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INDEX TO BENET LABORATORIES TECHNICAL REPORTS - 1988

R. D. NEIFELD

TECHNICAL PUBLICATIONS AND EDITING SECTION

MAY 1989

US ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER
CLOSE COMBAT ARMAMENTS CENTER
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WATERVLIET, N.Y. 12189-4050

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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Equation of State
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Thermodynamic Properties
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Liquids

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A cell for high pressure sound velocity measurements of liquids was designed and used in a Birch-Bridgman high pressure system with a liquid propellant specimen. The dependence of the sound velocity on pressure to 4.2 kbar (4200 atmospheres) was measured at room temperature and on temperatures between 220 and 293 K at room pressure. These data, together with the temperature dependence of the specific heat which was also measured and some thermodynamic arguments, were used to obtain the full equation of state with

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20. ABSTRACT (CONT'D)

temperature and the pressure dependence of the specific heat and of the volume expansivity at room temperature. We compare our results with data obtained by volumetric and other ultrasonic measurements.

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4. TITLE (and Subtitle) STRESS CORROSION CRACKING OF A723 STEEL PRESSURE VESSELS: TWO CASE STUDIES		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
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Stress Corrosion
Pressure Vessels
Residual Stress
Cannon
Fracture Mechanics
High Strength Steel
Fatigue

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Two separate investigations of apparent stress corrosion cracking of cannon tubes under field service conditions are described. The first investigation involved several tubes in which cracking initiated at the inner diameter surface due to the combination of cannon firing products and tensile residual stresses. Results of metallographic and fracture surface studies; residual stress measurements; fatigue life and material mechanical tests; and stress corrosion simulation tests of tube sections are presented and discussed.
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7. AUTHORS (CONT'D)

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20. ABSTRACT (CONT'D)

The second investigation involved two tubes in which apparent stress corrosion cracking occurred on the outer diameter surface due to the combination of an unknown substance, presumed to be a cleaning product, and tensile residual stress due to autofrettage of the tube.

The critical requirements for stress corrosion cracking are discussed in general and in relation to the pressure vessels of the two investigations. Conclusions are drawn regarding design and service conditions for pressure vessels which will help prevent the occurrence of stress corrosion cracking.

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18. SUPPLEMENTARY NOTES

S. Van Dyke-Restifo - Benet Laboratories Project Engineer

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Howitzer Improvement Program
XM283 Cannon
Primer Feed Mechanism
Fatigue
Noise Suppressor Unit
M203 Propelling Charge
Polyphoshazene

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

As part of the Howitzer Improvement Program, a 500-round fatigue firing test was conducted utilizing the 155-mm XM283 Cannon in a facility gun mount at the Wright-Malta Test Station, Ballston Spa, New York. The primary purpose of the test was to initiate firing damage in the XM283 Cannon tube sufficient for subsequent laboratory fatigue cycling until failure to establish an interim safe fatigue life for the tube. Test rounds were fired with the

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20. ABSTRACT (CONT'D)

M203 propelling charge temperature conditioned to 145°F with muzzle blast attenuated through a unique Noise Suppressor Unit. Functioning of the screw block breech was cam actuated, and primer loading and extraction were accomplished using an automatic primer feed mechanism.

During the course of testing, design changes were incorporated in the breech mechanism to improve functioning and component reliability. An experimental polyphoshazene obturator pad was test fired and found unsuitable due to cracking of the gas check seat surface. Inspection of the tube at the conclusion of testing indicated that the desired firing damage, in the form of heat checking, was obtained.

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4. TITLE (and Subtitle) THE FORCES OF CONSTRAINT ON A PROJECTILE IN A RIFLED GUN BORE (PART 1)		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) David F. Finlayson		8. CONTRACT OR GRANT NUMBER(s)
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Spiral Wear	Balloting	Projectile Balance
Muzzle Wear	Rifled Gun Tubes	Projectile Alignment
Secondary Wear	Tube Curvature	
Projectile Dynamics	Lateral Forces on Projectiles	
Gun Dynamics	Constraint Forces on Projectiles	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The general equations of the six-degree of freedom problem of the lateral (constraint) forces on a projectile traveling in a gun bore are indicated. In general, the bore is not straight, the projectile is imbalanced, and the principal axis of inertia of the projectile is not aligned with the spin axis. Complete equations are derived for two special cases where the rifling is of constant pitch: the first case being that of an imbalanced and misaligned projectile traveling in a perfectly straight bore, and the second case being that of a perfectly balanced and aligned projectile traveling in a crooked bore.

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7. AUTHOR(s) J. Frankel and W. Scholz (See Reverse)		8. CONTRACT OR GRANT NUMBER(s)
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Ultrasonics
Residual Stresses
Third Order Elastic Constants
Acoustoelasticity
Tension and Compression
Plastic Deformation

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A steel bar subjected to four-point bending was instrumented so that various strains and sound velocities could be measured during elastic and plastic deformation on both the tension and compression side of the bar. During plastic deformation, the load was reduced several times before it was increased again. We present the acoustoelastic constants and the corresponding third-order elastic constants l, m, and n in both tension and compression in the "as-treated" specimen and after various amounts of plastic deformation.
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7. AUTHORS (CONT'D)

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20. ABSTRACT (CONT'D)

The changes in various sound velocities with plastic deformation are also discussed.

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4. TITLE (and Subtitle) THE GASDYNAMICS OF PERFORATED MUZZLE BRAKES		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
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Perforated Muzzle Brake
Muzzle Brake
Muzzle Brake Efficiency
Weapon Impulse

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In a study of perforated muzzle brakes, Nagamatsu, Choi, Duffy, and Carofano calculated the three-dimensional steady flow of a perfect gas through one vent hole and used the results to predict overall brake performance. The importance of the gas covolume is considered here by using the Abel equation of state.

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20. ABSTRACT (CONT'D)

The brake performance calculations in the above study were limited to sets of holes of a single diameter. The merit of using sets of varying diameters is explored with particular emphasis on enhancing the structural integrity of the brake.

In studies of conventional muzzle brakes, the gasdynamic efficiency, β, has been found useful for comparing various brake designs and for scaling. A simple formula is presented which represents the efficiency of a wide variety of axisymmetric perforated brakes.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AST-1120X-005-86	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): EXPLOITATION OF THE T-62 RECOIL SYSTEM'S OPERATIONAL CHARACTERISTICS	5. TYPE OF REPORT & PERIOD COVERED: Final
6. PERFORMING ORG. REPORT NUMBER: ARCCB-TR-88007	
7. AUTHOR(s): Ronald G. Gast	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: N/A
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000	12. REPORT DATE: February 1988 13. NUMBER OF PAGES: 119
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): US Army Foreign Science and Technology Center 220 Seventh Street, N.E. Charlottesville, VA 22901-5396	15. SECURITY CLASS. (of this report): UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Recoil System	Soviet Armament	T-62 Tank
Energy Conversion	Hydraulic Cylinders	Butyl Rubber
Rigid Body Dynamics	Numerical Methods	Impulse Shapers
Impact Loading	Reverse Engineering	Simulation
Computer Analysis		

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In this report, the quantitative and qualitative operational characteristics of the recoil system used on the T-62 Tank are presented. The operational characteristics were determined by testing an existing system in a laboratory environment and replicating the results by computer simulation. The goal was the exploitation of the Soviet's technical expertise such that the design of our defense equipment may be improved.

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20. ABSTRACT (CONT'D)

This work resulted in the incorporation of many of the T-62 design features into developmental recoil systems for U.S. tank guns. The test results were used to verify the accuracy of newly developed recoil system design and analysis computer simulations. Upon verification, these codes were incorporated into the recoil system design loop. The impact of various design features may now be evaluated by computer long before system hardware is manufactured. The end product is now brought to market much quicker.

The test procedures and hardware which were devised for evaluating of the Soviet brake are now being used routinely for testing recoil hardware for U.S. gun systems.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-88008	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) COMPUTER INTEGRATED MANUFACTURING FOR CANNON		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) A. Wakulenko		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.0 PRON No. 1A-7-2RZWV-NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE February 1988 13. NUMBER OF PAGES 14
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer Integrated Manufacturing
Distributed Numerical Control
Computer Numerical Control
Retrofit

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report contains the results of one segment of a Computer Integrated Manufacturing (CIM) program for cannon under the Manufacturing Methods and Technology program. This portion of the CIM program addresses the expansion of Watervliet Arsenal's CIM system, operating under Distributed Numerical Control, with early generation numerical control machine tools. Project activities concentrated on the integration feasibility of old inventory

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20. ABSTRACT (CONT'D)

numerical control machines and the current computer numerical control technology to determine the viability of retrofitting a state-of-the-art control to an older numerical control machine for direct Distributed Numerical Control communication. Based on this investigation, a numerical control machine tool was remanufactured and connected to Watervliet Arsenal's Distributed Numerical Control system.

REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: ARCCB-TR-88009	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): MANUFACTURING OF TITANIUM ALLOY CANNON COMPONENTS	5. TYPE OF REPORT & PERIOD COVERED: Interim Technical Report Feb 86 to Dec 86
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Alex Wakulenko	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6126.23.1BL0.0 PRON No. 1A-7-2RCBT-NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000	12. REPORT DATE: February 1988
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Titanium Alloy
Beta-C
3Al-8V-6Cr-4Zr-4Mo
Machinability Data

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report contains the results of the first phase of a multi-year Manufacturing Methods and Technology project which addresses the manufacturing approach of new materials under consideration for cannon tube components. Activities concentrated on the assemblage of preliminary machinability data for a Beta-C, 3Al-8V-6Cr-4Zr-4Mo, titanium (Ti) alloy to support in-house machining requirements. In addition, machinability tests were performed by an

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20. ABSTRACT (CONT'D)

independent laboratory to develop a substantial database for optimizing the manufacture of Ti alloy production components.

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ARCCB-TR-88010

2. GOVT ACCESSION NO.:

3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): AN ADAPTIVE OVERLAPPING LOCAL GRID REFINEMENT METHOD FOR TWO-DIMENSIONAL PARABOLIC SYSTEMS

5. TYPE OF REPORT & PERIOD COVERED: Final

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): Peter K. Moore and Joseph E. Flaherty (See reverse)

8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
US Army ARDEC
Benet Laboratories, SMCAR-CCB-TL
Watervliet, NY 12189-4050

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AMCMS No. 6126.23.1BL0.0
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11. CONTROLLING OFFICE NAME AND ADDRESS:
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Finite Element Methods
Adaptive Methods
Overlapping Grids
Local Refinement
Parabolic Systems

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

We present an adaptive local refinement finite element method for solving vector systems of parabolic partial differential equations in two-space dimensions and time. The algorithm uses the finite element-Galerkin method in space and backward Euler temporal integration. At each time step we obtain an estimate of the error on each element, group the elements whose error violates a user prescribed tolerance, form new local grids, and solve the

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20. ABSTRACT (CONT'D)

problem again on each of the new grids. We discuss several aspects of the algorithm including the necessary data structures, the error estimation technique, and the determination of initial and boundary conditions at coarse-fine mesh interfaces. Finally, we present several examples which demonstrate the viability of our approach.

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1. REPORT NUMBER ARCCB-TR-88011	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ELASTIC, STRENGTH, AND STRESS RELAXATION PROPERTIES OF A723 STEEL AND 38644 TITANIUM FOR PRESSURE VESSEL APPLICATIONS		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. H. Underwood, R. R. Fujczak, and R. G. Hasenbein		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6940.00.6570.012 PRON No. 1A62ZH7QNMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE March 1988 13. NUMBER OF PAGES 28
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18. SUPPLEMENTARY NOTES

Presented at the Army Symposium on Solid Mechanics, U.S. Military Academy, West Point, NY, 7-9 October 1986.
Published in Proceedings of the Symposium.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Tensile Strength	High Strength Steel
Elevated Temperature	Titanium Alloy
Stress Relaxation	Elastic Properties

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Mechanical properties of a high strength steel and a titanium alloy have been measured for application to compound cylinders of steel and titanium subjected to elevated temperature. Results are presented from tests and analyses of elastic and failure strength, stress relaxation, fracture toughness, and microstructure and microhardness. Conclusions are drawn regarding the suitability of the two materials when subjected to conditions typical of cannon fabrication processes and service loading.

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1. REPORT NUMBER ARCCB-TR-88012	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FUNCTION SMOOTHING BY REPEATED AVERAGING		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Royce Soanes		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6940.00.6570.012 PRON No. 1A62ZH7QNMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE March 1988 13. NUMBER OF PAGES 50
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Smoothing	Shape Preserving	Convolution
Filter	Kernel	
Approximation	B Splines	
Error Analysis	Twicing	
Piecewise Polynomial	Asymptotics	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

General formulas for smooth univariate shape preserving approximation and allied accuracy preserving approximation are derived. Shape preserving properties of the smoothing operators are discussed, equivalent kernel forms are obtained, and thorough error analyses (with and without noise) are conducted for the smoothing operators and their derivatives. The class of functions to be approximated is the piecewise polynomials of possibly low smoothness.

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1. REPORT NUMBER ARCCB-TR-88013	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DESIGN OF A FEELING-THINKING MACHINE		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Raymond Scanlon and Mark Johnson		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.01.91A0.0 PRON No. 1A7BZ701NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE March 1988 13. NUMBER OF PAGES 19
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Published in Proceedings of the Conference.

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Non-Living Intelligence
Neural Networks
Machine Intelligence
Thinking Machines

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A feeling-thinking machine has been designed using the mammalian brain as a model and current psychobiology concepts as a guide. The machine has been successfully run as a computer simulation. It mimics a primitive organism with eight functional brain centers. They are the reticular ascending substance (RAS), the amygdala, the cingulate gyrus, the medial forebrain bundle, the hippocampus, thalamus, hypothalamus, and the neocortex.

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18. SUPPLEMENTARY NOTES (CONT'D)

Presented at Compcon Spring '88 Conference - "Implementations of Neural Networks," San Francisco, CA, 29 February - 4 March 1988.
Published in Proceedings of the Conference.

Submitted for publication in Scientific American.

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1. REPORT NUMBER: ARCCB-MR-88014	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): A TECHNIQUE FOR MEASURING AREA UNDER A CURVE	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): J. H. Underwood	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6126.23.1BL0.0 PRON No. 4A7DF7YK1A1F
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000	12. REPORT DATE: March 1988
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18. SUPPLEMENTARY NOTES

Submitted to Experimental Techniques.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Area Measurement
Mechanical Tests
Fracture Toughness
Plane Geometry

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A plane-geometry technique for measuring the area under a curve is described. Areas under mechanical load-deflection curves can be approximated by the area of a trapezoid. Accuracy of the technique is checked by applying it to a graphical construction of known area.

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4. TITLE (and Subtitle) A NON-CONTACT THREE-DIMENSIONAL MEASURING SYSTEM		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) David Concordia		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.0 PRON No. 1A52GX3E1A1A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE March 1988 13. NUMBER OF PAGES 35
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Non-Contact Measurement
Video Inspection
Three-Dimensional Measurement

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A non-contact video inspection system has been developed and implemented for inspection of small parts (smaller than 12 inches by 10 inches by 6 inches). The system uses a computer which processes the video image. Edge definition is determined through an algorithm which locates the point of maximum contrast. Parts are located on a movable table, with table motion programmed through a user-friendly menu. Once a program is established for a particular part, the program can be rerun any number of times desired. Part inspection time has been reduced from hours to minutes.

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1. REPORT NUMBER ARCCB-TR-88016	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FRACTURE AND FATIGUE		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. O. Ritchie, W. W. Gerberich, and J. H. Underwood (See Reverse)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 694000084 PRON No. AW6MC00103AW1A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research, Develop, & Engr Center Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE April 1988 13. NUMBER OF PAGES 69
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

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18. SUPPLEMENTARY NOTES

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Published as Technical Report No. UCB/RP/86/M1043, University of California, Berkeley, CA, May 1986.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fracture Mechanics
Fatigue
Concepts
Micromechanisms
Environmental Effects

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report has attempted to provide, with necessary brevity, a basic framework for understanding the macroscopic and microscopic aspects of fracture and fatigue crack propagation in engineering materials from a fracture mechanics viewpoint. Further details may be obtained with reference to the attached bibliography.

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7. AUTHORS (CONT'D)

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20. ABSTRACT (CONT'D)

In the last twenty years, much progress has been made with the continuum mechanics characterization of crack growth rates through the application of linear elastic and elastic-plastic fracture mechanics, and such analyses are now in widespread use for defect-tolerant design codes. Similarly, an understanding of the role of microstructure in improving the resistance to fracture and fatigue has emerged to the point where alloy design guidelines exist for the production of alloys with optimum resistance to fatigue failure. However, much work remains in the definition of mechanisms associated with environmentally-influenced crack growth, with the effect of variable amplitude loading, with the problem of the short flaw, and in the fracture of microscopic structures (e.g., packaging problems in the electronics industry). These problems demand an interdisciplinary approach to fracture and fatigue research involving applied mechanics, materials science, and surface chemistry studies, and clearly offer substantial opportunities for further investigations both of fundamental nature and to provide reliable engineering data needed in the design and maintenance of fracture and fatigue-critical structures.

REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: ARCCB-TR-88017	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): AN ADAPTIVE METHOD WITH MESH MOVING AND LOCAL MESH REFINEMENT FOR TIME-DEPENDENT PARTIAL DIFFERENTIAL EQUATIONS	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): David C. Arney and Joseph E. Flaherty (See Reverse)	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army ARDEC, Benet Laboratories, SMCAR-CCB-TL, Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6111.02.H600.0, PRON No. 1A6DZ602NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army ARDEC, Close Combat Armaments Center, Picatinny Arsenal, NJ 07806-5000	12. REPORT DATE: April 1988
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18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Adaptive Methods
Moving Mesh Methods
Local Refinement
Hyperbolic Systems
Partial Differential Equations

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

We discuss mesh moving, static mesh regeneration, and local mesh refinement algorithms that can be used with a finite difference or finite element scheme to solve initial-boundary value problems for vector systems of time-dependent partial differential equations in two-space dimensions and time. A coarse base mesh of quadrilateral cells is moved by an algebraic mesh movement function so that it may follow and isolate spatially distinct phenomena. The local mesh refinement method recursively divides the time step and spatial cells of the

(CONT'D ON REVERSE)

7. AUTHORS (CONT'D)

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18. SUPPLEMENTARY NOTES (CONT'D)

This research was partially supported by the U.S. Air Force Office of Scientific Research, Air Force Systems Command, USAF, under Grant Number AFOSR 85-0156 and the U.S. Army Research Office under Contract Number DAAL 03-86-K-0112. This work was used to partially fulfill the Ph.D. requirements of the first author at Rensselaer Polytechnic Institute.

20. ABSTRACT (CONT'D)

moving base mesh in regions where error indicators are high until a prescribed tolerance is satisfied. The static mesh regeneration procedure is used to create a new base mesh when the existing ones become too distorted.

In order to test our adaptive algorithms, we implemented them in a system code with an initial mesh generator, a MacCormack finite difference scheme for hyperbolic systems, and an error indicator based upon estimates of the local discretization error obtained by Richardson extrapolation. Results are presented for several computational examples.

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: ARCCB-TR-88018	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): ADDITIONAL FRACTURE AND STRENGTH TEST RESULTS FOR A723 STEEL AND 38644 TITANIUM	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): J. H. Underwood, M. H. Kamdar, and R. R. Fujczak	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army ARDEC, Benet Laboratories, SMCAR-CCB-TL, Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6126.23.1BL0.0, PRON No. 1A82ZJ9YNMSC
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fracture Toughness
Mechanical Properties
Elevated Temperature
Fatigue Crack Initiation
Pressurized Cylinder

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Four types of additional mechanical test results are described for high strength steel and titanium alloys, as a continuation of previous work.

1. The effects of elevated temperature on the circumferential orientation tensile properties of titanium and steel cylinders are described.

2. A comparison is presented of strength and fracture toughness results from two titanium ingots.

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20. ABSTRACT (CONT'D)

3. The fatigue lives of notched bend specimens of titanium are measured and compared with calculated fatigue lives for steel.

4. The effects of elevated temperature cycles and a plasma spraying process on the strength of steel are presented.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-88019	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PREMARTENSITE TRANSFORMATION IN $Ni_{50.5}Ti_{49.5}$		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) L. V. Meisel and P. J. Cote		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H610.011 PRON No. 1A82Z8CANMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE April 1988 13. NUMBER OF PAGES 19
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18. SUPPLEMENTARY NOTES

Submitted to Physical Review (American Physics Society).

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Shape Memory Alloys
Nickel-Titanium Alloys
Martensite Transformations
Differential Scanning Calorimetry

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Small deviations from stoichiometry in the thermoelastic NiTi martensitic alloy yield sufficiently large separation of the martensite and premartensite transformations to allow a thermal analysis study of the premartensite transformation without the complication of competing phenomena. The nature of the premartensite transformation in $Ni_{50.5}Ti_{49.5}$ and its relation to similar phenomena in stoichiometric and iron-doped NiTi is the subject of the present report. Data indicate that the premartensite transformation width in

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20. ABSTRACT (CONT'D)

$Ni_{50.5}Ti_{49.5}$ is due to a distribution of regions of the sample that transform from the cubic to the rhombohedrally distorted CsCl phase over a range of temperatures, and these regions transform back to cubic CsCl structure in reverse order upon reheating. In contrast to the results in iron-doped NiTi, no evidence of a two-step transformation could be found in a series of studies of the metastability and transformation kinetics of mixtures of phases produced by partially transforming from the pure CsCl phase and from the pure rhombohedrally distorted CsCl phase. This lack of evidence may not be conclusive since the physical properties of the charge density wave state (on cubic CsCl lattice) and the rhombohedrally distorted CsCl may be similar; however, if these two phases exist in $Ni_{50.5}Ti_{49.5}$, then they must also have essentially identical ranges of temperature for metastability and identical transformation kinetics.

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1. REPORT NUMBER ARCCB-MR-88020	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ESTABLISHMENT OF A CRITICAL FLAW SIZE FOR THE 120-MM STUB CASE		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) M. D. Witherell, J. A. Kapp, and M. A. Scavullo		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.0 PRON No. 1A72ZJWENMSC
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

120-mm	Critical Crack Size
Stub Case	Finite Element
K_{Ic} Tests	Stress Analysis
Tensile Tests	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Test specimens were fabricated from 120-mm stub cases. The test specimens were used to measure mechanical properties (tensile strength, yield strength) and fracture properties (K_{Ic} and J_{Ic}). These experimental results were used in conjunction with a finite element stress analysis to calculate a critical flaw size for the 120-mm stub case. The stub case was divided into three zones and a different flaw size was established for each zone.

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1. REPORT NUMBER ARCCB-TR-88021	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ACOUSTOELASTIC EFFECT FOR RAYLEIGH SURFACE WAVES IN THE PRESENCE OF A NONUNIFORM STRESS FIELD		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) M. E. Todaro and G. P. Capsimalis		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H610.0 PRON No. 1A-8-3Z8CA-NMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE May 1988 13. NUMBER OF PAGES 15
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18. SUPPLEMENTARY NOTES

Presented at 1986 IEEE Ultrasonics Symposium, Williamsburg, VA, 17-19 November 1986.
Published in Proceedings of the Symposium.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Acoustoelastic Effect
Rayleigh Waves
Surface Waves
Ultrasonic
Stress
Acoustic Waves
Steel

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The acoustoelastic effect for Rayleigh waves on the inner diameter of a right circular steel cylinder was investigated. The velocity dependence on stress was studied as a function of frequency. As expected, the change in velocity was proportional to the applied stress at the surface. As a result of the nonuniformity of the applied stress field, however, the proportionality constant was expected to depend on frequency. Such a frequency dependence was

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20. ABSTRACT (CONT'D)

observed and interpreted in light of existing theoretical predictions for the velocity behavior of Rayleigh waves in the presence of a nonuniform stress field.

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1. REPORT NUMBER: ARCCB-TR-88022	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): WIDE RANGE STRESS INTENSITY FACTOR EXPRESSION FOR AN EDGE-CRACKED ROUND BAR BEND SPECIMEN	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): J. H. Underwood and R. L. Woodward (See Reverse)	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army ARDEC, Benet Laboratories, SMCAR-CCB-TL, Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6111.02.H610.011, PRON No. 1A82Z8CANMSC
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army ARDEC, Close Combat Armaments Center, Picatinny Arsenal, NJ 07806-5000	12. REPORT DATE: May 1988
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18. SUPPLEMENTARY NOTES

Presented to ASTM Committee E-24 on Fracture, Sparks, NV, 25-28 April 1988.

Submitted to Experimental Techniques.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fracture Testing
Limit Solution
Bend Specimen
Cylindrical Geometry

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An edge-cracked round bar was analyzed for use as a fracture mechanics test specimen. Shallow and deep crack limit solutions were developed and combined with experimental and numerical results to obtain K expressions which apply for all crack depths. Specimen and loading geometries were suggested for standardized fracture mechanics tests using a round bar.

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1. REPORT NUMBER ARCCB-SP-88023	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) INDEX TO BENET LABORATORIES TECHNICAL REPORTS - 1987		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. D. Neifeld		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS N/A
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE June 1988 13. NUMBER OF PAGES 95
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Benet Laboratories
Technical Publications
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Abstracts
Document Control Data

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is a compilation of technical reports published by Benet Laboratories during 1987.

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1. REPORT NUMBER: ARCCB-TR-88024	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): A POSTERIORI ERROR ESTIMATION OF ADAPTIVE FINITE DIFFERENCE SCHEMES FOR HYPERBOLIC SYSTEMS	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): David C. Arney, Rupak Biswas, and Joseph E. Flaherty (See Reverse)	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army ARDEC, Benet Laboratories, SMCAR-CCB-TL, Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6126.23.1BL0.0, PRON No. 1A72ZJ5MNMSC
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army ARDEC, Close Combat Armaments Center, Picatinny Arsenal, NJ 07806-5000	12. REPORT DATE: June 1988
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18. SUPPLEMENTARY NOTES

Presented at the Fifth Army Conference on Applied Mathematics and Computing, U.S. Military Academy, West Point, New York, 15-18 June 1987. Published in Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hyperbolic Systems
Adaptive Methods
A Posteriori Error Estimation
Finite Difference Methods

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

We describe several techniques that are based on Richardson's extrapolation for estimating discretization errors of finite difference solutions of one- and two-dimensional hyperbolic systems. These a posteriori error estimates are intended for use with adaptive mesh moving and local refinement procedures. Mesh moving algorithms produce nonuniform grids which necessitate special treatment of solution and error estimation techniques. The required adjustments are discussed using a two-step MacCormack method as a model finite

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Close Combat Armaments Center
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20. ABSTRACT (CONT'D)

difference scheme. We also discuss automatic time step selection procedures and the effects of artificial viscosity. Extrapolation schemes that produce separate estimates of the temporal and spatial discretization errors are presented and we show how these may be used to control local mesh refinement procedures. Several examples illustrating these procedures are presented.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-88025	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DETERMINATION OF PHOSPHORIC ACID, SULFURIC ACID, CHROMIC ACID, AND THEIR MATRIX EFFECTS IN CHROMIUM PLATING AND ASSOCIATED POLISHING SOLUTIONS BY ION CHROMATOGRAPHY		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Samuel Sopok		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.0 PRON No. 1A72ZJ7BNMSC
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18. SUPPLEMENTARY NOTES

Submitted to LC-GC Magazine of Liquid and Gas Chromatography.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Phosphoric Acid	Chromium Plating Solutions
Sulfuric Acid	Polishing Solutions
Chromic Acid	Ion Chromatography

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The determination of phosphoric, sulfuric, and chromic acids in chromium plating and polishing solutions is essential to optimize the plating quality of low alloy steels. An ion chromatographical procedure, which is an improvement on an established procedure now in practice, is described for these analytes. Despite previous beliefs, standards and samples must have similar acid-base characteristics and concentrations in order to eliminate potential matrix effects that may cause up to forty percent variation in the accuracy of

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20. ABSTRACT (CONT'D)

these determinations. Established precisions and sensitivities did not vary in this new procedure.

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1. REPORT NUMBER: ARCCB-TR-88026	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): DETERMINATION OF SULFURIC ACID, OXALIC ACID, AND THEIR MATRIX EFFECTS IN ALUMINUM ANODIZING SOLUTIONS BY ION CHROMATOGRAPHY	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Samuel Sopok	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army ARDEC, Benet Laboratories, SMCAR-CCB-TL, Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6126.23.1BL0.0, PRON No. 1A72ZJ7BNMSC
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18. SUPPLEMENTARY NOTES

Submitted to Plating and Surface Finishing.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Sulfuric Acid
Oxalic Acid
Aluminum Hardcoating
Aluminum Anodizing
Ion Chromatography

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Process optimization of aluminum anodizing and hardcoating solutions requires determinations of sulfuric and oxalic acids. An improved ion chromatographic procedure is given for standards and samples of these analytes addressing matrix effects caused by dissimilar acid-base characteristics and concentrations.

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1. REPORT NUMBER ARCCB-TR-88027	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) FATIGUE - FRACTURE PROPERTIES OF A SEMI-AUSTENITIC PRECIPITATION HARDENING STAINLESS STEEL		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. Farrara		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.0AR PRON No. 1A72RZPJNMSC
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE June 1988 13. NUMBER OF PAGES 26
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Published as Technical Report No. MRL-R-1041, Materials Research Laboratories, Victoria, Australia, February 1987.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Stainless Steels
Precipitation Hardening Steels
105-mm Light Gun
Fracture Toughness
Crack Propagation
Fatigue
Gun Carriages

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Fatigue and fracture toughness properties were determined for STA 60 precipitation hardening stainless steel used in the structure of the 105-mm Light Gun. Fatigue properties (S-N crack for initiation and da/dN versus ΔK crack growth rate) and fracture toughness (J_{Ic}) were measured on both parent sheet and welded joints for a range of heat treatments including fully re-heat treated and peak aged (450°C), overaged as in production (530°C), and as-welded joints not re-heat treated.

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20. ABSTRACT (CONT'D)

The material was found to be notch sensitive. Fatigue crack growth was much faster, and fracture toughness much lower, in the longitudinal (rolling) direction of the sheet because of the presence of nonmetallic stringers in the microstructure. Overaging had little effect on fatigue properties compared with peak aging, but did achieve a significant improvement in fracture toughness. Weld metal was more resistant to fatigue crack initiation than parent sheet, but welds not re-heat treated were drastically limited in all three properties because the weld heat-affected zones remained in the soft condition.

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1. REPORT NUMBER: ARCCB-TR-88028	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): COMPARISON OF COMPLIANCE RESULTS FOR THE WEDGE-LOADED COMPACT SPECIMEN	5. TYPE OF REPORT & PERIOD COVERED: Final
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s): J. H. Underwood and J. C. Newman, Jr. (See Reverse)	8. CONTRACT OR GRANT NUMBER(s)
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18. SUPPLEMENTARY NOTES

Presented to ASTM Committee E-24 on Fracture, Sparks, NV, 25-28 April 1988.

Submitted to ASTM Journal of Testing and Evaluation.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Compliance	Crack Arrest
Stress Intensity Factor	Compact Specimen
Wedge Load	Deep Crack Limit

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Results of the ratio of stress intensity factor to crack mouth displacement as a function of crack length are presented for the wedge-loaded compact specimen. Comparisons are made between experimental compliance results, numerical results from collocation methods, and deep crack limit solution results. Applications are for crack arrest and stress corrosion cracking tests for metals and other materials under predominantly linear elastic conditions.

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7. AUTHORS (CONT'D)

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-88029	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DISCUSSION AND EXPLANATION OF UNPLANNED IGNITION INCIDENT: IGNITION CAUSED BY RAPID PRESSURIZATION OF A PROPELLANT CONTAINING BUBBLES		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Julius Frankel		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H270.011 PRON No. 1A8DZ8AANMTS
11. CONTROLLING OFFICE NAME AND ADDRESS US Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000		12. REPORT DATE July 1988 13. NUMBER OF PAGES 12
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Liquid Propellant
Adiabatic Compression
Ullage

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The unplanned incident is discussed from the point of view of adiabatic compression of gas bubbles in the liquid propellant. Reference is made to previous Army work in this field.

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REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: ARCCB-TR-88030	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): A SIMPLE ANALYSIS OF THE SWAGE AUTOFRETTAGE PROCESS	5. TYPE OF REPORT & PERIOD COVERED: Final
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Peter C. T. Chen	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army ARDEC, Benet Laboratories, SMCAR-CCB-TL, Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6126.24.1BL0.OAR, PRON No. 1A72ZH7QNMSC
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army ARDEC, Close Combat Armaments Center, Picatinny Arsenal, NJ 07806-5000	12. REPORT DATE: July 1988 / 13. NUMBER OF PAGES: 14
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18. SUPPLEMENTARY NOTES

Presented at the Fifth Army Conference on Applied Mathematics and Computing, U.S. Military Academy, West Point, New York, 15-18 June 1987. Published in Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Gun Tube	Swaging
Autofrettage	Plasticity
Residual Stress	Bauschinger Effect
Hardening	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Many solutions have been reported for the hydraulic autofrettage process. In this report a simple analysis of the swage autofrettage process is presented. The contact pressure at different locations is determined as a function of interference. The deformation and stress distribution during autofrettage is obtained. At the end of the autofrettage process, the permanent bore enlargement and residual stresses are calculated. Numerical results are presented in graphical form.

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1. REPORT NUMBER: ARCCB-TR-88031

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): LIQUID PHASE SINTERING OF CARBIDES USING A NICKEL-MOLYBDENUM ALLOY

5. TYPE OF REPORT & PERIOD COVERED: Final

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): J. M. Barranco and R. A. Warenchak

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
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18. SUPPLEMENTARY NOTES

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Published in Proceedings of the Conference: Progress in Powder Metallurgy, Volume 43.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Liquid Phase Sintering
Carbides
Nickel-Molybdenum Alloy
Powder Metallurgy

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Liquid phase vacuum sintering was used to densify four carbide groups. These were titanium carbide, tungsten carbide, vanadium carbide, and zirconium carbide. The liquid phase consisted of nickel with additions of molybdenum from 6.25 to 50.0 weight percent at doubling increments. The liquid phase or binder comprised 10, 20, and 40 weight percent of the pressed powders. The specimens were tested using three-point bending. Tungsten carbide showed the greatest improvement in bend rupture strength, flexural modulus, fracture
(CONT'D ON REVERSE)

20. ABSTRACT (CONT'D)

energy, and hardness using 20 percent binder with lesser amounts of molybdenum (6.25 or 12.5 weight percent) added to nickel compared to pure nickel. A refinement in the carbide microstructure and/or a reduction in porosity was seen for both the titanium and tungsten carbides when the alloy binder was used, compared to using the nickel alone. Curves depicting the above properties are shown for increasing amounts of molybdenum in nickel for each carbide examined. Loss of binder phase due to evaporation was experienced during heating in vacuum at sintering temperatures. In an effort to reduce porosity, identical specimens were processed by hot isostatic pressing (HIP) at 15 Ksi and at temperatures averaging 110° below the sintering temperature. The tungsten carbide and titanium carbide series containing 80 and 90 weight percent carbide phase, respectively, showed improved properties after HIP, while properties decreased for most other compositions.

REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: ARCCB-TR-88032
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): PROPOSED STANDARD ARC-BEND CHORD-SUPPORT FRACTURE TOUGHNESS SPECIMENS AND K EXPRESSIONS

5. TYPE OF REPORT & PERIOD COVERED: Final

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): J. H. Underwood

8. CONTRACT OR GRANT NUMBER(s):

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Submitted to ASTM Journal of Testing and Evaluation.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fracture Toughness
Test Methods
Collocation
Cylindrical Shape

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Collocation and finite element calculations and limit solutions were used to propose standard geometries and K expressions for measuring fracture toughness with arc-bend chord-support specimens. Polynomial expressions for K were determined for a wide range of crack length and for two span-to-depth ratios. Fracture toughness of steel and aluminum alloys was measured using the proposed methods and compared with results from existing standard methods.

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4. TITLE (and Subtitle) DETERMINATION OF ETHYLENE GLYCOL DEGRADATION PRODUCTS IN CHROMIUM PLATING AND ASSOCIATED POLISHING SOLUTIONS BY ION CHROMATOGRAPHY		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Samuel Sopok		8. CONTRACT OR GRANT NUMBER(s)
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18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ethylene Glycol
Acid Degradation Products
Chromium Plating Solutions
Polishing Solutions
Ion Chromatography

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Ethylene glycol resulting from cooling system leaks can adversely affect plating properties when added to chromium plating and associated polishing solutions. Ion chromatography can be used to monitor these leaks by quantitatively determining the glycolic, oxalic, and formic acid degradation products of ethylene glycol.

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1. REPORT NUMBER ARCCB-MR-88034	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DETERMINATION OF RESIDUAL STRESS DISTRIBUTIONS IN AUTOFRETTAGED TUBING: A DISCUSSION		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Boaz Avitzur		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.0 PRON No. 1A82ZK24NMSC
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18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Thick-Walled Tubing
Pressurization
Autofrettage
Mises' Yield Criterion
Tresca's Yield Criterion
Elastic-Plastic Deformation
Retained Stresses

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

There is a long-standing interest in developing a capability to predict the distribution of residual stresses in thick-wall tubes after internal pressurization--autofrettage. Since autofrettage involves partial or full plastic deformation of the tube, any computation of stress under pressure and, hence of the post-pressurization residual stresses, depends upon the assumed yield criterion. The latter may or may not include the material's strain-hardening and/or strain-softening capabilities. The most commonly used

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20. ABSTRACT (CONT'D)

criteria are those named after Tresca and Mises.

In the absence of exact solutions for plastic deformations, simplifying assumptions concerning the material's behavior are being made for the development of workable solutions, sometimes with the knowledge that certain physical principles are being violated.

Many suggested solutions to the problem of autofrettage assume that Tresca's yield criterion prevails. Recent attempts to treat a "modified Tresca's yield criterion" as Mises' yield criterion and/or attempts to add strain-hardening and/or strain-softening (Bauschinger effect) to Tresca's yield criterion are being questioned here.

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1. REPORT NUMBER ARCCB-TR-88035	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THERMAL RESISTANCE MODEL AND SUGGESTED IMPROVEMENTS FOR THERMAL SHROUDS OF TANK GUNS		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Jeffrey W. Haas		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6126.23.1BL0.0 PRON No. 1A82ZK24NMSC
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Thermal Resistance
Thermal Shrouds
Thermal Sleeves
Gun Tubes
Heat Transfer

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The total thermal resistance R_{total} is proposed as a parameter for evaluating thermal shroud design and performance. The primary effect of this parameter is to resist the flow of heat between the gun barrel and the external environment which may result in the production of temperature asymmetries and associated muzzle deflection.

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20. ABSTRACT (CONT'D)

A theoretical heat transfer model of the shroud/gun tube assembly predicts that internal convection effects in conventional air-gap type shrouds impose a definite limit on the thermal resistance. The model also demonstrated that surface emissivities on the shroud interior greatly affect the radiation heat transfer between the shroud shell and gun tube, and that the thermal resistance can be increased by incorporating low emissivity materials in the design.

To support the theoretical analysis, a laboratory experiment was performed on a three-foot long shroud/tube section. The assembly was externally heated to simulate the effects of direct sun. Cross-tube temperature differences were recorded to assess the effects of radiation heat transfer for different configurations. Tests indicate a decrease in temperature difference of 68% in the air-gap type and over 160% in the insulated type can be obtained for configurations employing foil barriers to reduce the internal radiative effects.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARCCB-TR-88036	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) MATHEMATICAL ASPECTS OF THE OFF-LINE PROGRAMMING OF FILAMENT WINDING MACHINES FOR GENERAL SURFACES OF REVOLUTION		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Royce N. Soanes		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army ARDEC Benet Laboratories, SMCAR-CCB-TL Watervliet, NY 12189-4050		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 6111.02.H610.011 PRON No. 1A86Z8CANMSC
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Composite Materials	Surface of Revolution	Indefinite Integration
Filament Winding	Differential Geometry	Error Analysis
Off-Line Programming	Variational Calculus	Error Equidistribution
Geodesics	Asymptotics	Nonuniform Mesh

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report contains a reasonably complete description of the analytical, geometrical, numerical, and computational aspects of the off-line programming of a rotating-traversing composite filament winding machine for wrapping general axisymmetric surfaces of revolution. The topics addressed are geodesic winding paths, path/angle relations, quasi-geodesic paths, wrappable paths and surfaces, path behavior near turning points, a square root singularity quadrature formula, piecewise linear approximation, path

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20. ABSTRACT (CONT'D)

computation, path/winder relations, winder data generation, time base computation, surface coverage relations, surface buildup relations, function definition, and indefinite integration.

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1. REPORT NUMBER: ARCCB-TR-88037	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): FINITE ELEMENT ANALYSIS OF THE SWAGE AUTOFRETTAGE PROCESS	5. TYPE OF REPORT & PERIOD COVERED: Final
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s): Peter C. T. Chen	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army ARDEC, Benet Laboratories, SMCAR-CCB-TL, Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6126.23.1BL0.0, PRON No. 1A82ZK24NMSC
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Published in Proceedings of the Conference.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Gun Tube	Residual Stress
Autofrettage	Plasticity
Swaging	Finite Element Analysis

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The swage autofrettage process is often used to produce favorable residual stresses in a tube. In this report a finite element analysis of the swage autofrettage process is presented. The nonlinear finite element program (ABAQUS) is used to obtain numerical results for the displacements, strains, and stresses in the tube during and after autofrettage. Approximate solutions are obtained for one- and two-dimensional tubes pressed by rigid or elastic mandrels. The longitudinal effect and the elasticity of the mandrel on the permanent bore enlargement and the residual stresses are discussed.

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1. REPORT NUMBER: ARCCB-TR-88038	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): RESIDUAL STRESS IN QUENCHED STEEL CYLINDERS	5. TYPE OF REPORT & PERIOD COVERED: Final
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s): M. E. Todaro, M. A. Doxbeck, and G. P. Capsimalis	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: US Army ARDEC, Benet Laboratories, SMCAR-CCB-TL, Watervliet, NY 12189-4050	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 6111.02.H610.0, PRON No. 1A7AZ703NMSC
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Residual Stress	Steel
Stress	X-Ray Diffraction
Heat Treatment	Ultrasonics
Quenching	Quench Cracking

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Measurements were made on high strength, low allow steel cylinders to determine the residual stress distributions resulting from various heat treatments. Cylinders of 239-mm outer diameter and 94-mm inner diameter were austenitized at 843°C and quenched at various rates to 93°C. Residual stress measurements were made on cylindrical cross sections which had been cut from the larger cylinder at least one foot from the nearest end. Using ultrasonic and x-ray diffraction techniques, we measured tangential and radial components of stress as a function of radial position.

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2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): STRESS-CORROSION CRACKING OF LIQUID-PHASE SINTERED TUNGSTEN ALLOYS
5. TYPE OF REPORT & PERIOD COVERED: Final
6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): M. Z. Shah Khan, J. H. Underwood, and I. A. Burch (See Reverse)
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Stress-Corrosion Cracking	Kinetic Energy Penetration
Liquid-Phase Tungsten	Fracture Mechanics
Unloading Compliance	Crack Closure

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study addresses the stress-corrosion cracking susceptibility of liquid-phase sintered tungsten alloys during long-term storage. These alloys are used for kinetic energy penetrators in military applications and it is essential that the structural integrity of the penetrator is not diminished due to the combined action of the chemical environment and the residual manufacturing stresses.

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7. AUTHORS (CONT'D)

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20. ABSTRACT (CONT'D)

This report describes test methods used for assessing the resistance to stress-corrosion cracking in terms of the stress intensity parameter, K_{Iscc}. The alloys were obtained from different sources and had up to 10 weight percent additions of selected combinations of nickel (Ni), iron (Fe), copper (Cu), and cobalt (Co), and different process variables. Cantilever-bend specimens were used and the test environment was an immersion in 3.5 percent sodium chloride (NaCl) aqueous solution followed by sustained loading in 95 percent relative humidity air.

The findings of this study were as follows: (1) Fracture mechanics was shown to give a good assessment and ranking of the resistance to stress-corrosion cracking of the various alloys. (2) Evidence of stress-corrosion cracking was found in the region controlled by the stress intensity factor, generally designated as region III. (3) An unloading compliance procedure similar to that applied in J-integral testing was shown to give accurate measurements of stress-corrosion crack growth. (4) A crack closure phenomenon was identified using the unloading compliance procedure and attributed to the accumulation of corrosion products between the crack faces following certain exposure times to the environment.

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Presented at the Australian Bicentennial Congress on Mechanical Engineering, Brisbane, Australia, 9-13 May 1988. Published in Proceedings of the Congress. Presented to ASTM Committee E-24 on Fracture, Atlanta, GA, 7-10 November 1988. Submitted to Journal of Composite Materials.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Tensile Fracture	Fracture Toughness
Interlaminar Fracture	Carbon Bismaleimide
Fracture Surface	Glass Epoxy
Carbon Epoxy	Scanning Electron Microscope

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Tensile fracture and interlaminar mode I delamination failure may be considered as the upper and lower bounds of performance for fracture of fiber composite laminates. While these failures have been studied extensively in the literature, little progress has been made towards developing an understanding of the micromechanisms of the failure processes which, in fact, govern the macroscopic performance.

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20. ABSTRACT (CONT'D)

This report emphasizes the microscopic deformation processes and seeks to explain (1) the superior tensile fracture toughness of a commercial laminate of the new composite system carbon/bismaleimide over a commercial laminate of the conventional material carbon/epoxy, and (2) the dependence of interlaminar failure in glass and carbon fiber/epoxy laminates on the fracture energy of the matrix resin.

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4. TITLE (and Subtitle) FRACTOGRAPHIC ANALYSIS OF A FAILED CRANE BOLT		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) A. A. Kapusta		8. CONTRACT OR GRANT NUMBER(s)
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Failure Analysis
Fractography
Fatigue

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A failed crane bolt was examined by scanning electron microscopy to determine its failure mode. Failure occurred by fatigue crack initiation at the root of a thread with subsequent propagation by fatigue through essentially the entire 0.7-inch diameter cross section of the bolt.

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18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Orthotropic
Cylinder
Weight Savings
Composite Jacket

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents the results of a theoretical and experimental investigation of the effects on bore strain when a portion of the wall thickness of a steel cylinder is replaced with organic composite material. The pressure vessel is pressurized internally and the bore strain is theoretically predicted and experimentally measured as a function of wall ratio. Theoretical results for various ratios of steel to composite, from all-steel to all-composite, are given. The theoretical solution was obtained by equating the

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20. ABSTRACT (CONT'D)

hoop strain of the steel with the hoop strain of the composite at the material interface. Lame's stress solution was used as input for the steel hoop strain, whereas Lekhnitskii's stress solution obtained for orthotropic cylinders was used as input to the composite hoop strain equation. The experimental results are for steel liners that have two thicknesses and are wrapped in the circumferential direction with a graphite-bismaleimide organic composite. Also presented are predicted weight savings achieved by replacing steel with the organic composite. The results show that a penalty is paid in wall thickness, but that a weight savings is achieved when a part of the steel cylinder is replaced with an organic composite.

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3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): THE BLAST FIELD PRODUCED BY A CANNON HAVING A PERFORATED MUZZLE BRAKE	5. TYPE OF REPORT & PERIOD COVERED: Final
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s): G. C. Carofano	8. CONTRACT OR GRANT NUMBER(s)
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Published in Proceedings of the Symposium.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Muzzle Brake
Perforated Muzzle Brake
Internal Ballistics
Muzzle Blast

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In a study of perforated muzzle brakes, Nagamatsu, Choi, Duffy, and Carofano calculated the three-dimensional steady flow through one vent hole and used the results to predict overall brake performance. In the present study, the analysis is extended to the calculation of the blast field. The results compare favorably with previously unpublished shadowgraphs obtained by Dillon in his experimental program.

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7. AUTHOR(s) Mark F. Pleszar		8. CONTRACT OR GRANT NUMBER(s)
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Differential Scanning Calorimetry
Epoxy
Glass Transition
Heat of Reaction
Cure

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Differential scanning calorimetry is a reliable and effective method for the quality control of an epoxy resin prepreg material. There are two basic methods for determining the extent of cure for this material, the glass transition temperature and the heat of reaction. The first method requires the measurement of the glass transition temperature for the uncured material and the glass transition temperature for a fully cured material. This data can then be used to determine the degree of cure for an unknown sample. The

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20. ABSTRACT (CONT'D)

second method requires the measurement of the enthalpy of the cure reaction for an uncured material and relates this value to the enthalpy of a sample. The use of one or both of these methods can be used to evaluate an epoxy resin to determine the extent of cure of the material.

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