A Report on New Matrix-Stiffened Nickel-Chromium Welding Products

Inconel electrode 112 for covered electrode welding and filler metal for gas-shielded arc and submerged-arc welding produce welds with high tensile strength at room and elevated temperatures and high impact strength at cryogenic temperatures

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ABSTRACT. Welding products are now commercially available for similar and dissimilar welding as well as for surfacing a newly developed matrix-stiffened nickel-chromium composition. These products are for use with the shielded metal-arc, gas tungsten-arc, submerged-arc, and various gas metal-arc processes.

The weld deposits, like the base metal, require no postweld heat treatments to maintain their high strength and toughness. The room-temperature fatigue strengths of these weld deposits are exceptionally high. At cryogenic temperatures, the tensile and impact strengths of these products are well in excess of requirements of various codes.

Stress-rupture tests on all-weld-metal specimens show that the weld metals have excellent stress-rupture properties through 2000° F.

The corrosion resistance of the weld metal resembles that of the base metal.

Tests on several dissimilar joints made between alloy 625 and various other high-temperature alloys indicate that these welding products will tolerate dilution from a wide range of alloys and still maintain much of their strength and ductility.

Introduction

Two welding products have been developed for joining the recently introduced matrix-stiffened nickel-chromium alloy, Inconel[*] alloy 625. The products—a bare filler metal and a covered electrode—have compositions similar to the wrought alloy and are designed for welding the alloy to itself or to dissimilar metals and also for applying overlays of the matrix-stiffened composition. The new welding materials are designated Inconel filler metal 625 and Inconel welding electrode 112.

In wrought form, alloy 625 is becoming widely used for aerospace and chemical-processing applications. The alloy has excellent resistance to corrosion and oxidation and has high strength and toughness at temperatures from the cryogenic range to 2000° F. It also has good weldability and needs no postweld heat treatment to maintain strength and corrosion resistance. The weldability of the alloy has been described in detail by other investigators.[1,2]

The chemical compositions of the filler metal and deposited weld metal from the electrode are listed with the composition of the wrought alloy in Table 1. The materials derive their strength from the stiffening effect of molybdenum and columbium on the nickel-chromium matrix.

The filler metal is designed for use with the gas tungsten-arc, submerged-arc, and various gas metal-arc processes. Operating characteristics are similar to those of other nickel-chromium filler metals. A standard commercial flux for nickel-chromium alloys is used with the submerged-arc process.[3]

The covered electrode has operability similar to that of electrode in the ENiCrFe-3 AWS classification. The slag produced is hard, but it detaches in large sections when fractured, leaving clean weld metal.

Filler metal 625 and electrode 112 are the first welding products of the matrix-stiffened, alloy 625 composition. An extensive laboratory testing program was conducted to define the mechanical properties and corrosion resistance of welds in alloy 625 base metal and to determine the performance of the weld metals in joining some dissimilar metals.

Mechanical Properties

Tensile tests were performed on transverse and all-weld-metal speci-

Table 1—Limiting Chemical Compositions, of Alloy 625 and Welding Products, %

Element	Alloy 625	Filler metal 625	Welding electrode 112[a]
Nickel (plus cobalt)	Remainder	Remainder	Remainder
Carbon	0.10 max	0.10 max	0.10 max
Manganese	0.50 max	0.50 max	1.0 max
Iron	5.0 max	5.0 max	7.0 max
Sulfur	0.015 max	0.015 max	0.02 max
Silicon	0.50 max	0.50 max	0.75 max
Chromium	20.00–23.0	20.0–23.0	20.0–23.0
Columbium (plus tantalum)	3.15–4.15	3.15–4.15	3.15–41.15
Molybdenum	8.0–10.0	8.0–10.0	8.0–10.0
Aluminum	0.40 max	0.40 max	...
Titanium	0.40 max	0.40 max	...
Cobalt (if determined)	1.0 max	1.0 max	1.0 max

[a] All weld metal.

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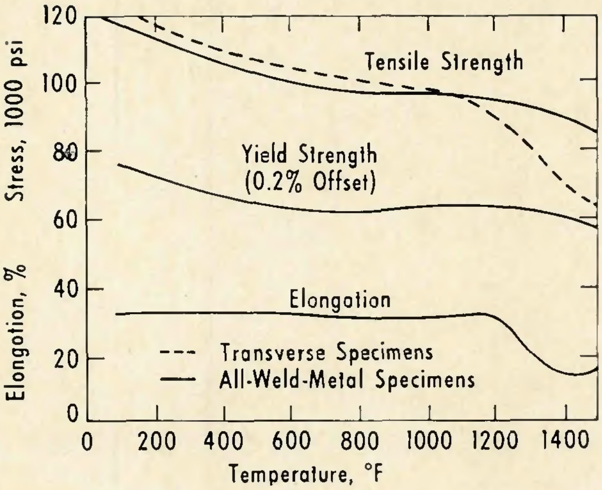

Fig. 1—Tensile properties of alloy 625 $^1/_2$ in. thick plate welded by gas tungsten-arc process using filler metal 625

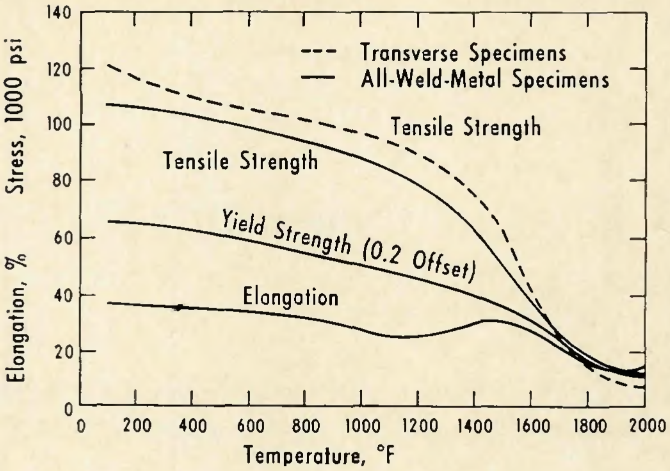

Fig. 2—Tensile properties of welds in alloy 625 made with electrode 112

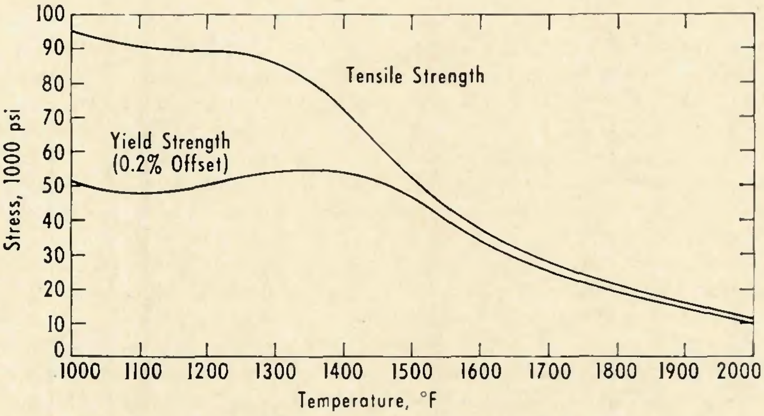

Fig. 3—Tensile properties of all-weld-metal specimens from joints in alloy 625 made by submerged-arc process using filler metal 625

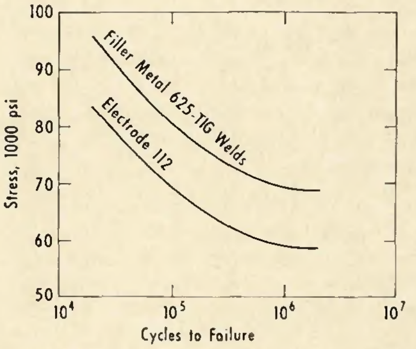

Fig. 4—Rotating-beam fatigue strength of all-weld-metal specimens. The filler-metal specimens were from gas tungsten-arc welds

mens at room and elevated temperatures. The weld metals have good strength at room temperature and retain a large part of their strength at high temperatures. As shown by Figs. 1-3, little reduction in strength occurs until temperatures in the 1200 to 1400° F range are reached, and the materials retain usable strength at temperatures to 2000° F.

Charpy V-notch impact tests were performed at room and low temperatures on welds made with electrode 112. The toughness of the weld metal decreased somewhat as the temperature was lowered but was still relatively high at —320° F. The test results are shown in Table 2.

Rotating-beam fatigue tests were run at room temperature on all-weld-metal specimens of both the filler metal and the electrode. The weld deposit for the filler metal was made by the gas tungsten-arc process. Testing was done at 10,000 rpm on an R. R. Moore fatigue-testing machine. All specimens were polished with 500-grit paper before being tested. The fatigue strengths of the two weld metals are among the highest obtainable with nonage-hardenable, nickel-chromium weld metals. At 10^6 cycles, the fatigue strength of the deposited filler metal is about 68,000 psi and that of the deposited electrode is about 58,000 psi. The fatigue strengths of both weld metals are plotted in Fig. 4.

Table 2—Charpy V-Notch Impact Strength of All-Weld-Metal Specimens

		—Impact strength, ft-lb—		
Welding material	Notch orientation	Room temp.	—110° F	—320° F
Filler metal 625 (gas tungsten-arc)	Perpendicular to welding direction	68.5	60.0	57.0
Electrode 112	Perpendicular to welding direction	45.6	42.5	34.8
Electrode 112	Parallel to welding direction	45.0	41.5	32.8

The results of stress-rupture tests performed on all-weld-metal specimens of electrode 112 are shown in Fig. 5. The specimens were tested in the as-welded condition. Also, five stress-rupture tests were performed on alloy 625 welded by the gas tungsten-arc process using filler metal 625. The tests were on transverse specimens from joints in $^1/_2$ in. thick, solution-annealed plate. The results were used to establish the 100 hr rupture-strength curve shown in Fig. 6. Both welding products produced welds having slightly lower rupture strengths than published values for solution-treated alloy 625.[1]

The weld metals, like the wrought alloy, exhibit higher strength after long-time exposure to intermediate temperatures. This strengthening is the result of a mild age-hardening reaction. On continuing exposure, overaging occurs and all mechanical

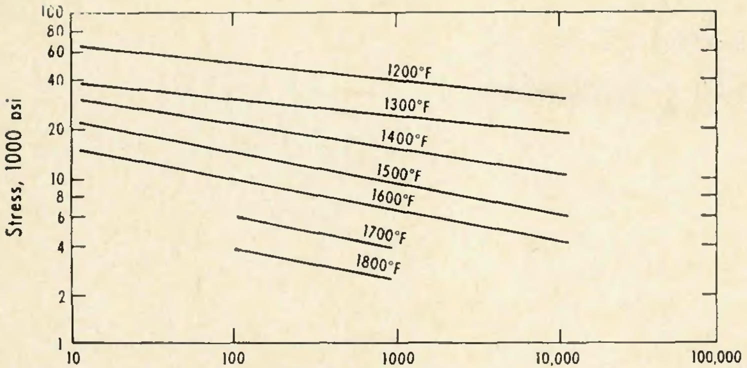

Fig. 5—Rupture strength of all-weld-metal specimens of electrode 112

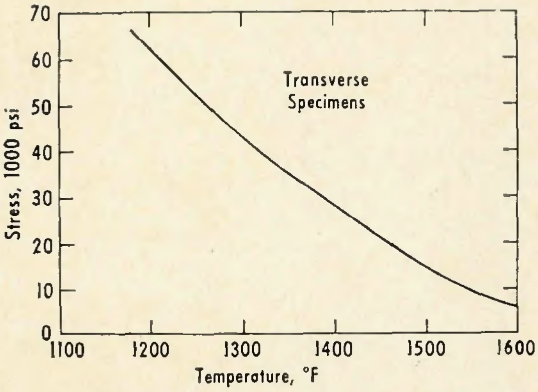

Fig. 6—100 hr rupture strength of transverse specimens from joints in alloy 625 made by gas tungsten-arc process using filler metal 625

properties return to the initial values. The effects of 200 hr exposure to various temperatures on the room-temperature tensile properties of hot-rolled, annealed plate and all-weld-metal specimens of electrode 112 are shown in Fig. 7. Strengthening is virtually complete after 100 to 200 hr exposure, but a decrease in ductility can occur after long exposures to temperatures between approximately 1100° and 1300° F. As shown in Fig. 8, the room-temperature elongation of tensile-test specimens can be as low as 10% after 1000 hr exposure to intermediate temperatures.

Corrosion Resistance

The weld metals were subjected to several corrosion tests to compare their corrosion resistance with that of alloy 625.

The ferric sulfate/sulfuric acid (Streicher) test and the Huey test, standard tests for susceptibility to sensitization,[5] were performed on all-weld-metal deposits from the covered electrode and the filler metal. The filler-metal deposits were made by the gas metal-arc (pulsing arc) process.

The as-welded specimens were first exposed to temperatures of 1100 to 1700° F and then tested for degree of sensitization. The results indicate that the weld metals have good stability, but are slightly more susceptible to sensitization than the wrought base metal. Maximum sensitization occurred at 1300° F for the covered-electrode deposits and at 1400° F for the filler-metal deposits. After exposure to those temperatures, the Huey-test rates averaged 77 mpy (mils penetration per year) for electrode 112 and 97 mpy for filler metal 625. The Huey-test rate for solution-treated alloy 625 in a state of maximum sensitization (sensitized at 1400° F) is approximately 70 mpy.

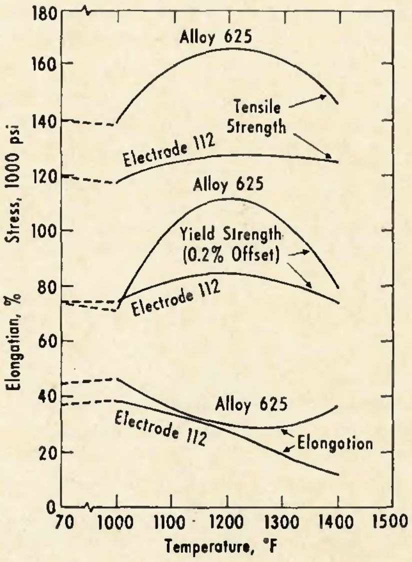

Fig. 7—Effect of 200 hr exposure to intermediate temperatures on the room-temperature tensile properties of hot-rolled, annealed alloy 625 plate and all-weld-metal deposits of electrode 112

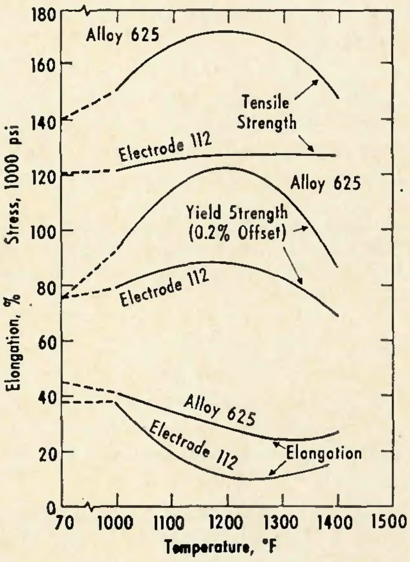

Fig. 8—Effect of 1000 hr exposure to intermediate temperatures on the room-temperature tensile properties of hot-rolled, annealed alloy 625 plate and all-weld-metal deposits of electrode 112

Table 3—Tensile Properties[a] of Welds in Alloy 625 Joined to Dissimilar Materials by Shielded Metal-Arc Process and Welding Electrode 112

Dissimilar material	Joint thickness, in.	tensile strength, psi	Fracture location
Hastelloy alloy X	3/8	118,500	Alloy X
INCONEL alloy 718	3/8	110,250	Alloy 625
Type 304 stainless steel	3/8	91,250	304 stainless steel
Type 410 stainless steel	3/8	61,600	410 stainless steel
MO-RE I	1/2	94,700	MO-RE I

[a] Transverse specimens.

Table 4—Tensile Properties[a] of Gas Tungsten-Arc Welds in Alloy 625 Joined to Dissimilar Metals With Filler Metal 625

Dissimilar material	Joint thickness, in.	Tensile strength, psi	Fracture location
Hastelloy alloy X	3/8	119,700	Alloy X
INCONEL alloy 718	3/8	107,500	Alloy 625
Type 304 stainless steel	3/8	92,000	304 stainless steel
Type 410 stainless steel	3/8	67,600	410 stainless steel
MO-Re 1	1/2	97,300	MO-RE 1

[a] Transverse specimens.

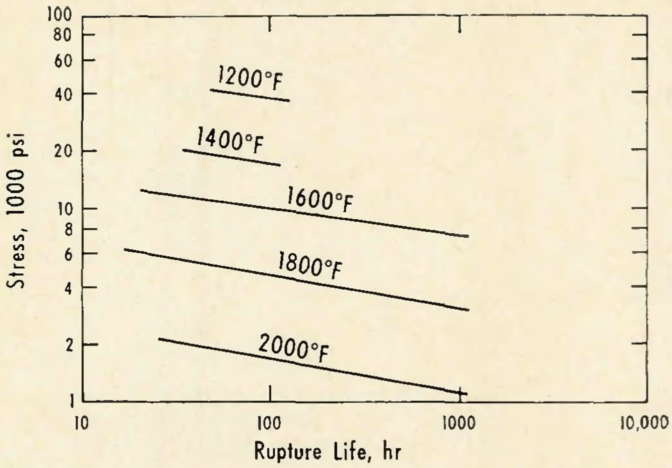

Fig. 9—Rupture strength of transverse specimens from joints in nickel-iron-chromium alloy 802 welded with electrode 112

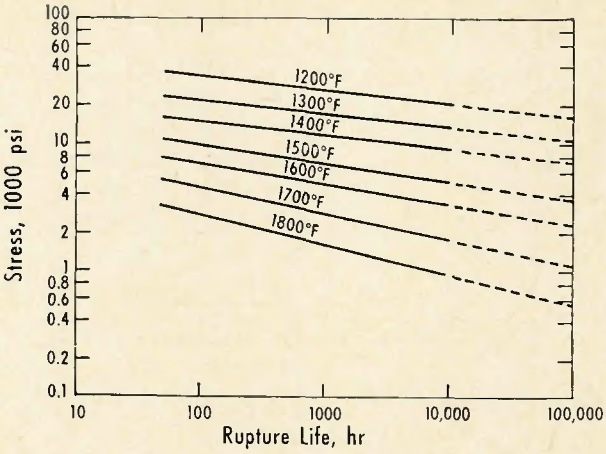

Fig. 10—Rupture strength of transverse specimens from joints in nickel-iron-chromium alloy 800 welded with electrode 112

Ferric chloride pitting tests (Smith tests) performed on weld deposits from both the electrode and the filler metal showed that the weld metals have high resistance to pitting. The test involves exposure to a ferric chloride/hydrochloric acid solution for 4 hr at 95° F. None of the specimens showed any indication of pitting after completion of the test.

The weld metals were exposed to boiling solutions of sulfuric acid at various concentrations. Similar tests were conducted in solutions of hydrochloric acid. In both media, the performance of the weld metals was approximately the same as that of the wrought alloy.

The weld metals exhibited excellent resistance to stress-corrosion cracking. Neither weld metal showed any indications of cracking after 40 days' exposure of stressed specimens (restrained U-bends) to boiling 42% magnesium chloride and to boiling 70% sodium hydroxide.

Properties of Dissimilar Joints

Electrode 112 and filler metal 625 were used to join alloy 625 to some other metals and to join three high-temperature alloys to themselves. The mechanical properties of the joints indicate that both weld metals will tolerate dilution from a variety of metals with no impairment of strength. The joints tested included alloy 625 joined to a nickel-iron-chromium-molybdenum alloy (Hastelloy* alloy X), an age-hardenable nickel-chromium alloy (Inconel alloy 718), a cast chromium-nickel-iron-tungsten alloy (MO-RE 1†), and Types 304 and 410 stainless steel. Other joints were Incoloy alloys 802 and 800 welded to themselves. All joints passed dye-penetrant and radiographic inspections. The joints involving Type 410 stainless steel were preheated to 300° F.

The room-temperature tensile properties of joints made with electrode 112 between alloy 625 and some dissimilar metals are listed in Table 3.

Table 5—Tensile Properties[a] of Gas Metal-Arc (Spray Transfer) Welds in Alloy 625 Joined to Dissimilar Metals with Filler Metal 625

Dissimilar material	Tensile strength, psi	Fracture location
Hastelloy alloy X	121,200	Alloy X
INCONEL alloy 718	120,700	Alloy 625
Type 304 stainless steel	88,500	304 stainless steel
Type 410 stainless steel	65,600	410 stainless steel

[a] Transverse specimens from 3/8-in.-thick plate.

Table 6—Tensile Properties of Gas Metal-Arc (Pulsing Arc) Welds in 9% Nickel Steel Made With Filler Metal 625

Plate thickness, in.	Specimen	Joint angle,[a] deg	Tensile strength, psi	Yield strength (0.2% offset), psi	Elongation in 2 in., %	Fracture location
1/4	Transverse	80	117,200	...	...	[b]
1/4	All-weld	80	112,300	67,000	38	...
3/8	Transverse	80	106,100	...	...	Base Metal
1/2	Transverse	80	109,000	...	...	Fusion Zone
1/2	All-weld	80	109,000	60,300	35	...
1	Transverse	60	112,000	...	..	[c]
1	All-weld	60	119,500	79,100	29	...

[a] Included angle of single-V joint.
[b] 4 tests, 3 fractured in base metal, 1 in fusion zone.
[c] 9 tests, 7 fractured in base metal, 2 in fusion zone.

Table 7—Tensile Properties of Submerged-Arc Welds in 9% Nickel Steel Made With Filler Metal 625

Plate thickness, in.	Specimen	Joint angle,[a] deg.	Tensile strength, psi	Yield strength (0.2% offset), psi	Elongation in 2 in., %	Fracture location
1/4	Transverse	80	112,300	...	...	Weld Metal
3/8	Transverse	80	111,300	...	...	Base Metal
1/2	Transverse	80	112,400	...	...	Fusion Zone
1	Transverse	70	115,100	...	...	[b]
1	All-Weld	70	113,500	68,500	32.5	...

[a] Included angle of single-V joint.
[b] 6 tests, 4 fractured in base metal, 2 in weld metal.

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* Trademark of Union Carbide Corp.
† Trademark of Blaw Knox Corp.

Table 8—Tensile Properties[a] of Shielded Metal-Arc Welds in 9% Nickel Steel Made with Electrode 112

Welding position	Plate thickness, in.	Specimen	Tensile strength, psi	Yield strength (0.2% offset), psi	Elongation in 2 in., %	Fracture location
Flat	1/4	Transverse	119,000	...	...	Weld Metal
Vertical up	1/4	Transverse	108,000	...	...	Base Metal
Flat	3/8	Transverse	108,000	...	...	Base Metal
Flat	1/2	Transverse	115,000	...	...	Weld Metal
Vertical up	1/2	Transverse	115,500	...	...	[b]
Flat	1	Transverse	114,500	...	...	Weld Metal
Flat	1	All-weld	115,000	74,000	36	...

[a] Joint design was single-V with 80-deg included angle.

[b] 3 tests, 2 fractured in weld metal, 1 in base metal.

Joint efficiency was 100% in all cases; all speciments fractured in one of the base metals.

Stress-rupture tests were performed on transverse specimens from welds made with electrode 112 in two nickel-iron-chromiun alloys, Incoloy alloys 800 and 802. The results are shown in Figs. 9 and 10.

Filler metal 625 was used to join several metals to alloy 625 by the gas tungsten-arc and gas metal-arc (spray transfer) processes. The room-temperature tensile properties of transverse specimens from the gas tungsten-arc welds are listed in Table 4, and the transverse properties of the gas metal-arc welds are in Table 5. Again, all specimens fractured in one of the base metals.

Properties of Joints in 9% Nickel Steel

The principal uses of 9% nickel steel involve exposure to cryogenic temperatures, and nickel-chromium welding products are commonly used to join the metal to achieve the necessary low-temperature properties in the welds. However, 100% joint efficiency has not been possible with the available nickel-chromium weld metals. The results of tensile and impact tests on joints in 9% nickel steel made with electrode 112 and filler metal 625 show that the products will produce substantially stronger welds than have been achieved with other weld metals.[6,7]

Various thicknesses of 9% nickel steel plate were welded with electrode 112. The same joints were made with filler metal 625 using the gas metal-arc (pulsing arc) and submerged-arc processes.

Transverse tensile tests were run on all of the joints. The room-temperature tensile properties of the joints made by the three processes are given in Tables 6-8. The tensile strengths of all joints were consistently higher than 105,000 psi; the present design strength of welded 9% nickel steel is based on 95,000 psi.[8]

Charpy V-notch impact tests were performed on transverse specimens from welds in $^1/_2$ in. thick plate. The welds were made with electrode 112 and with filler metal 625. The welds with the filler metal were made by the gas metal-arc process using both spray-transfer and pulsing arc. A joint design with one faying surface perpendicular to the plate surface (Westport joint) was used to provide a vertical heat-affected zone. This design enables accurate measurement of the impact strength of the heat-affected zone. Impact strength was determined for the weld metal or for the heat-affected zone by machining the notch in the area to be tested. All notches were parallel to the direction of welding. The results of the tests are given in Table 9. Each value in the table is the average of four tests. The lowest value obtained in any test was 33 ft-lb.

Conclusions

Two newly developed welding products make possible the use of matrix-stiffened nickel-chromium weld metal for both similar and dissimilar welding. The products, a covered electrode and a bare filler metal, are for use with the shielded metal-arc, gas tungsten-arc, submerged-arc, and various gas metal-arc processes.

Applications for the welding materials include joining wrought alloy 625 to itself and to various other alloys. The materials also give good results in joining some nickel-iron-chromium high-temperature alloys.

Tensile tests performed on joints made with the electrode and filler metal show that the weld metals have high strength at room temperature and maintain a high degree of strength at elevated temperatures.

The weld metals have high impact strength and retain much of their toughness at cryogenic temperatures. Charpy V-notch values for all-weld-metal samples are well in excess of ASME Boiler and Pressure Vessel Code requirements.

The fatigue strengths of the weld metals are among the highest obtainable with nickel-chromium welding materials. Rotating-beam tests on all-weld-metal specimens showed fatigue strengths of over 58,000 psi at 10^6 cycles.

The stress-rupture strengths of the weld metals are slightly lower than the rupture strength of alloy 625.

Long-time exposure to moderately high temperatures increases the room-temperature strength and decreases the room-temperature ductility of the weld metals.

The corrosion resistance of the two welding materials is essentially the same as that of wrought alloy 625.

The covered electrode and the filler metal produce high-efficiency joints in 9% nickel steel. The tensile strengths of all-weld-metal and transverse specimens from such joints are in excess of 105,000 psi. Joints in 9% nickel steel retain their toughness at cryogenc temperatures.

Although the base metal is now being used primarily in the aerospace

Table 9—Charpy V-Notch[a] Impact Strength of Joints in 9% Nickel Steel

	Impact strength, ft-lb			
	Room temperature		−320° F	
Welding material	Heat-affected zone	Weld	Heat-affected zone	Weld
Filler metal 625 (gas metal-arc, spray transfer)	52.3	57.6	40.7	57
Filler metal 625 (gas metal-arc, pulsing arc)	99.3	67.5	62.0	53.5
Electrode 112	72.0	56.0	35.5	47.0

[a] Notch parallel to direction of welding.

and chemical industries, the welding products developed for the alloy show a potential for a wide variety of applications which demand hgh strength and toughness at temperatures from the cryogenic range to 2000° F.

References

1. Gilliland, R. G., and Slaughter, G. M., "The Welding of New Solution-Strengthened Nickel-Base Alloys," Welding Journal, 45 (7), Research Suppl., 314-s to 320-s (July, 1966).

2. Barker, J. F., Cox, J. D., and Margolin, E., "INCONEL 625—An Alloy for Steam and Gas Turbines," *Metal Progress*, 93 (4), 91-94 (April 1968).

3. "INCOFLUX 5 and 4 Submerged Arc Fluxes," Huntington Alloy Products Division, The International Nickel Company, Inc., Huntington, West Virginia 25720 (1966).

4. "Engineering Properties of INCONEL Alloy 625," Huntington Alloy Products Division, The International Nickel Company, Inc., Huntington, West Virginia 25720 (1966).

5. "Recommended Practices for Detecting Susceptibility to Intergranular Attack in Stainless Steels," Standard A 262-64T, *1966 Book of ASTM Standards*, Part 3, American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

6. "Why Stress Relieve Cryogenic Vessels Made From 9% Nickel Steel?" *Welding Design and Fabrication*, Vol. 33, No. 12, pp. 57-59 (December, 1960).

7. Coutts, D. K., and Whitelaw, R. B., "Low Carbon Nickel Steels for Cryogenic Applications," *Welding Fabrication and Design* (September, 1963).

8. "ASME Boiler and Pressure Vessel Code," Section VIII, Div. 1, Table UHT-23, p. 186. The American Society of Mechanical Engineers, 345 East 47th Street, New York, New York. (1968).

USSR Welding Research News

By Rudolph O. Seitz

Avtomaticheskaya Svarka 22, No. 2 (Feb. 1969)

- Sterenborgen, Yu. A. et al.: Kinetics of the formation of chemical heterogencity in the heat-affected zone.—The causes of the formation of chemical heterogencity in the HAZ are discussed. The kinetics of the process was studied with the aid of a mathematical model and a digital computer. It was found that the content of this heterogeneity is greatly affected by boundary migrations during the grain growth in the HAZ (6-10).
- Pokhodnya, I. K. and Yavdoshchin, I.R.: Porosity in welds obtained with rutile-coated electrodes.—The effect of the calcination temperature of the electrodes and of the current level on weld porosity was investigated. It was found that the porosity is caused mainly by hydrogen and that it can be prevented by increasing the partial pressure of hydrogen in the arc atmosphere by the addition of suitable minerals to the coating (mica, kaolin, talc) for the purpose of intensifying hydrogen adsorption and release (11-14).
- Medovar, B. I. and Pavliichuk, G. A.: Effect of boron in the properties and weldability of nickel base alloys. —It has been established that the addition of 0.3-0.5% B increases in cracking resistance. A welding procedure for B-containing stainless nickel alloys has been developed, using a Ni-Cr-Mo electrode with 0.6% B (15-18).
- Rabkin, D. M. et al.: Growth mechanisms of the interlayers in aluminum-copper bimetal.—The mechanisms of the growth of interlayers in the bimetal upon heating have been uncovered by ordinary and by color metallography. The energies of activation have been calculated and the diffusion coefficients have also been determined (19-23).
- Mandel'berg, S. L. et al.; Magnetohydrodynamic phenomena in twin arc welding and how to utilize them.—The problems of interaction of the intrinsic electromagnetic fields and the technological features of different twin arc welding methods are discussed. It is shown that with the most effective method, using a-c, the bead formation is determined largely by the action of the self-generated magnetic field on the pool of liquid weld metal (24-28).
- Makara, A. M. and Nazarchuk, A. T.: How to increase the impact strength of diffusion-welded joints.—The impact strength, orientation and appearance of fracture of diffusion-welded joints in structural alloy steels obtained under widely varying welding conditions were determined. The causes of the lowering if the impact strength were established and recommendations are presented on how to raise the impact strength to the level of the base metal (29-34).
- Kalenski, V. K. and Frumin, I. I.: Determination of residual stresses in hardfaced valves and selection of heat-treating conditions.—The tangential tensile stresses responsible for the formation of radial cracks in type Kh25N40V6 hardfacing metal were determined by measuring the outside diameter of the valve and of the ring of hardfacing metal which was removed from the valve by electromachining. Minimum stress and acceptable hardness of the HAZ is obtained after a two-stage furnace tempering at 740° C of the hardfaced valve made of EI 992 steel (35-38).
- Kazimorov, A. A. et al.: Analytical description of the process of formation of longitudinal weld deformations and stresses.—The initial period in the formation of plastic deformations and stresses in the plate during the welding of a cylinder along the longitudinal seam has been examined. An approximation method of estimating the longitudinal weld deformations and stresses is presented (39-44).
- Chvertko, A. I. et al.: Study of electrode wire feed systems with flexible guide channels.—An efficient design of the flexible guide of wire feed hoses in automatic and semiautomatic welding is described. The authors studied the effect of channel configuration, type of drive rolls and kind of wire used. It was found that molybdenum disulfide greatly reduced wire friction (45-50).

Other articles of interest:

- Nazarenko, O. K. et al.: A new 13.5 kw electron beam welder (51-55).
- Garashchuk, V. P. et al.: Laser welding of electric record player panels (59-60).
- Raevskii, G. V. et al.: Welded tires for rotary furnaces (61-63).
- Belov, Yu, M.: Effect of operating variables on composition of weld deposit in automatic submerged-arc hardfacing with strip electrodes and FR-45 flux (64-68).

(*Continued on page* 40-s)

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