Temper Brittleness of Some Fe-Ni-Cr Alloys

by L. D. Jaffe

IN 1945-1946, the author measured temper brittleness in ingots of varying composition prepared by remelting SAE 3135 bar stock under vacuum. Since other investigators¹⁻³ have been referring to this hitherto unpublished work, belated publication seems worthwhile.

Steel in 7 lb batches⁴ was induction melted with nickel additions in a magnesia crucible under a pressure of 10 microns of Hg or less and cast into a 2 in. diam chill mold. The compositions of ingots A, B, and C prepared in this way are shown in Table I; the vacuum melting lowered carbon, manganese, sulphur, and nitrogen content. Ingot B was homogenized 24 hr at 1095°C; ingots A and C were not homogenized. Blanks, ½ in. square, were cut from each ingot, austenitized 1 hr at 870°C, water quenched, tempered 1 hr at 595°C, and water quenched. Half the blanks from each ingot were given an embrittling treatment of 50 hr at 455°C and water quenched. A few specimens, embrittled and unembrittled, were finally heated 1 hr at 580°C and water quenched.

Charpy specimens machined from the blanks were V-notched on the side closest to ingot mid-radius and paired as to radial position in the ingot, one of each pair having received the embrittling treatment and the other not. Specimens were broken in a standard impact machine at various temperatures, the same temperature, in general, being used for both bars of a pair. Fig. 1 shows the results. It is evident that temper brittleness, as measured by the increase in temperature of transition from brittle to tough failure introduced by the 455°C treatment, was decreased but not eliminated by reducing carbon to 0.006 pct, manganese to < 0.004 pct, and nitrogen to 0.001 pct. In another study,⁵ temper brittleness was apparently eliminated by reducing carbon to 0.003 pct, with 0.80 pct Mn and 0.0015 pct N (ingot D).*

* Analyses given for carbon below 0.02 pct were made by Jensen method; for nitrogen, by Kjeldahl method. Values quoted elsewhere^{1-3,5} for carbon content of ingot C and for nitrogen content of ingot D were obtained by conventional combustion and by vacuum fusion methods, respectively, and are considered much less accurate.

The 580°C final treatment removed previous embrittlement (ingot B particularly), indicating that this was "reversible embrittlement."⁶

Metallographic examination of ingot C with 1 pct nital etch revealed only ferrite; ingot A had carbide spheroids uniformly distributed in a ferrite matrix. With ethereal picric acid plus zephiran chloride etchant,⁷ no differences between embrittled and un-

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Fig. 1—Experimental data. Circle is impact energy, unembrittled; square, impact energy, embrittled; ×, percent fibrous fracture, unembrittled; +, percent fibrous fracture, embrittled; and arrow designates specimens reheated to 580°C and water quenched.

embrittled specimens of ingots A, B, or C were noted. Fracture of C and D below the transition temperature was predominantly transcrystalline, with traces of intercrystalline, in both embrittled and unembrittled conditions. The corresponding fracture of unembrittled B was mixed transcrystalline and intercrystalline; of embrittled B, predominantly intercrystalline with some transcrystalline areas.

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Table I. Compositions, Pct; Balance Nominally Fe

Heat	C	Mn	Si	S	P	Cr	Ni	Mo	V	Al	Mg	Sb	B	N	O	H
3135 melting stock	0.35	0.87	0.22	0.022	0.029	0.50	1.16	0.005	0.003	0.020	—	—	0.0005	0.005	—	—
A	0.11	0.004	<0.31	0.006	0.028	0.40	5.85	—	0.003	0.057	<0.001	<0.01	0.001	0.002	—	—
B	0.04	0.004	<0.32	0.005	0.033	0.40	5.24	—	—	0.021	<0.001	<0.01	0.0027	0.001	—	—
C	0.006	0.004	<0.35	0.004	0.034	0.27	4.92	—	—	0.009	<0.001	<0.01	0.0029	0.0015	—	—
D	0.003	0.80	0.02	0.005	0.002	0.61	1.49	0.002	—	—	—	—	—	0.0015	0.017	0.00006