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STUDY OF HIGH PERFORMANCE ALLOY ELECTROFORMING

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# STUDY OF HIGH PERFORMANCE ALLOY ELECTROFORMING

## ABSTRACT

Nickel-manganese electroformed specimens and nickel-cobalt-manganese samples were heat treated at 343°C (650°F) for comparison of room temperature ductility with that observed for alloys heat treated at 315.6°C (600°F). All heat treatments were for 24 hours. This heat treatment temperature increase generally did not result in significant improvements in ductility. However, increases in yield strength - with slight decreases in tensile strengths - were noted for the nickel-manganese and nickel-cobalt-manganese alloys. For the case of employing fairly high manganese contents in the electrolyte and countering ensuing high tensile stress in the alloy by saccharin additions to the bath, it was noted that nickel-manganese alloys with over 0.4% by weight manganese retained high ultimate and yield strengths after the 343°C (650°F) heat treatment for 24 hours. Elongations were still lower than desired. For alloys with less than 0.4% by weight manganese this heat treatment provided excellent ductility, but very significant reductions in ultimate and yield strengths were noted. A last series of specimens are in test to (1) examine the effects of heat treatments at 371°C (700°F) for 24 hours, (2) expand the test data for mechanical properties of nickel-manganese alloys at 149°C (300°F) and 260°C (500°F), and (3) provide comparison mechanical property data for nickel-cobalt-manganese at these same intermediate temperatures simulating service requirements on the Space Shuttle MCC.

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

The ten sets of nickel-manganese alloy panels reported as produced last month in the progress narrative have been tested for mechanical properties as deposited and after various moderate heat treatments. Table I reports these results. It should be noted that those specimens coded "NM" refer to

deposits from a bath without saccharin as a stress reducing additive. The samples coded "NMS" refer to deposits from a bath containing saccharin to reduce stress. In the report of last month, we considered that certain samples containing sulfur as a codeposit from the saccharin exhibited better yield strengths up to a test temperature of 260°C (500°F) than normal "low" sulfur deposits with higher manganese contents. Based on data in Table I of this report, we can not confirm the beneficial effect of the sulfur. It would appear that promising mechanical properties are obtained when the sulfur induced by saccharin is below 100 parts per million by weight. The mechanics behind this performance are not understood at this time. The high "as deposited" properties are likely due to grain refinement characteristic of deposits from a stress reduced bath.

It will be noted that the data in Table I is presented in order of increasing manganese content in the deposits. Certain columns have been included with no data. This will be updated during the next reporting period. The data for the various heat treatments (not already performed) will be of significant value prior to starting Task I of Phase B, Heat Treatment of Alloy Structural Shells. This will complete all Phase A investigations leading to the selection of one set of electroforming and heat treating parameters for producing the sets of round test bars for official evaluation by MSFC and ourselves.

Similar panels of nickel-cobalt-manganese alloy were tested for mechanical properties after various heat treatments as shown in Table II. These specimens are listed in order of increasing manganese content. For this group of alloys the cobalt content was in the range of  $54 \pm 4$  percent. It will be noted that there is a gradual increase in ultimate and yield strengths with increasing manganese content. The ductility improvement with moderate heat treatments is excellent. The mechanical property test results at 149°C (300°F) and 260°C (500°F) should be available shortly. The internal stress problem associated with this alloy may not be an insurmountable problem for shroud applications due to the mass strength of the nickel electroform making up the outer shell of the main combustion chamber itself. We still plan to produce stock of sufficient thickness to machine round test bars from the nickel-cobalt-manganese alloy - if the intermediate test temperature mechanical properties look good.

### III. CURRENT PROBLEMS

Although the backlog of mechanical property testing was completed in September, as planned, the additional testing at new heat treatment conditions and with moderate test temperatures is progressing slowly due to an unexpected workload in our metallurgical group. We expect to finish all flat strip testing by the second week of November, at the latest. This will be necessary if round bars are to be made and delivered by January 1985.

### IV. WORK PLANNED

1. Confirm performance of latest sets of specimens showing useful properties by testing at 149°C (300°F) and 260°C (500°F).

2. Tabulate test data for those nickel-manganese and nickel-cobalt-manganese alloy samples (and deposition parameters) showing best combination of mechanical strength and ductility. Advise MSFC personnel of results for final selections and recommend most optimum parameters for duplication as round test bars.

V. FINANCIAL DATA

See attached NASA Form 533P. Note that nominal expenditures were incurred during the month of September. This was due to the fact that a great part of the work effort involved evaluation of nickel-cobalt-manganese alloys which are technically not a part of this contract. Since we are considering such alloys as a back-up material for the nickel-manganese alloy, most of the testing costs were separately funded. We make this point as fulfilling a previous promise that data on the nickel-cobalt-manganese alloys would be freely available to MSFC.

TABLE I - MECHANICAL PROPERTY/HARDNESS DATA FOR ELECTROFORMED  
NICKEL-MANGANESE ALLOYS

Sample Number	Alloy Composition Manganese Sulfur (% by Wt.) (PPM)	Property Tested	Mechanical Property/Hardness Test Results at Ambient Temperature							
			As Deposited	Heat Treated 400°F (72 Hr)	Heat Treated 500°F (72 Hr)	Heat Treated 600°F (24 Hr)	Heat Treated 650°F (24 Hr)	Heat Treated 700°F (24 Hr)	Heat Treated 800°F (4 Hr)	Heat Treated
NM-23	0.101	Ultimate (ksi)	154.8		150.3	134.7				117.3
		Yield (ksi)	108.7		118.0	113.5				93.2
		Elong. (% in 1")	9.0		10.0	11.0				20.0
		Hardness (R <sub>C</sub> )								
NMS-31	0.174	Ultimate (ksi)	218.2		96.6	81.8				78.3
		Yield (ksi)	121.5		77.6	63.5				63.9
		Elong. (% in 1")	13.0		BOG*	42.0				41.0
		Hardness (R <sub>C</sub> )								
NM-24	0.198	Ultimate (ksi)	167.2		172.2	168.0				157.1
		Yield (ksi)	120.0		138.4	145.1				127.5
		Elong. (% in 1")	8.0		11.0	9.0				10.0
		Hardness (R <sub>C</sub> )								
NMS-33	0.323	Ultimate (ksi)	232.4		142.9	97.5				93.0
		Yield (ksi)	152.8		104.3	80.0				76.5
		Elong. (% in 1")	6.0		2.5	23.0				31.0
		Hardness (R <sub>C</sub> )								
NM-25	0.358	Ultimate (ksi)	182.0		186.8	185.7				178.1
		Yield (ksi)	136.3		156.2	159.0				158.9
		Elong. (% in 1")	10.0		10.0	11.0				10.0
		Hardness (R <sub>C</sub> )								
NM-28	0.387	Ultimate (ksi)	174.0		179.7	186.0				169.7
		Yield (ksi)	120.3		162.3	162.6				146.7
		Elong. (% in 1")	9.0		10.0	10.0				14.0
		Hardness (R <sub>C</sub> )								
NMS-32	0.478	Ultimate (ksi)	235.9		135.1	156.2				152.7
		Yield (ksi)	149.5		No Data	125.7				105.9
		Elong. (% in 1")	2.5		1.0	6.0				9.0
		Hardness (R <sub>C</sub> )								
NM-27	0.495	Ultimate (ksi)	241.5		292.7	281.9				266.3
		Yield (ksi)	177.6		242.0	257.5				217.0
		Elong. (% in 1")	BOG*		4.5	6.0				6.0
		Hardness (R <sub>C</sub> )								
NM-26	0.512	Ultimate (ksi)	211.7		226.0	225.7				214.7
		Yield (ksi)	152.3		198.5	202.1				197.8
		Elong. (% in 1")	5.0		8.0	7.5				7.0
		Hardness (R <sub>C</sub> )								
NMS-30	0.677	Ultimate (ksi)	238.4		213.7	204.9				234.4
		Yield (ksi)	No Data		No Data	No Data				216.7
		Elong. (% in 1")	BOG*		1.0	1.0				4.0
		Hardness (R <sub>C</sub> )								

\* BOG refers to "broke out of gauge".

TABLE II - MECHANICAL PROPERTY/HARDNESS DATA FOR ELECTROFORMED  
NICKEL-COBALT-MANGANESE ALLOYS

Sample Number	Alloy Composition		Property Tested	Mechanical Property/Hardness Test Results at Ambient Temperature							
	Cobalt (Wt.%)	Mangan. (Wt.%)		Sulfur (PPM)	AS Deposited	Heat Treated 400°F(72 Hr)	Heat Treated 500°F(72 Hr)	Heat Treated 600°F(24 Hr)	Heat Treated 650°F(24 Hr)	Heat Treated 700°F(24 Hr)	Heat Treated 800°F(4 Hr)
NCM-42	57.6	0.012	44	Ultimate (ksi)	180.0			169.1	158.7		132.4
				Yield (ksi)	104.4			120.9	132.7		112.6
				Elong. (% in 1")	10.0			18.0	24.0		22.0
				Hardness (R <sub>C</sub> )							
NCM-43	53.0	0.025	30	Ultimate (ksi)	207.0			186.9	166.8		139.6
				Yield (ksi)	126.4			134.7	138.4		125.9
				Elong. (% in 1")	7.0			15.0	16.0		14.0
				Hardness (R <sub>C</sub> )							
NCM-47	54.8	0.037	10	Ultimate (ksi)	206.1			190.5	175.7		157.8
				Yield (ksi)	127.3			147.5	142.4		135.4
				Elong. (% in 1")	8.0			14.0	13.0		19.0
				Hardness (R <sub>C</sub> )							
NCM-44	51.2	0.041	32	Ultimate (ksi)	207.5			194.0	187.6		156.8
				Yield (ksi)	144.2			146.6	152.5		135.6
				Elong. (% in 1")	4.0			14.0	17.0		18.0
				Hardness (R <sub>C</sub> )							
NCM-45	54.6	0.055	15	Ultimate (ksi)	209.4			194.2	174.1		168.4
				Yield (ksi)	127.5			148.9	151.1		131.2
				Elong. (% in 1")	6.0			13.0	11.0		13.0
				Hardness (R <sub>C</sub> )							
NCM-46	53.1	0.081	25	Ultimate (ksi)	215.9			197.1	179.2		178.7
				Yield (ksi)	139.6			149.6	154.8		135.2
				Elong. (% in 1")	3.5			13.0	13.0		14.0
				Hardness (R <sub>C</sub> )							
NCM-50	52.8	0.087	22	Ultimate (ksi)	214.6			193.6	175.8		169.7
				Yield (ksi)	139.5			144.7	140.6		134.0
				Elong. (% in 1")	8.0			14.0	15.0		14.0
				Hardness (R <sub>C</sub> )							
NCM-48	50.6	0.089	14	Ultimate (ksi)	205.0			199.4	188.9		177.3
				Yield (ksi)	137.5			137.3	151.4		139.2
				Elong. (% in 1")	2.0			13.0	15.0		13.0
				Hardness (R <sub>C</sub> )							
NCM-49	52.8	0.117	14	Ultimate (ksi)	217.8			201.1	183.9		176.4
				Yield (ksi)	148.5			157.3	140.2		141.0
				Elong. (% in 1")	3.0			15.0	13.0		15.0
				Hardness (R <sub>C</sub> )							



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