The Development of a SMAW Procedure for Cast Iron

Implant test results lead to recommendation of E-NiCrFe-2 electrode and 700°F preheat and postheat

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Introduction

This project entailed the development of a procedure for SMAW under field conditions of cast iron. The quantitative results provided an insight to SMAW procedures for cast iron. Variables of electrodes, preheats, and postheats were observed. The procedure was evaluated by the use of a test which was a modification of the implant test (Granjon, 1979) whereby threaded cast iron was welded to carbon steel plate. Each implant was tested by placing a nut on the threaded cast iron and using a torque wrench to determine the energy required to break the implant from the weld.

The problem was to determine what procedure would produce welds in cast iron with the highest strength when welded with the SMAW process under field conditions. This procedure was developed in a welding laboratory, but used only equipment applicable to field welding conditions. No furnaces were to be used with this process. Field conditions were to be a welding truck equipped with an engine-driven welding unit and oxyacetylene equipment.

Objectives of the Project

This study, dealing with the development of an optimum SMAW procedure, had the following objectives:

1. Determine a standard for cast iron when tested in this manner.
2. Determine suitable filler metals.
3. Determine suitable preheats and postheats.

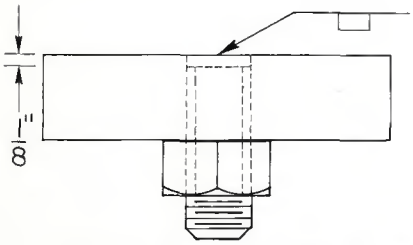

Fig. 1—Implant test as modified by the authors

An implant test was used as a means to gather information indicative of an acceptable welding procedure for cast iron by the SMAW process under field conditions. This test was originally developed by Granjon of France, and later modified by Sawhill and others of the USA (Savage, 1976). A further modification was made by the authors whereby torque, rather than direct tension was used for pulling the implant from the specimens. For this study a threaded piece of cast iron was welded to a low carbon steel base metal—Fig. 1.

Variables consisting of filler metals, preheats, and postheats were studied. The electrodes used in this study were E-NiCrFe-2 and E-Ni-1. The chemistry for these electrodes is stated in AWS A5.14 and is given in Table 1. The preheats used in this investigation were 500°F (260°C), 600°F (315°C), and 700°F (371°C). The postweld heat treatments (PWHT) used were also 500°F (260°C), 600°F (315°C), and 700°F (371°C).

All welding was done with an arc voltage of 18-20 volts (V) and 90-100 amperes (A) direct current reverse polarity using 1/8 in. (3.2 mm) diameter electrodes. After welding the samples were air-cooled and tested as welded or PWHT and tested. The evaluation test was accomplished by placing a nut on the threaded cast iron and using a torque wrench on the nut to determine the amount of energy required to remove each implant from its weld—Fig. 2.

Equipment and Materials

Equipment and materials used included:

1. Implants of 0.750 in. (19 mm) diameter cast iron threaded National Coarse.
2. Low carbon steel plates.
3. E-NiCrFe-2 and E-Ni-1 electrodes.
4. A heat source capable of preheating and PWHT of assemblies as required in the range of 500°F (260°C) to 700°F (371°C).
5. Nuts of 0.750 in. (19 mm) National Coarse.
6. A torque wrench.
7. A welding power supply with amp and volt meters.
8. Temperature indicating crayons to measure preheats and postheats.

Evaluation

Each weld was evaluated using the foot-pounds (Joules) of energy that each individual implant absorbed before cracking free of the plate. Comparisons were made between the welds to determine the most suitable filler metal, preheat and postheat for a field weld of cast iron.

No attempt was made to analyze the type of failure or preliminary microcracking. The evaluation was the complete energy level required to remove the implant of cast iron from the weld. The strength of the cast iron was determined by machining a special implant specimen (Fig. 3) with a flange on one end similar to a bolt head. This specimen was tested and found to require 170 ft-lb (230.5 Joules) of energy to break—Fig. 4.

Table 1—Chemical Compositions of Electrodes Used in Study, %

	E-NiCrFe-2	E-Ni-1
C	0.1	0.1
Mn	1.0-3.5	0.75
Fe	12	0.75
P	0.03	0.03
S	0.02	0.02
Si	0.75	1.25
Cu	0.5	0.25
Ni	62 min.	92 min.
Cr	13-17	–
Cb	0.5-3.0	–
Mo	0.5-3.0	–
Al	–	1.0

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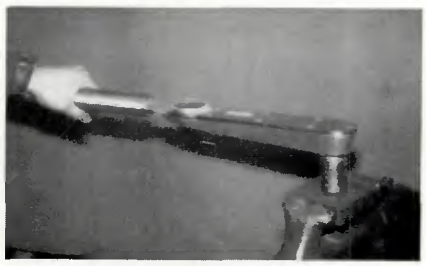

Fig. 2—Determining the energy required to remove implant from its weld

Fig. 3—Implant test specimen

Fig. 4—Fractured implant test specimen

Table 2—Implant Test Results

Temperature of Specimen when welded	E-NiCrFe-2	E-Ni-1
75°F (24°C)	30 ft-lb (40.68 joules)	48 ft-lb (65 joules)
Preheat only to 500°F (260°C)	38 ft-lb (51.5 joules)	57 ft-lb (77.3 joules)
Preheat and PWHT to 500°F (260°C)	102 ft-lb (138.3 joules)	63 ft-lb (85.4 joules)
Preheat only to 600°F (315°C)	83 ft-lb (112.5 joules)	60 ft-lb (81.4 joules)
Preheat and PWHT to 600°F (315°C)	122 ft-lb (165.4 joules)	98 ft-lb (132.9 joules)
Preheat only to 700°F (371°C)	92 ft-lb (124.7 joules)	57 ft-lb (77.3 joules)
Preheat and PWHT to 700°F (371°C)	138 ft-lb (187 joules)	92 ft-lb (124.7 joules)
Strength of unwelded implant was 170 ft-lb (230.5 joules)		

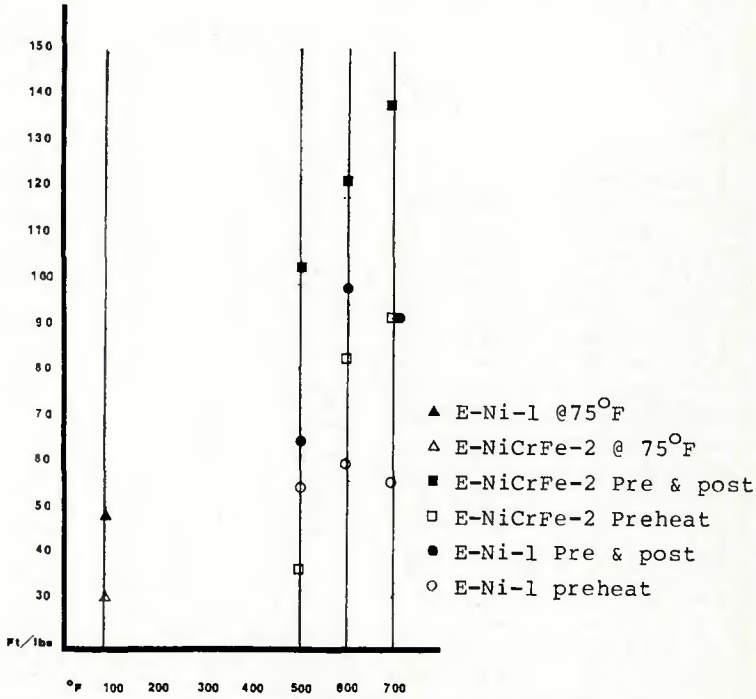

Fig. 5—The effects of various preheats and PWHT's on two electrodes

Results

The variables and results are presented in tabular form for simplicity, and all numbers are stated in foot-pounds and Joules. The strengths of all the various welds are presented in Table 2. The data are also presented graphically in Fig. 5 where the superiority of E-NiCrFe-2 with a 700°F (371°C) pre- and postheat may be seen.

The effect of pre and postheat on E-NiCrFe-2 is more easily seen in Fig. 6. The effect is an increase from 30 ft-lb (40.68 Joules) to 138 ft-lb (187 Joules). This is an increase of 460% from welding at 75°F (24°C). A weld made with E-NiCrFe-2 and using a 700°F (371°C) pre and postheat develops 81.17% of the base metal. The correlation coefficient for these tests was 0.99973, indicating strong correlation.

The use of preheat only produced the results illustrated in Fig. 7. This shows that

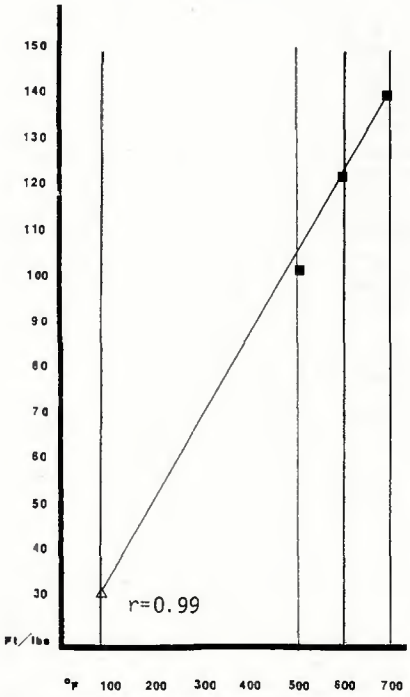

Fig. 6—Effect of increasing preheat and PWHT on E-NiCrFe-2

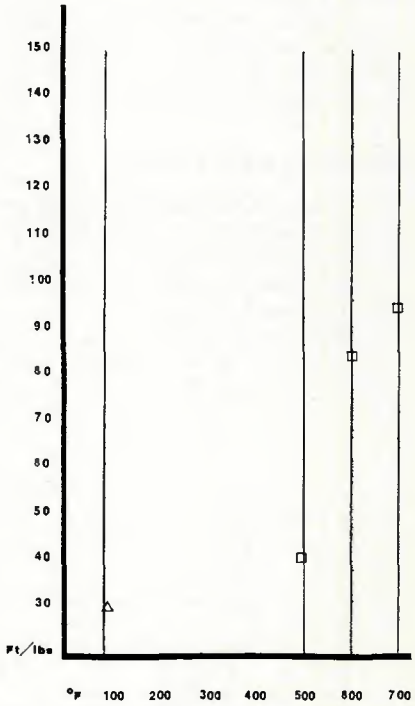

Fig. 7—Effect of increasing preheat on E-NiCrFe-2

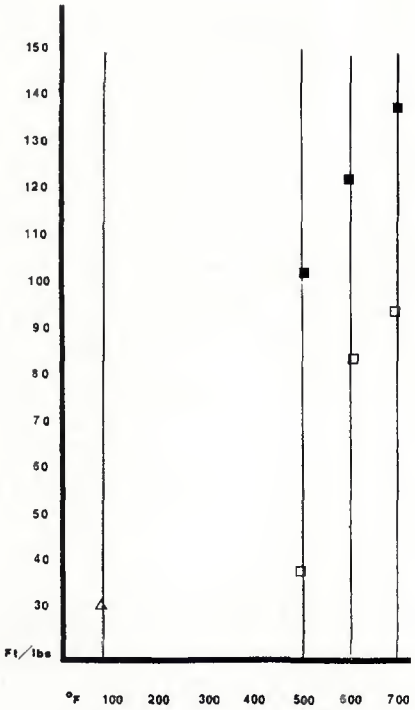

Fig. 8 — Effect of preheat vs. preheat and PWHT on E-NiCrFe-2

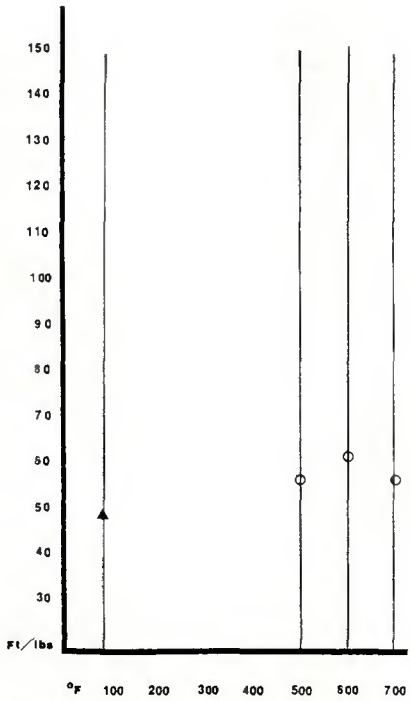

Fig. 9 — Effect of increasing preheat on E-Ni-1

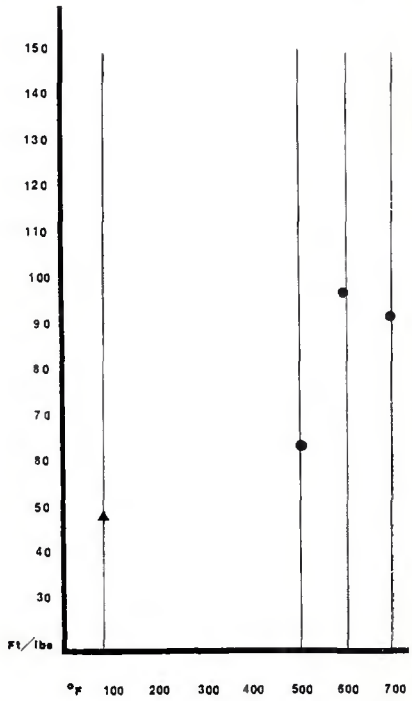

Fig. 10 — Effect of increasing preheat and PWHT on E-Ni-1

there was little advantage to a 500°F (260°C) preheat alone, but 700°F (371°C) preheat did produce a strength of 92 ft-lb (124.7 Joules).

The results of using preheat and postheat with E-NiCrFe-2 are presented in Fig. 8. The 500°F (260°C) postheat caused a charge from 38 ft-lb (51.5 Joules) to 102 ft-lb (138.3 Joules). This is a charge of approximately 268%, but only 60% of the base metal strength.

The effect of preheat only on E-Ni-1 is shown in Fig. 9. Note that the strength of a weld with this filler metal is less at 700°F (371°C) than when welded with a 600°F (315°C) preheat.

The effect of preheat and postheat on E-Ni-1 is shown in Fig. 10. The weld made with 700°F (371°C) pre and postheat has a lower strength than that made with 600°F (315°C) pre and postheat. This is similar to the situation for preheat only.

Conclusion

The data indicate that the strongest weld on the basis of torque required for fracture was made with preheat and postheat using E-NiCrFe-2. An interesting point is that with increasing temperature there is an increase in torque strength of the specimens made with the E-NiCrFe-2. Further tests are needed to determine the ultimate strength of welds made with this electrode. There is an indication that the welds made with E-Ni-1 develop their ultimate strength when postweld heat treated to 600°F (315°C).

Based upon the data collected during this investigation, the welding procedure for cast iron under field conditions developing the greatest torque value on an implant test has three primary variables:

1. The electrode is E-NiCrFe-2.
2. The preheat is 700°F (371°C).
3. The weld is postheated to 700°F (371°C).

References

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3. Savage, W. F.; Nippes, E. F.; and Sawhill, J. M., Jr. 1976. Hydrogen induced cracking during implant testing of alloy steels. *Welding Journal* 55 (12) : 400-s to 407-s.