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METHOD OF HEAT TREATING STEEL

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This invention relates broadly to a novel treatment of open-hearth steel plates and the improved product resulting from such treatment.

More particularly, the invention relates to quenching semi-killed open hearth ship plates of ¼" thickness or greater from rolling temperatures to obtain a microstructure comprising pseudo-martensite intermingled with ferrite to lower the transition temperature in notched-bar impact tests of said plates.

The object of this invention is to obviate brittle fracturing in welded ships. Characteristics of such brittle fracturing are that the fracture starts at imperfections in the weld, generally aggravated also by other notch conditions, and that the fracture occurs in cold weather. While the design of the ship and the workmanship are of the greatest importance in obviating such brittle fracturing, recent work has indicated that the quality of the steel also plays an important part.

It has recently been shown that ship plate steel which becomes brittle in notched-bar impact tests at relatively warm temperatures is more likely to be the origin of brittle fracturing in a welded ship than ship plate steel which only becomes brittle in notched-bar impact tests at relatively cold temperatures. The temperature at which such brittleness ensues in a series of notched-bar impact tests at continually lowered testing temperatures has been called transition temperature.

It has also recently been shown that ship plate steel of the semi-killed type containing, for example, .18% carbon and .70% manganese, and thus having a lower carbon content and a somewhat higher manganese content than ordinary ship plate steel, has a lower transition temperature. Fully aluminum killed steel of the same lower carbon and higher manganese contents has an even lower transition temperature. Since thicker ship plate is more susceptible to brittle fracturing than thinner plate it has become the practice to use ordinary ship plate steel in thicknesses up to ½", semi-killed lower carbon higher manganese ship plate steel in thicknesses from ½" to 1", and fully aluminum killed lower carbon higher manganese ship plate steel in thicknesses over 1". By "ordinary ship plate steel" is meant a steel having a tensile strength of 58,000 to 71,000 lbs. p. s. i. Such steel may contain, for

example, .25% carbon and .45% to .50% manganese.

We have discovered, however, that severe accelerated cooling, by water quenching from the rolling temperature, of semi-killed open hearth ship plate steel, containing .05% to .20% carbon and ordinary manganese content, i. e., .25% to .60% manganese can give as low transition temperatures as are obtained upon ordinary rolling and air cooling of the recently developed semi-killed and fully aluminum-killed lower carbon higher manganese ship plate steels, producing transition temperatures ranging from 0° to —70° F. in the unwelded condition and from 20° to —50° F. in the welded condition.

The explanation of this appears to be that the severe accelerated cooling by water quenching of the coarse grained steel present after the ordinary finishing temperature in commercial rolling produces a pseudo-martensitic structure with which ferrite is intermingled. This structure of pseudo-martensite and ferrite produced by water quenching has a quite low transition temperature in notched-bar impact tests, considerably lower than the structure of ferrite and pearlite produced by ordinary cooling from the rolling temperature.

Such water quenched open-hearth semi-killed ship plate steel has appreciably higher yield and tensile strength and lower transition temperature than such steel air cooled from the rolling temperature. The lower transition temperature is evident not only in notched-bar impact tests of the unwelded steel but also in notched tests of the as-welded plate.

This is shown in the following data in Table I on semi-killed open hearth ship plate steel ¾" thick of the following composition:

C	Mn	P	S	Si
0.13%	0.50%	0.0.0%	0.025%	0.05%

Table I

	Tensile Properties				Transition Temperature	
					Not Welded	Welded
	Yield Strength, p. s. i.	Tensile Strength, p. s. i.	El. in 2", Percent	Red. of Area, Percent	Keyhole Charpy Impact Test, °F.	Notched Weld-Bead Tensile Test, °F.
As Air Cooled from the Finishing Temperature in Rolling, of 1,650° F.	33,000	56,000	40.0	68.0	15	10
As Water-Quenched for 15 Seconds from the Same Finishing Temperature	46,000	70,000	30.0	70.0	—40	—30

The data in Table I indicate that by proper choice of the carbon and manganese content of the steel it is possible to stay within the yield, tensile, and elongation requirements in the tensile test for ordinary ship plate steel (yield strength 32,000 p. s. i. minimum, tensile strength 58,000 to 71,000 p. s. i., elongation in 2" 22% minimum) after water quenching.

The increased yield strength and tensile strength after water quenching are of marked advantage. The decreased transition temperature produced by the water quenching indicates the water quenching to be of definite help in obviating brittle fracturing. At present two new special classes of ship plate steel are required by the American Bureau of Shipping, Class B, maximum carbon content 0.23%, manganese content 0.60 to 0.90%, semi-killed steel for plates ½" to 1" thick, and Class C of approximately the same composition but of fully aluminum-killed steel for plates over 1" thick. Both of these classes of

steel require higher than ordinary manganese content. While manganese is generally not very costly it may yet become scarce during a period of great activity in steel-making and/or shipbuilding. Class C steel furthermore being fully aluminum-killed steel made in hot-topped big-end-up molds may also require additional hot-topping and stripping facilities during such a period but our water-quenched plate of low carbon semi-killed steel in which the manganese content has not been increased shows transition temperatures in notched-bar tests as low as the new special classes of B and C steel with their increased manganese contents. This is true of the unwelded steel and also of the as-welded steel.

This is indicated by the following data in Table II for Class B and Class C steel, which may be compared with the data in Table I for our semi-killed open hearth steel which has been water-quenched from the rolling temperature.

Table II

	Tensile Properties				Transition Temperature	
					Not Welded	Welded
	Yield Strength, p. s. i.	Tensile Strength, p. s. i.	El. in 2" percent	Red. of Area, Percent	Keyhole Charpy Impact Test, °F.	Notched Weld-Bead Tensile Test, °F.
Class B Steel, Air Cooled from the Finishing Temperature in Rolling (C 0.19%, Mn 0.71%, Si 0.05%) Semi-Killed	35,000	62,000	32.0	62.0	7	23
Class C Steel, Also Air Cooled as Above (C 0.17%, Mn 0.73%, Si 0.21%) Fully Aluminum-Killed	37,000	62,000	32.0	61.0	−33	12

The water-quenched semi-killed steel of Table I shows better yield strength, tensile strength, and transition temperature in the unwelded condition and after welding than the new special Class C lower carbon higher manganese fully aluminum-killed steel.

Regarding the preceding data, the transition temperature in the notched-bar impact test was obtained in the usual way with standard Charpy specimens with keyhole notches, and with the transition temperature read when the impact resistance vs. temperature curve crossed 20 ft. lbs. as the testing temperature was lowered.

The specimens for the notched weld-bead tensile tests were made as follows. A longitudinal specimen, the full thickness of the ¾" plate, 12" long and 2.6" wide, was welded by laying a narrow weld bead longitudinally along the center of one of the flat surfaces, using a 5/16" in. diameter E–6010 electrode, 175 amperes, 28 volts, and 12 in. travel per minute. The weld bead was then notched by machining the notch perpendicular to the bead down to the plate surface. The notch was made quite sharp, the radius at the base of the notch being 0.0015 in. The specimens were then loaded in tension to fracture at a series of lowered temperatures and a transition temperature obtained by measuring the reduction in thickness beneath the notch of the fractured specimens. The transition temperature was read when the reduction in thickness vs. temperature curve crossed 5% reduction of thickness as the testing temperature was lowered.

In water-quenching the plate steel from the rolling temperature the steel is led, for example, into a large tank of cold water, the water being preferably of a temperature of from 40° to 120° F., after passing through the finishing rolls. The plate being quenched is held in the water tank for the time necessary to produce the structure of pseudo-martensite intermingled with ferrite, preferably from 5 to 60 seconds. As has been shown, 15 seconds immersion of ¾" thick plate in the water at 60° F. is sufficient for this. After such quenching the plate is still quite warm, amply so to aid in subsequent straightening. However, if longer quenching times than this are used no great harm is done as the transition temperature is just as low after complete quenching to the water temperature. The steel can then be tempered if desired to as high as 1000° F. without raising the transition temperature; such tempering lowers the yield and tensile strength somewhat by approximately 5000 p. s. i.

The lowered transition temperature after water quenching is obtained over a wide range of finishing temperatures in rolling. As low transition temperatures are obtained after water quenching from a high finishing temperature in rolling of 1850° to 1900° F. as from a rather low finishing temperature in rolling of 1600° to 1650° F. Such quenching should, however, be from above the critical temperature of the steel being rolled.

We claim:

1. A method of lowering the transition temperature in the notched bar impact test of semi-killed open-hearth steel plate containing .05% to .20% carbon, .25% to .60% manganese, and the balance consisting essentially of iron, comprising hot rolling said plate and water quenching the said steel plate immediately from the hot rolling operation, the temperature at which said plate is quenched being above the upper critical temperature of the said steel plate.

2. A method of lowering the transition temperature in the notched bar impact test of semi-killed open-hearth steel plate containing .05% to .20% carbon, .25% to .60% manganese, and the balance consisting essentially of iron, comprising hot rolling said plate and directly water quenching said plate from the hot rolling operation at temperatures of from 1600° to 1900° F.

3. A method of lowering the transition temperature in the notched bar impact test of semi-killed open-hearth steel plate containing .05% to .20% carbon, .25% to .60% manganese, and the balance consisting essentially of iron, comprising hot rolling said plate and directly quenching said steel plate from the rolling operation at temperatures of from 1600° to 1900° F. in water, said water being at temperatures of from 40° to 120° F.

4. A method of lowering the transition temperature in the notched bar impact test of semi-killed open-hearth steel plate containing .05% to .20% carbon, .25% to .60% manganese, and the balance consisting essentially of iron, comprising hot rolling said plate and directly quenching said steel plate from the rolling operation at temperatures of from 1600° to 1900° F. for from 5 to 60 seconds in water, said water being at temperatures of from 40° to 120° F.

5. A method of lowering the transition temperature in the notched bar impact test of semi-killed open-hearth steel plate containing .05% to .20% carbon, .25% to .60% manganese, and the balance consisting essentially of iron, comprising hot rolling said plate and directly water

quenching the said steel plate from the hot rolling operation.

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