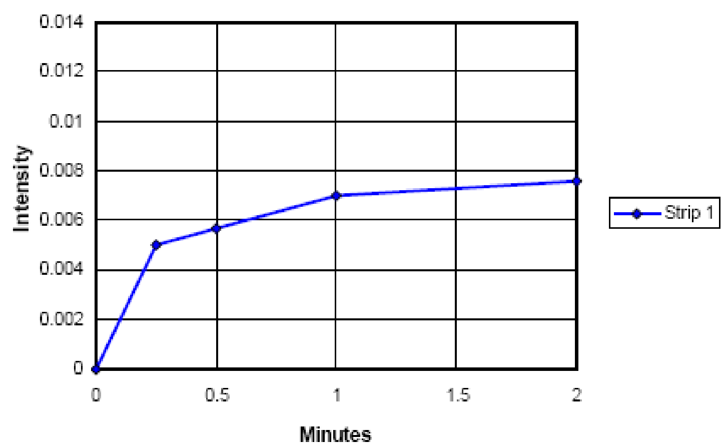
Minutes		Strip 1
0		0.0000
0.25		0.0079
0.5		0.0087
1	T1	0.0108
2	T2	0.0113



SHOT SIZE: 230, AIR PRESSURE: 55 PSI, NOZZLE ANGLE: 25 DEG, AIR JET: 1/4", NOZZLE DISTANCE: 7.25"

WORST CASE SATURATION CURVE

Minutes		Strip 1
0		0.0000
0.25		0.0050
0.5		0.0057
1	T1	0.0070
2	T2	0.0076



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Appendix G. MIC Flow Rate Calculations for S070, S110, S170, and S230 Shot and All Included Test Setups*

*Received from MIC, November 2005.
This appendix appears in its original form, without editorial change.

Baseline No.	Shot Size	Air Pressure	Nozzle Angle	Air Jet Size	Nozzle Distance	Intensity 1	Intensity 2	Intensity 3	Average Intensity	Est. Flow Rate (lb/min)
Baseline	MI-070R	10	65	1/4	7	.0097	.0094	.0093	.0095	9.2
2B1	MI-070R	25	65	1/4	7	.0142	.0144	.0142	.0143	8.7
2B2	MI-070R	20	65	1/4	7	.0140	.0140	.0142	.0141	8.8
2B3	MI-070R	15	65	1/4	7	.0108	.0107	.0106	.0107	9.0
2C1	MI-070R	10	65	1/8	7	.0029	.0025	.0028	.0027	10
2C2	MI-070R	10	65	3/16	7	.0064	.0065	.0066	.0065	12
2D1	MI-070R	10	65	1/4	3	.0104	.0102	.0102	.0103	9.2
2D2	MI-070R	10	65	1/4	5	.0095	.0098	.0098	.0097	9.2
2D3	MI-070R	10	65	1/4	9	.0091	.0089	.0091	.0090	9.2
2D4	MI-070R	10	65	1/4	11	.0090	.0090	.0091	.0090	9.2
2A1	MI-070R	10	90	1/4	7	.0103	.0103	.0103	.0103	9.2
2A2	MI-070R	10	85	1/4	7	.0102	.0100	.0101	.0101	9.2
2A3	MI-070R	10	75	1/4	7	.0096	.0095	.0098	.0096	9.2
2A4	MI-070R	10	55	1/4	7	.0092	.0090	.0092	.0091	9.2
2A5	MI-070R	10	45	1/4	7	.0087	.0085	.0082	.0085	9.2
2A6	MI-070R	10	35	1/4	7	.0080	.0079	.0079	.0079	9.2
2A7	MI-070R	10	25	1/4	7	.0070	.0066	.0068	.0068	9.2
Low 2A8	MI-070R	10	25	1/4	11	.0059	.0053	.0058	.0057	9.2
High 2A9	MI-070R	25	90	1/4	3	.0156	.0161	.0160	.0159	8.7

Baseline No.	Shot Size	Air Pressure	Nozzle Angle	Air Jet Size	Nozzle Distance	Intensity 1	Intensity 2	Intensity 3	Average Intensity	Est. Flow Rate (lb/min)
Baseline	MI-110R	75	65	1/4	7	.0099	.0096	.0097	.0097	7.75
3D1	MI-110R	75	65	1/4	3	.0103	.0103	.0101	.0102	7.75
3D2	MI-110R	75	65	1/4	5	.0097	.0094	.0095	.0095	7.75
3D3	MI-110R	75	65	1/4	9	.0081	.0084	.0084	.0083	7.75
3D4	MI-110R	75	65	1/4	11	.0078	.0077	.0080	.0078	7.75
3B1	MI-110R	60	65	1/4	7	.0078	.0078	.0079	.0078	8.5
3B2	MI-110R	45	65	1/4	7	.0069	.0068	.0069	.0069	8.75
3B3	MI-110R	80	65	1/4	7	.0096	.0095	.0096	.0096	7.5
3C1	MI-110R	75	65	1/8	7	.0036	.0036	.0036	.0036	17
3C2	MI-110R	75	65	3/16	7	.0069	.0066	.0065	.0066	16.75
3A1	MI-110R	75	90	1/4	7	.0096	.0098	.0099	.0098	7.75
3A2	MI-110R	75	85	1/4	7	.0097	.0098	.0096	.0097	7.75
3A3	MI-110R	75	75	1/4	7	.0098	.0099	.0099	.0099	7.75
3A4	MI-110R	75	55	1/4	7	.0086	.0082	.0084	.0084	7.75
3A5	MI-110R	75	45	1/4	7	.0080	.0081	.0082	.0081	7.75
3A6	MI-110R	75	35	1/4	7	.0074	.0070	.0072	.0072	7.75
3A7	MI-110R	75	25	1/4	7	.0061	.0062	.0060	.0061	7.75
High 3A8	MI-110R	80	90	1/4	3	.010	.0101	.0101	.0101	7.5
Low 3A9	MI-110R	45	25	1/4	11	.0042	.0042	.0043	.0042	8.75

Baseline No.	Shot Size	Air Pressure	Nozzle Angle	Air Jet Size	Nozzle Distance	Intensity 1	Intensity 2	Intensity 3	Average Intensity	Est. Flow Rate (lb/min)
Baseline	MI-170R	75	65	1/4	7	.0100	.0101	.0101	.0101	9.5
4B1	MI-170R	75	65	1/4	7	.0109	.0109	.0108	.0109	9.5
4B2	MI-170R	80	65	1/4	7	.0094	.0094	.0096	.0095	9.33
4B3	MI-170R	60	65	1/4	7	.0087	.0090	.0087	.0088	10
4C1	MI-170R	45	65	1/8	7	.0038	.0040	.0039	.0039	18
4C2	MI-170R	75	65	3/16	7	.0083	.0080	.0083	.0082	19
4D1	MI-170R	75	65	1/4	3	.0105	.0104	.0103	.0104	9.5
4D2	MI-170R	75	65	1/4	5	.0102	.0102	.0100	.0101	9.5
4D3	MI-170R	75	65	1/4	9	.0099	.0102	.0100	.0100	9.5
4D4	MI-170R	75	65	1/4	11	.0096	.0094	.0096	.0095	9.5
4A1	MI-170R	75	90	1/4	7	.0105	.0105	.0104	.0105	9.5
4A2	MI-170R	75	85	1/4	7	.0102	.0103	.0104	.0103	9.5
4A3	MI-170R	75	75	1/4	7	.0104	.0102	.0104	.0103	9.5
4A4	MI-170R	75	55	1/4	7	.0098	.0097	.0098	.0098	9.5
4A5	MI-170R	75	45	1/4	7	.0092	.0091	.0092	.0092	9.5
4A6	MI-170R	75	35	1/4	7	.0088	.0090	.0090	.0089	9.5
4A7	MI-170R	75	25	1/4	7	.0083	.0083	.0084	.0083	9.5
High 4A8	MI-170R	80	90	1/4	3	.0114	.0116	.0114	.0115	9.33
Low 4A9	MI-170R	45	25	1/4	11	.0070	.0074	.0072	.0072	9.75

Baseline No.	Shot Size	Air Pressure	Nozzle Angle	Air Jet Size	Nozzle Distance	Intensity 1	intensity 2	intensity 3	Average Intensity	Est. Flow Rate (lb/min)
Baseline	230R	60	65	1/4	7	.0111	.0111	.0110	.0111	10.5
5B1	230R	80	65	1/4	7	.0132	.0134	.0130	.0132	9.8
5B2	230R	72	65	1/4	7	.0117	.0120	.0116	.0118	10.1
5B3	230R	48	65	1/4	7	.0101	.0101	.0099	.0100	10.3
5B4	230R	36	65	1/4	7	.0089	.0085	.0089	.0088	10.1
5C1	230R	60	65	1/8	7	.0044	.0043	.0043	.0043	25
5C2	230R	60	65	3/16	7	.0087	.0087	.0089	.0088	21
5A1	230R	60	90	1/4	7	.0112	.0113	.0113	.0113	10.5
5A2	230R	60	85	1/4	7	.0112	.0111	.0110	.0111	10.5
5A3	230R	60	75	1/4	7	.0110	.0110	.0108	.0109	10.5
5A4	230R	60	55	1/4	7	.0102	.0103	.0101	.0102	10.5
5A5	230R	60	45	1/4	7	.0097	.0096	.0094	.0096	10.5
5A6	230R	60	38	1/4	7	.0095	.0096	.0091	.0094	10.5
5A7	230R	60	25	1/4	7	.0078	.0077	.0080	.0078	10.5
5D1	230R	60	65	1/4	3	.0114	.0116	.0119	.0116	10.5
5D2	230R	60	65	1/4	5	.0108	.0108	.0112	.0109	10.5
5D3	230R	60	65	1/4	9	.0109	.0107	.0110	.0109	10.5
5D4	230R	60	65	1/4	11	.0100	.0102	.0102	.0101	10.5
Low	230R	36	25	1/4	11	.0063	.0061	.0064	.0063	10.1
High	230R	80	90	1/4	3	.0145	.0141	.0144	.0143	9.8

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