N84-30013

CONTRACT NAS 8-35817

STUDY OF HIGH PERFORMANCE ALLOY ELECTROFORMING

SEVENTH MONTHLY TECHNICAL PROGRESS NARRATIVE

JULY 2, 1984 TO JULY 27, 1984

ELECTROFORMING OPERATIONS DEPARTMENT

BELL AEROSPACE TEXTRON

POST OFFICE BOX ONE

BUFFALO, NEW YORK 14240

BY

G. A. MALONE

AUGUST 6, 1984

PREPARED FOR:

GEORGE C. MARSHALL SPACE FLIGHT CENTER

MARSHALL SPACE FLIGHT CENTER, AL 35812

STUDY OF HIGH PERFORMANCE ALLOY ELECTROFORMING

ABSTRACT

The first series of heat treated nickel-manganese alloys has been tested for mechanical properties at temperatures of 148.9°C (300°F) and 260°C (500°F). All material received the same heat treatment in order to provide a common basis for comparison of results. Test data disclosed that mechanical property performance improved with increasing manganese content in the alloy. Although all manganese-bearing alloy was significantly superior to conventional electroformed nickel, that containing over 3000 ppm manganeses displayed outstanding ultimate and yield strengths while maintaining reasonably satisfactory ductility. Alloy containing over 6000 ppm of manganese was very competitive to Inconel 718 (mill annealed and age hardened) at all temperatures of interest, although ductility was not as great in the electrodeposited counterpart.

I. INTRODUCTION

The purpose of this work is to develop and demonstrate a system for electroforming materials with improved strength and high-temperature properties. The Space Shuttle Main Engine employs a main combustion chamber (MCC) where final combustion of propellant at high temperature and pressure takes place. This critical component must be structurally supported by a nickel-base alloy jacket. Producing this jacket from formed wrought metal segments requires numerous weldments which alter the mechanical properties of the base metal through heat affected zones. This requires thickening the alloy where joints are to be made to meet the structural requirements of the shroud. The use of electroformable alloys with great strength would have the potential for simplifying fabrication procedures for structural jackets and reducing overall weight by removing weldments. Such an electroformable alloy might also afford a possible use in advanced engines where light weight and good strength at high temperatures are necessary.

II. TECHNICAL PROGRESS SUMMARY

A. Task I - Literature Survey (Phase A)

Draft is in review at MSFC. No further action pending results of review.

B. Task II - Alloy Characterization and Optimization (Phase A)

Numerous test specimens of nickel-manganese alloy electroformed under a wide variety of bath compositions and plating parameters have been produced during the past several months. It has been possible to manufacture eight flat test strips from each set of panels. Although many of these strips have been used in evaluating heat treatment conditions on mechanical properties at ambient temperature, sufficient strips were retained for elevated temperature testing. This has made it possible to select a fairly representative group of alloys to evaluate the affects of varied manganese content on mechanical property performance at temperatures bracketing the expected thermal range to be encountered by the Space Shuttle Main Combustion Chamber (MCC) shroud.

All of the sample strips selected were heat treated at 315.6°C (600°F) for a period of 24 hours in vacuum. Each specimen was mounted in the mechanical testing machine and enclosed by a fixture containing quartz heating elements. Thermocouples attached to the specimen supplied a potential which was read on a calibrated potentiometer to determine when the test temperature was reached. The temperature was held at this point for a period of at least ten minutes before actual testing was started. Test data is summarized in Table I.

TABLE I - MECHANICAL PROPERTY TEST DATA

Sample Number	Bath Temp.	Peak Current Density, A/dm^2	Mn in Dep., %	Ultimate Str. MPa	Ultimate Str. ksi	Yield Str. MPa	Yield Str. ksi	Elong., % in 2.5cm.	Elong., % in 5.1cm.
Heat Treated at 315.6°C (24 Hrs) - Tested at 25°C:									
NM-21	49.4°C	8.61 (1.08)	0.018	803	116.5	622	90.2	- - -	12.0
NM-22	49.4°C	17.22 (2.15)	0.103	1161	168.3	845	122.6	15.0	8.5
NM-20	55.6°C	12.92 (3.23)	0.167	Sample damaged in machining					
NM-17	49.4°C	12.92 (3.23)	0.259	1159	168.1	905	131.2	14.0	8.5
NM-18	55.6°C	3.23 (3.23)	0.331	Sample damaged in machining					
NM-16	49.4°C	6.46 (3.23)	0.488	1369	198.5	1178	170.9	Broke out of gage	
NMS-7	48.9°C	3.23 (3.23)	0.542	Not tested					
NMS-6	48.9°C	3.23 (3.23)	0.590	1496	217.0	1190	172.5	14.0*	6.0
NM-15	48.1°C	3.23 (3.23)	0.660	1260	182.8	1079	156.6	10.0	5.0
Heat Treated at 315.6°C (24 Hrs) - Tested at 149°C (300°F):									
NM-21	49.4°C	8.61 (1.08)	0.018	633	91.9	461	66.8	21.0	13.0
NM-22	49.4°C	17.22 (2.15)	0.103	990	143.6	714	103.6	11.0	6.5
NM-20	55.6°C	12.92 (3.23)	0.167	990	143.6	760	110.3	15.0	8.0
NM-17	49.4°C	12.92 (3.23)	0.259	925	134.2	725	105.1	12.0	6.5
NM-18	55.6°C	3.23 (3.23)	0.331	1092	158.4	874	126.7	14.0	9.0
NM-16	49.4°C	6.46 (3.23)	0.488	1156	167.7	935	135.5	9.5	5.0
NMS-7	48.9°C	3.23 (3.23)	0.542	1419	205.9	1183	171.6	6.0	3.5
NMS-6	48.9°C	3.23 (3.23)	0.590	1317	191.0	1043	151.2	Broke out of gage	
NM-15	48.1°C	3.23 (3.23)	0.660	1329	192.8	889	128.9	10.0	6.0
Heat Treated at 315.6°C (24 Hrs) - Tested at 260°C (500°F):									
NM-21	49.4°C	8.61 (1.08)	0.018	579	84.0	395	57.3	20.0	11.0
NM-22	49.4°C	17.22 (2.15)	0.103	819	118.8	573	83.1	21.0	12.0
NM-20	55.6°C	12.92 (3.23)	0.167	838	121.6	553	80.2	18.0	9.5
NM-17	49.4°C	12.92 (3.23)	0.259	853	123.7	604	87.6	16.3	11.5
NM-18	55.6°C	3.23 (3.23)	0.331	974	141.3	682	98.9	19.0	11.0
NM-16	49.4°C	6.46 (3.23)	0.488	1049	152.1	794	115.2	13.0	6.8
NMS-7	48.9°C	3.23 (3.23)	0.542	1149	166.7	816	118.4	8.5	5.5
NMS-6	48.9°C	3.23 (3.23)	0.590	1136	164.8	782	113.4	9.0	5.0
NM-15	48.1°C	3.23 (3.23)	0.660	1136	164.8	815	118.2	14.5	8.9

* Indicates elongation in 0.125 cm.

The data in Table I discloses that nickel-manganese alloys tend to retain great percentages of room temperature strength as the test temperature is increased to 260°C (500°F). Outstanding ultimate and yield strengths are obtained at manganese concentrations exceeding 0.45% by weight in the alloy. At the elevated test temperatures it appears that electroformed Ni-0.50Mn can out perform Ni-55Co although one might argue that ductility of the latter is better. Test results from round bars to be made later might prove otherwise.

It has been noted that stress in nickel-manganese alloys starts to become significant as manganese contents of 0.4% and higher are achieved. This can

readily be countered by addition of a very nominal amount of saccharin to the electrolyte - as was done when Sample Nos. NMS-6 and NMS-7 were produced. This increases sulfur content from the range of 10-20 ppm to 50-100 ppm. Upon heat treatment, the great excess of manganese combines with sulfur to form a totally innocuous manganese sulfide. As can be noted by test data for the "NMS" coded samples, the use of a modest amount of stress reducer decreases ductility. This decrease in elongation is not believed due to sulfur - rather it is due to the finer grain size of the microstructure caused by the stress reducer also acting as a grain refiner. Elongation appears to improve with increasing the electrolyte temperature and using a higher temperature heat treating cycle. Pulsing the power supply current also helps improve ductility. Unfortunately, pulsing and increasing bath temperature lead to decreased manganese contents in the alloy.

Now that we have the desired ultimate and yield strengths for our shroud alloy, most work will center on improving stress and ductility prior to making round test bars. We are currently making flat test panels from a bath with moderate stress reducer added. Some material will also be made using a higher bath temperature. All of these samples will have the higher manganese concentration found to be so greatly significant.

As of this report, the formal pricing of a full scale and half scale MCC simulator was in preparation with an anticipated delivery date of 3 August 1984.

III. CURRENT PROBLEMS

The bath suspected of possible contamination in the report of last month was purified and panels electroformed for ductility testing. No current problems are known to exist.

IV. WORK PLANNED

A. Evaluate techniques for ductility improvement for alloys with the higher manganese content:

1. Evaluate increasing heat treatment temperature to 343°C (650°F) for 24 hours. (This is the temperature at which the electroformed outer close-out of the MCC is stress relieved by Rocketdyne.)

2. Investigate pulsing with slightly higher bath temperature on ductility while maintaining the higher manganese contents of importance in high yield strength.

B. Start testing of previous sample retainers showing best properties for:

1. Rockwell C hardness before and after heat treatment.

2. Microstructure

3. Room temperature creep (after heat treatment).

V. FINANCIAL DATA - See attached NASA Form 533P.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MONTHLY CONTRACTOR FINANCIAL MANAGEMENT PERFORMANCE ANALYSIS REPORT

Form Approved
Budget Bureau No. 104-R0011

2. REPORT FOR PERIOD ENDING AND NUMBER OF OPERATING DAYS: July 27, 1984 (20 Operating Days)

TO: PROCUREMENT OFFICE
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

FROM: NIAGARA FRONTIER OPERATIONS
BELL AEROSPACE TEXTRON
POST OFFICE BOX ONE, BUFFALO, NY 14240

3. CONTRACT VALUE: a. COSTS $ 183,986 b. FEE $ 11,721

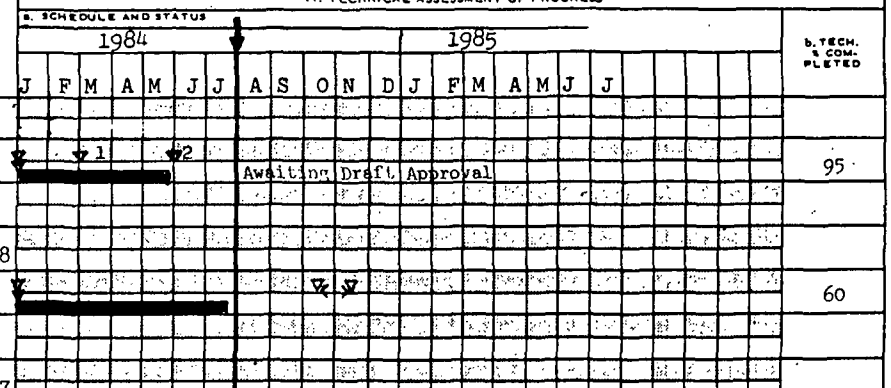
1. DESCRIPTION OF CONTRACT
a. TYPE: Cost-Plus-Fixed-Fee
b. CONTRACT NO. AND LATEST DEFINITIZED AMENDMENT NO.: NAS 8-35817
c. SCOPE OF WORK: Study of High Performance Alloy Electroforming
d. AUTH. CONTR. REP. (Signature): H. A. Malone DATE: August 7, 1984

4. FUND LIMITATION $

5. BILLING: a. INVOICE AMTS BILLED $ b. TOTAL PYTS REC'D $

6. REPORTING CATEGORY	7. PLANNED VALUE OF WORK (CUM. COSTS/HOURS THROUGH CURRENT PERIOD) a. SCHEDULED	b. ACCOMPLISHED	8. ACTUAL COSTS/HOURS	9. VARIANCE a. SCHEDULE (Col 7b - 7a)	b. COSTS/HOURS (Col 7b - 8)	10. CONTRACTOR'S ESTIMATED FINAL COST	b. TECH. % COMPLETED
PHASE A							
Task I - Literature Review							95
Hours	112.5	136.1	136.1	+ 23.6			
Dollars	6,998	6,652	6,652	- 346		6,998	
Task II - Alloy Characterization & Optimizat.							60
Hours	814.0	763.5	763.5	- 51.5			
Dollars	49,897	48,123	48,123	- 1,774		78,707	
PHASE B							
Task I - Heat Treatment of Alloy Struct. Shells							0
Hours	0.0	0.0	0.0	0.0			
Dollars	0	0	0	0		18,934	
Task II - Tooling for EF of Prototype SSME							0
Hours	0.0	0.0	0.0	0.0			
Dollars	0	0	0	0		4,734	
Task III - Prototype MCC Prep. for Electroform'g							0
Hours	0.0	0.0	0.0	0.0			
Dollars	0	0	0	0		37,868	
Task IV - Electroforming Operations/Final Report							0
Hours	0.0	0.0	0.0	0.0			
Dollars	0	0	0	0		33,134	

11. TECHNICAL ASSESSMENT OF PROGRESS — a. SCHEDULE AND STATUS



NASA FORM 533P SEP 71

Baseline Plan Identification (Col. 7a): Revision No. _____, Dated _____.

NASA APPROVED SCHEDULE
CONTRACTOR'S WORKING SCHEDULE

NASA APPROVED SCHEDULE DATE _____

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MONTHLY CONTRACTOR FINANCIAL MANAGEMENT PERFORMANCE ANALYSIS REPORT

Form Approved
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BELL AEROSPACE TEXTRON
POST OFFICE BOX ONE° BUFFALO, NY 14240

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c. SCOPE OF WORK: Study of High Performance Alloy Electroforming
d. AUTH. CONTR. REP. (Signature): H. A. Malone
DATE: August 7, 1984

4. FUND LIMITATION: $

5. BILLING
a. INVOICE AMTS BILLED: $
b. TOTAL PYTS REC'D: $

6. REPORTING CATEGORY	CUM. COSTS/HOURS THROUGH CURRENT PERIOD: 7. PLANNED VALUE OF WORK: SCHEDULED a.	7. PLANNED VALUE OF WORK: ACCOMPLISHED b.	8. ACTUAL COSTS/HOURS	9. VARIANCE: SCHEDULE (Col 7b - 7a) a.	9. VARIANCE: COSTS/HOURS (Col 7b - 8) b.	10. CONTRACTOR'S ESTIMATED FINAL COST	11. TECHNICAL ASSESSMENT OF PROGRESS: a. SCHEDULE AND STATUS	b. TECH. % COMPLETED
SUB-TOTAL								30
Hours	926.5	899.6	899.6	- 26.9		3,204		
Dollars	56,895	54,775	54,775	- 2,120		183,986		
FIXED FEE DOLLARS	3,624	3,489	3,489			11,721		
TOTAL FUNDING REQUIRED								30
Hours	926.5	899.6	899.6			3,204		
Dollars	60,519	58,264	58,264			195,707		

NASA FORM 533P SEP 71

Baseline Plan Identification (Col. 7a): Revision No. _____, Dated _____.

NASA APPROVED SCHEDULE
CONTRACTOR'S WORKING SCHEDULE

NASA APPROVED SCHEDULE DATE _____