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DEVELOPMENT OF LOW COST FILLER MATERIALS FOR WELDING  
HIGH STRENGTH STEELS(U) OHIO STATE UNIV COLUMBUS DEPT  
OF WELDING ENGINEERING D G HOWDEN 82 SEP 82

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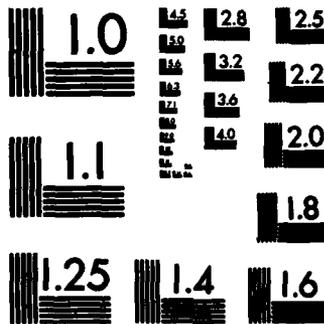
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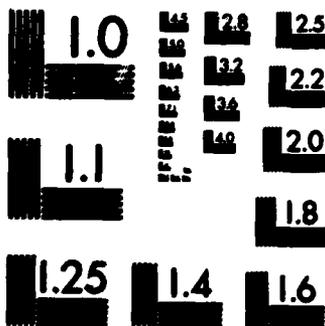
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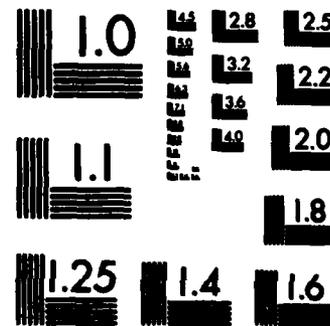
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ANNUAL

# REPORT

By

THE OHIO STATE UNIVERSITY  
RESEARCH FOUNDATION

1314 KINNEAR RD.  
COLUMBUS, OHIO 43212

To OFFICE OF NAVAL RESEARCH  
Department of the Navy  
800 N. Quincy Street  
Arlington, Virginia 22217  
Contract No. N00014-81-K-0788

On DEVELOPMENT OF LOW COST FILLER MATERIALS FOR WELDING  
HIGH STRENGTH STEELS ~~AND TITANIUM ALLOYS~~

For the period September 1, 1981 - August 31, 1982

Submitted by David G. Howden  
Department of Welding Engineering

Date September 2, 1982

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Contract # N00014-81-K-0788

OSURF Project # 714158

Annual Letter Report August 31, 1982

Gentlemen:

Technical efforts in the first year of the program have involved the synthesis of weld metal using a two wire approach in GMAW and SMAW systems. Target compositions were those suitable for the HY-130 weldment system.

In the GMAW system, equipment was built to feed a second wire into the leading edge of the pool. Commercial welding wires were selected and used to produce the required composition with good homogeneity in the weld metal. In the SMAW system two approaches were investigated to produce weld metal of target composition by alloying two wires rather than by relying on alloying elements contained in the coating of the rod (as per commercial practice). Electrodes made from a tube with an alloy wire inside and others made from a solid rod with a ribbon of alloy material tacked to the outside both showed excellent welding characteristics with homogenous weld metal compositions.

The program is on schedule and within budget.

#### Gas Metal Arc Welding

Equipment. Using standard commercial wire feeders and welding torch, equipment was assembled to feed a second wire into the leading edge of a weld pool produced with a regular GMAW system. Each wire feed system operated independently and was calibrated so that the "mix" of wires could be controlled and varied continuously. The main wire, fed through the GMAW torch, controlled the arc current and the second wire speed was

①

adjusted to obtain the required composition.

Welding wires. Preliminary work has been carried out using two commercially available wires, Linde 44B of 0.063 inch diameter and Hastelloy X of 0.035 diameter. Table 1 gives the nominal chemical compositions of these wires, the composition ranges for MIL-130S weld metal and the predicted composition using a mixture of 4 percent Hastelloy X and 96 percent Linde 44-B.

In evaluating this system a porosity problem was encountered. The Linde 44-B wire is designed for submerged arc welding and as such has a low silicon content. The Hastelloy X also has low silicon. When used in the GMAW system with argon-2 percent oxygen shielding gas, there is not sufficient deoxidation of the weld metal to avoid carbon monoxide porosity. A replacement wire for the L-44B is being sought. The probable choice for the next phase of the work will be an E-80S-D2 wire which has a higher silicon content than L-44B.

This combination - E-80S-D2 and Hastelloy X will produce a composition similar to that of the previous solid wire produced by Airco (AX-140) and which achieved satisfactory weld mechanical properties. The nominal composition ranges for Si, C, P and S are in the E-80S-D2 specification are not quite in the MIL-140S range but it is hoped selection of heats will alleviate this problem.

Once optimized, this system will be used in Phase II to produce weldments for mechanical testing.

### Shielded Metal Arc Welding

Two approaches were taken to allow introduction of alloying elements into the weld pool directly in the metallic form rather than from ferro alloys mixed in the coating.

### Tubular electrode cores (5/32 inch diameter).

A low carbon-manganese tubing conforming to the chemical composition given in Table II was purchased. The inside diameter of the tube was slightly larger than the diameter of the Hastelloy X wire which was then inserted in the tube. Both swaging and drawing processes were used successfully to shrink the tube onto the Hastelloy wire. The "tubing" was then cut to 14 inch lengths and coated by Airco Welding Products using a standard E-7018-moisture resistant coating.

The electrodes had excellent operating characteristics with respect to arc stability, slag removal and bead appearance. Based on metallographic and microprobe analyses the deposited weld metal was homogeneous, and when compared to MIL-14018 electrodes, showed a more uniform microstructure.



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**Table I: Chemical Compositions of Filler Wires for GMAW**

Element	MIL-130s	Airco AX-140	Linde 44-B	Hastelloy X	96% Linde 44B 4% Hastelloy X
Carbon	0.12	0.10	0.12	0.07	0.12
Manganese	1.5-2.0	1.75	2.10	0.60	2.04
Phosphorus	0.01	0.004	0.009	0.014	0.01
Sulfur	0.01	0.008	0.008	0.002	0.008
Silicon	0.3-0.5	0.33	0.09	0.37	0.1
Copper	0.15	0.1	0.2		0.02
Nickel	1.95-3.1	2.2	0.63	46.7	2.47
Chromium	0.65-1.05	1.04	0.07	22.0	0.93
Molybdenum	0.4-1.0	0.62	0.43	8.9	0.77
Vanadium	0.04	0.02	--		0.001
Titanium	0.04	0.008	--		--
Zirconium	0.04	--	--		--
Aluminum	0.04	0.01	0.028		--
Cobalt				1.92	

**Table II: CHEMICAL ANALYSIS OF BASIC MATERIALS**

Element	Core wire(1)	Tube	Hastelloy X	7018 MR (2) Deposit Core Only	7018 MR (3) Deposit Airco #1
C	0.037	0.073	0.07	0.036	0.041
Mn	0.53	0.41	0.60	0.87	0.93
Si	0.012	0.21	0.37	0.28	0.30
P	0.009	0.027	0.014	0.011	0.009
S	0.023	0.042	0.002	0.018	0.015
Ni	0.016	0.12	46.7	0.029	0.016
Cr	0.010	0.15	21.98	0.024	0.036
Mo	0.007	0.024	8.87	0.007	0.015
Co	0.003	0.012	1.93	0.003	0.002
W	0	0	0.53	0	0
V	0.001	0.006	0	0.003	0.004
Al	0.004	0.034	0	0.002	0.002
Ti	0	0.036	0	0.004	0.005
Nb	0.006	0.004	0	0.004	0.005
Cu	0.017	0.28	0	0.028	0.022

- (1) Core wire from commercial electrodes with coating removed.  
(2) Core wire from (1) recoated with Airco E-7018 MR coating.  
(3) Standard Airco E-7018 commercial electrode.

Predicted weld metal compositions, based on relative cross sectional areas, actual deposit composition and the calculated transfer efficiencies of major elements are shown in Table III. Note should be taken that the coating did contain iron powder ferromanganese and ferrosilicon to maintain the operating characteristics of the electrode.

Ribbon electrodes (5/32 inch diameter)

The second approach tried was that of using a standard solid core wire (composition Table II) with a ribbon of Hastelloy X, tacked along the length by resistance welding. The Hastelloy wire was rolled into a ribbon for this purpose. Again these "cores" were coated with a standard E-7018 coating with little trouble.

In a manner similar to that of the "tubular" electrodes, the welding characteristics, arc stability, slag removal, bead appearance and deposit homogeneity were excellent. On a preliminary basis all the above properties appeared superior to the standard MIL-14018 electrode systems.

The predicted weld metal compositions, actual deposit composition and calculated element transfer efficiency are shown in Table IV.

For both type of electrodes the chemical composition was not the same as the deposited composition of MIL 14018 electrodes because of the limited range of commercial material composition available. During the next phase of the development it will be necessary to order a special Ni-Cr-Mo wire with the correct composition to produce a weld metal chemistry equal to that of the proven composition of MIL-14018 electrodes. The transfer efficiencies produced so far will be helpful in determining the composition of the special alloy.

A change to 0.125 inch diameter electrodes will also be made so that the results are more pertinent to the U.S. Navy. Since both types of electrodes performed equally well, it was decided to pursue the ribbon approach, based mainly on predicted cost. Solid wire is appreciably more available, and costs less per pound than tubular products. Further, attachment of the ribbon is estimated to cost less than a drawing or swaging operation needed in the case of tubular electrodes.

**Table III: COMPOSITION DATA ON TUBULAR ELECTRODES**

<b>Element</b>	<b>Predicted Composition based on area and iron powder in coating</b>	<b>Actual Deposit Composition</b>	<b>Transfer Efficiency</b>
C	0.073	0.041	56
Mn	0.418	1.08	--
Si	0.216	0.58	--
P	0.026	0.024	92
S	0.040	0.027	68
Ni	2.006	1.91	95
Cr	1.034	0.93	90
Mo	0.382	0.37	97
Al	0.033	0.004	12
Ti	0	0.011	--
Cu	0.269	0.22	82

**Table IV: COMPOSITION DATA ON RIBBON ELECTRODES**

<b>Element</b>	<b>Predicted Composition based on area and iron powder in coating</b>	<b>Actual Deposit Composition</b>	<b>Transfer Efficiency</b>
C	0.038	0.038	100
Mn	0.532	0.86	--
Si	0.024	0.28	--
P	0.009	0.013	(142)
S	0.022	0.019	85
Ni	1.575	1.50	95
Cr	0.744	0.66	89
Mo	0.303	0.29	96
Al	0.004	0.002	50
Ti	0	0.004	--
Cu	0.016	0.039	(237)

Once developed, these electrodes will be used to prepare weldments for mechanical testing in Phase II.

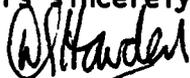
#### Submerged Arc Welding

Activities in this area are being initiated at this time. Now that the wire feeding technique has been developed for the GMAW system, the same equipment will be used for SAW. However, it is believed that the wire combination of Linde 44B and Hastelloy X will be used as the silicon problem encountered with GMAW is not likely to arise. A main wire of 0.063 inch diameter will be used.

This wire combination can be manipulated to produce a calculated composition of weld metal similar to that of the Airco AX-140 composition. Once optimized, this system will be used to produce weldments for mechanical testing in Phase II.

I very much appreciate your interest in and support of this program which I believe is producing interesting results. If you have any questions or comments, please do not hesitate to contact me at (614) 422-1735.

Yours sincerely,



Prof. David G. Howden  
Principal Investigator

DGH/pd

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