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STUDY OF HIGH PERFORMANCE ALLOY ELECTROFORMING

FOURTEENTH MONTHLY TECHNICAL PROGRESS NARRATIVE

JANUARY 28, 1985 TO FEBRUARY 22, 1985

ELECTROFORMING OPERATIONS DEPARTMENT

BELL SPACECRAFT TEXTRON

POST OFFICE BOX ONE

BUFFALO, NEW YORK 14240

BY

G. A. MALONE

MARCH 11, 1985

PREPARED FOR:

GEORGE C. MARSHALL SPACE FLIGHT CENTER

MARSHALL SPACE FLIGHT CENTER, AL 35812
STUDY OF HIGH PERFORMANCE ALLOY ELECTROFORMING

ABSTRACT

More panels electroformed with intentional variations of pulse plating parameters are in work. Pulse plating frequency has been noted to have a significant effect regarding mechanical properties. The use of a high pulse frequency (assuming fixed duty cycles) results in an increase in ductility and a decrease in ultimate and yield strengths. We are currently electroforming to intermediate frequencies to obtain the best possible combination of ductility and strength. Results of some tests from high frequency specimens are tabulated. The subscale mandrel design for Phase B is ready for review. A progress review will be held with MSFC personnel in early April.

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) - Previously completed.

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

In our nickel-manganese alloy optimization studies, we have narrowed the required ranges of manganese content, electrolyte temperature, pH, and current density for producing a heat treatable material competitive with Inconel 718 and far superior to electroformed nickel. Our baseline test results on which the present optimization/heat treatment studies are based were those obtained from Specimens NM-25, NM-26, and NM-27. The results are again summarized in Table I. It is interesting to note that the ultimate strengths and yield strengths increase dramatically as the pulsed peak current density increases (the average current density stays constant). However, elongation decreases inversely to yield strength as would be expected. We have also noted that the pulse current "off" times are fairly long. Equally interesting is the observation that (1) NM-27 had slightly less manganese present than NM-26, (2) NM-27 was electroformed
at the same average current density as NM-26, but NM-27 was also plated at a higher peak current density, and (3) NM-27 exhibited significantly higher ultimate and yield strengths than did NM-26.

In the current, and expected final, study of Phase A we are examining pulse plating parameters that will compromise the mechanical properties of the specimens in Table I to achieve better ductility in combination with the excellent strength features of the alloys. It was observed that all pulse "off" times for the Table I specimens were long - 20 to 30 milliseconds. We have evaluated shortening this "off" to determine if more uniform manganese dispersion is obtained and better ductility encountered. Test results obtained in this reporting period for these new specimens indicate that excellent elongations are being obtained (even with heat treatments of 260°C for 72 hours), but the ultimate and yield strengths are drastically reduced. The pulse "off" times were 2.0 milliseconds. We will be electroforming samples similar to NM-26 and NM-27 with pulse "off" times of about 12.0 milliseconds and various peak current densities from 40 to 80 ASF.

Heat treatments being evaluated on these specimens are "as deposited", 500°F(72 hours), 550°F(72 hours), 600°F(24 hours), 600°F(48 hours), 650°F(24 hours), and 700°F(24 hours). Once we have obtained sufficient comparative data for the effects of these heat treatments on mechanical properties for the new pulse frequencies being used, a full table of test results will be provided.

C. Task I - Heat Treatment of Alloy Structural Shell (Phase B)

Most of this effort has been moved under Phase A, Task II to complete optimization of the alloy resulting from various heat treatments and has been discussed above.

D. Task II - Tooling for EF of Prototype SSME (Phase B)

The subscale MCC mandrel design and drawing is complete and will be reviewed with MSFC personnel during our planned visit to review progress in early April.

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**TABLE I - FABRICATION AND TEST DATA FOR SPECIMENS NM-25, 26, & 27**

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Pulse Plating Information</th>
<th>Deposited Strip</th>
<th>Heat Treatment</th>
<th>Test Temp (ºF)</th>
<th>Ultimate Yield</th>
<th>Mechanical Properties (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NM-25</td>
<td>Duty Cycle 50% Panels</td>
<td>2 Each</td>
<td>None</td>
<td>Ambient</td>
<td>185,000</td>
<td>136,285</td>
</tr>
<tr>
<td></td>
<td>Pulse On 20.0 msec Size 4.38&quot; x 8.12&quot;</td>
<td></td>
<td>600°F(24 Hr)</td>
<td>Ambient</td>
<td>185,000</td>
<td>136,285</td>
</tr>
<tr>
<td></td>
<td>Pulse Off 0.0 msec Comp. 3580 ppm</td>
<td></td>
<td>650°F(24 Hr)</td>
<td>Ambient</td>
<td>185,000</td>
<td>136,285</td>
</tr>
<tr>
<td></td>
<td>Peak C.D. 40.0 ASF Comp. 24.1 ppm</td>
<td></td>
<td>800°F(4 Hr)</td>
<td>Ambient</td>
<td>178,110</td>
<td>128,115</td>
</tr>
<tr>
<td></td>
<td>Avg. C.D. 20.0 ASF Flatness Fair</td>
<td></td>
<td>500°F(24 Hr)</td>
<td>300°F</td>
<td>159,015</td>
<td>135,120</td>
</tr>
<tr>
<td></td>
<td>Ave. Volts 3.9</td>
<td>Thickness .0685 in</td>
<td>to .0690 in</td>
<td>500°F(24 Hr)</td>
<td>135,120</td>
<td>135,120</td>
</tr>
</tbody>
</table>

| NM-25         | Duty Cycle 40% Panels    | 2 Each          | None           | Ambient       | 211,800        | 152,910          | 5.0                         |
|               | Pulse On 20.0 msec Size 4.38" x 8.12" | | 600°F(24 Hr) | Ambient       | 225,765        | 186,825          | 10.0                        |
|               | Pulse Off 30.0 msec Comp. 3580 ppm | | 650°F(24 Hr) | Ambient       | 225,765        | 186,825          | 10.0                        |
|               | Peak C.D. 50.0 ASF Comp. 24.1 ppm | | 800°F(4 Hr) | Ambient       | 215,735        | 159,015          | 10.0                        |
|               | Avg. C.D. 20.0 ASF Flatness Fair | | 500°F(24 Hr) | 300°F        | 190,900        | 135,120          | 6.0                         |
|               | Ave. Volts 3.9            | Thickness .0700 in | to .0704 in | 500°F(24 Hr) | 135,120        | 135,120          | 6.0                         |

| NM-26         | Duty Cycle 25% Panels    | 2 Each          | None           | Ambient       | 241,480        | 177,642          | 9.0                         |
|               | Pulse On 10.0 msec Size 4.38" x 8.12" | | 600°F(24 Hr) | Ambient       | 225,895        | 186,825          | 5.5                         |
|               | Pulse Off 30.0 msec Comp. 3580 ppm | | 650°F(24 Hr) | Ambient       | 225,895        | 186,825          | 5.5                         |
|               | Peak C.D. 60.0 ASF Comp. 24.1 ppm | | 800°F(4 Hr) | Ambient       | 225,895        | 186,825          | 5.5                         |
|               | Avg. C.D. 20.0 ASF Flatness Fair | | 500°F(24 Hr) | 300°F        | 235,820        | 186,825          | 5.5                         |
|               | Ave. Volts 3.6            | Thickness .0680 in | to .0690 in | 500°F(24 Hr) | 186,825        | 186,825          | 5.5                         |

| NM-27         | Duty Cycle 25% Panels    | 2 Each          | None           | Ambient       | 241,480        | 177,642          | 9.0                         |
|               | Pulse On 10.0 msec Size 4.38" x 8.12" | | 600°F(24 Hr) | Ambient       | 225,895        | 186,825          | 5.5                         |
|               | Pulse Off 30.0 msec Comp. 3580 ppm | | 650°F(24 Hr) | Ambient       | 225,895        | 186,825          | 5.5                         |
|               | Peak C.D. 60.0 ASF Comp. 24.1 ppm | | 800°F(4 Hr) | Ambient       | 225,895        | 186,825          | 5.5                         |
|               | Avg. C.D. 20.0 ASF Flatness Fair | | 500°F(24 Hr) | 300°F        | 235,820        | 186,825          | 5.5                         |
|               | Ave. Volts 3.6            | Thickness .0680 in | to .0690 in | 500°F(24 Hr) | 186,825        | 186,825          | 5.5                         |

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C. Task I - Heat Treatment of Alloy Structural Shell (Phase B)

Most of this effort has been moved under Phase A, Task II to complete optimization of the alloy resulting from various heat treatments and has been discussed above.

D. Task II - Tooling for EF of Prototype SSME (Phase B)

The subscale MCC mandrel design and drawing is complete and will be reviewed with MSFC personnel during our planned visit to review progress in early April.
III. CURRENT PROBLEMS

The primary problem at this time is the rate of electroforming of the variety of specimens required to final optimize pulse parameters and heat treatments. To alleviate this problem we are setting up a second nickel-manganese electroforming facility operated at the same chemistry and deposition parameters as the first tank. This will allow metallurgical personnel to prepare specimens in large single groups rather than many small batches.

IV. WORK PLANNED

1. Complete second small scale nickel-manganese electroforming facility. Check product for precision of duplicating results from original electrolyte in first facility.

2. Complete intermediate pulse frequency samples at selected peak current densities and average current densities.

3. Perform "as deposited" and 260°C (72 hour) heat treatment tests for mechanical properties at room temperature.

4. Visit MSFC for review of progress to date.

V. FINANCIAL DATA

See attached NASA Form 533P. Note that the most recent schedule change and funding addition (subscale mandrel fabrication) are included. Although approval to start Phase B has not been requested, charges against Phase B funding have been made to (1) complete alloy optimization studies and (2) to design and purchase material for the subscale mandrel. Both efforts have been discussed with the MSFC-COR and concurrence obtained verbally.
## MONTHLY CONTRACTOR FINANCIAL MANAGEMENT PERFORMANCE ANALYSIS REPORT

**To:** PROCUREMENT OFFICE  
**From:** GEORGE C. MARSHALL SPACE FLIGHT CENTER

**Contract Information:**  
- **Type:** Cost-Plus-Fixed-Fee  
- **Project:** Study of High Performance Alloy Electroforming  
- **Contractor:** NASA 8-35817

### Phase A

#### Task I - Literature Review
- **Hours:** 112.5  
- **Dollars:** 6,593

#### Task II - Alloy Characterization & Optimization
- **Hours:** 1,314.7  
- **Dollars:** 79,053

### Phase B

#### Task I - Heat Treatment of Alloy Struct. Shells
- **Hours:** 60.0  
- **Dollars:** 3,608

#### Task II - Tooling for EF of Prototype SSME
- **Hours:** 48.0  
- **Dollars:** 2,925

#### Task III - Prototype MCC Prep. for Electroforming
- **Hours:** 0.3  
- **Dollars:** 0

#### Task IV - Electroforming Operations/Final Report
- **Hours:** 0.7  
- **Dollars:** 37,866

### Technical Assessment of Progress

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### Baseline Plan Identification

- **Col. 7a:** Revision No.  
- **Date:** Dated

---

**Notes:**  
- Costs/Hour:  
- Cumulative Costs:  
- Variances:  
- Schedules and Status:  
- Technical Assessment of Progress:  
- Baseline Plan Identification (Col. 7a): Revision No.  
- Dated
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**Total Funding Required**

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