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AEROPROJECTS INCORPORATED

310 EAST ROSEDALE AVENUE, WEST CHESTER, PENNSYLVANIA

October 25, 1961

NOX
62-1-3Bureau of Naval Weapons
Department of the Navy
Washington 25, D. C.

Attention: RRMA-231

Released to ASTIA by the
Bureau of **NAVAL WEAPONS**
without restriction.Via: Inspector of Naval Material
10 North 8th Street
Reading, PennsylvaniaSubject: ULTRASONIC WELDING OF REFRACTORY METALS
Progress Report No. 3
For the Period, June 1 through July 31, 1961
Bureau of Naval Weapons, Department of the Navy
Contract NOW 61-0410-c

Gentlemen:

The results of work carried out during the period June 1 through July 31, 1961, are presented herein.

MATERIALS

At the end of the last report period, an order* was placed for small quantities of 0.005-, 0.010-, 0.015-, and 0.020-inch D-31 alloy. In partial fulfillment of this order, one square foot of 0.020-inch sheet was received during the present period.

While molybdenum-0.5% titanium in 0.005- and 0.010-inch sheet is available on a two-week delivery schedule from the Universal Cyclops Steel Corporation, more than two weeks may be required for the delivery of the heavier gages. About 3 square feet of 0.015- and 0.020-inch sheet was ordered.

WELDING INVESTIGATION

Welding studies for the refractory metal, tungsten, and the refractory alloys, niobium-10% molybdenum-10% titanium (D-31) and molybdenum-0.5% titanium, were continued and the data evaluated. The tensile-shear strength of welds and metallography were utilized to evaluate these specimens.

MOLYBDENUM-0.5% TITANIUM (0.005-INCH SHEET)

The effect of input power, clamping force, and weld interval on the tensile-shear strength of welded 0.005-inch molybdenum-0.5% titanium specimens was studied. The quality of the weld was estimated by a visual examination of the interface region after shearing.

*Progress Report No. 2.

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On the basis of previous investigations*, the welding conditions shown in Table 1 were selected for further study. The tensile-shear results, and comments concerning the sheared interfaces at 40X magnification, are given in Table 1.

A statistical evaluation of the data in Table 1 indicated that the significance of differences in the shear strength values, as related to welding conditions, was inconclusive. There was evidence of a clamping force-weld interval interaction that may warrant further study.

MOLYBDENUM-0.5% TITANIUM (0.010-INCH SHEET)

Exploratory tensile-shear measurements were made with 0.010-inch Molybdenum-0.5% titanium specimens welded at an energy level of 1080 watt-seconds (1800 watts power applied for 0.6 seconds) and clamping force levels of 400 and 350 pounds. The results of this work are summarized in Table 2.

Table 2

TENSILE-SHEAR STRENGTH OF ULTRASONICALLY WELDED
 0.010-INCH MOLYBDENUM-0.5% TITANIUM
 AS A FUNCTION OF CLAMPING FORCE

Conditions: Power: 1800 watts
 Weld Interval: 0.6 second

Clamping Force (pounds)	Tensile-Shear Strength		
	Specimens (number)	Average (pounds)	Standard Deviation (percent*)
400	6	77	41
350	5	60	38

* Commonly designated as the coefficient of variation.

While the average difference between the shear strength of the two groups of specimens is 17 pounds, this is less than the standard deviation of either set of data. Therefore, this difference cannot be considered significant nor indicative of the better clamping-force level.

TUNGSTEN (0.005-INCH SHEET)

Coupons of 0.005-inch tungsten sheet were joined to establish the welding conditions for this material. The manual peel method for evaluating welds in more ductile material could not be used for tungsten bonds; instead, shear measurements on the Instron machine were used for

* Progress Report No. 2, page 2.

Table 1
 EFFECT OF WELDING CONDITIONS ON THE SHEAR STRENGTH
 OF ULTRASONICALLY WELDED 0.005-INCH MOLYBDENUM-0.5% TITANIUM ALLOY

Clamping Force (pounds)	Welding Conditions			Shear Strength		Condition of Sheared Interface***
	Power (watts)	Weld Interval (seconds)	Energy (watt-seconds)	Average* (pounds)	Range* (pounds)	
300	1000	0.4	400	21	18	Moderate metal transfer- no cracks
		.8	800	57	33	1. Metal transfer - crack 2. Partial nugget - no cracks
	1400	0.4	560	55	1	Moderate metal transfer - cracks in weld zone
		.8	1120	41	17	Partial or complete nugget
450	1200	0.6	720	42**	26**	Partial nuggets - cracks in weld zone
600	1000	0.4	400	34	22	Little metal transfer - no cracks
		.8	800	31	30	Moderate metal transfer - cracks in weld zone
	1400	0.4	560	50	6	1. Metal transfer - no cracks 2. Weld intact - cracks
		.8	1120	47	11	Slight to moderate metal transfer - no cracks

* N = 2

** N = 10

*** Cracks were associated with the application of shearing stresses during tensile-shear tests; for the most part, these occurred in the parent metal.

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this purpose. The tensile-shear strength of specimens, welded at a power level of 1600 watts, a weld interval of 0.3 second, and clamping forces in the range of 300 to 900 pounds, varied from 15 to 38 pounds; there was no evidence of a correlation between weld strength and clamping force. These inconclusive results are attributed, in part at least, to the existence of some uncontrolled variable which may be associated with the negligible ductility of tungsten at room temperature and, therefore, with cracking in the weld zone.

In future work with 0.005- and 0.010-inch tungsten, steps will be taken to reduce the cracking tendency of the material; first, material in the stress-relief, annealed condition will be procured for future work; and second, power programming, which was beneficial in previous work with brittle materials such as beryllium, will be used.

METALLOGRAPHIC EVALUATION OF WELDS

Specimens of 0.005-inch D-31 alloy, treated by etching with 10 parts HF, 30 parts HNO₃, and 50 parts lactic acid, or by degreasing in a detergent, were all welded at the same machine settings; the strength as well as the metallographic characteristics of these welds was determined. In the degreased specimens, the bonds were located in discontinuous regions along the interface surface; irregularities in the parent metal probably contributed to the formation of the isolated void areas.

The characteristic microstructure of the etched specimens is shown in Figure 1. Apparently, pre-etching removed surface films and other irregularities sufficiently to permit structural continuity across the bond interface and over more extensive regions of the contact area. There is no evidence of thermal effects, nor of turbulence along the interface, in the microstructure of Figure 1.

A comparison of the welds produced without surface etching (Figure 3 of Progress Report No. 2) and the etched sample shown here in Figure 1, is of interest. The degreased coupons exhibit some persistence of surface film and surface irregularities at the bond interface, and the magnitude of plastic flow at the contact surface seems to be somewhat less than might be expected. The more uniform surface produced by etching gave an improved degree of contact with more extensive bonds. The plastic flow usually associated with high-quality bonds in the molybdenum-0.5% titanium alloy, however, is less apparent in the D-31 welds. Additional investigation of surface preparation, including the relation thereof to the energy coupling between the weldment and the sonotrodes, is possibly needed before these differences in microstructure can be explained.

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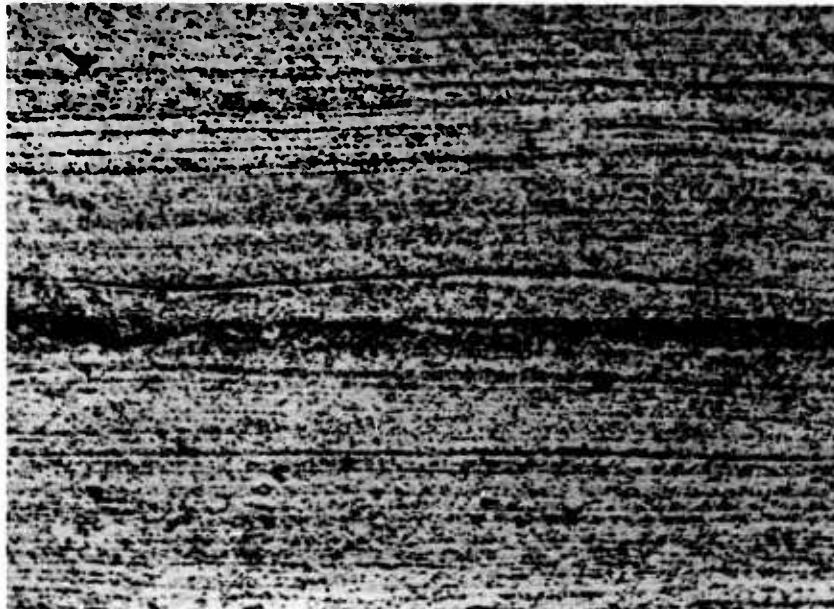


Figure 1: PHOTOMICROGRAPH OF ULTRASONIC WELD IN 0.005-INCH
NIOBIUM-10% MOLYBDENUM-10% TITANIUM (DuPont D-31 Alloy)
Surfaces etched with acid mixture (10 parts HF,
30 parts HNO_3 , and 50 parts lactic acid), before
welding.

Magnification: 500X

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FUTURE WORK

The work planned for the next report period includes:

1. Further investigation of the variability of shear-strength data for molybdenum-0.5% titanium and tungsten.
2. Determination of the clamping force necessary to achieve the best impedance match with the thicker gages of the three materials of interest in this program - the acoustic power transmitted through the coupling system will be measured by means of microphone sensing elements on the coupler elements.
3. Continuation of the work with the D-31 alloy - this work will be dependent on the receipt of additional sheet material.

Very truly yours,

CR Frownfelter

C. R. Frownfelter
Senior Engineer
Staff Assistant

CRF:nj

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