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METHOD OF HEAT TREATING METALLIC PIPES

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This invention relates to an improved method of producing heat treated tubular articles and more particularly to quenched and tempered tubular articles.

The beneficial effects of quenching and tempering steel articles have long been known. However, despite the economic advantages of so achieving enhanced physical properties as compared to resort to alloying elements, tubular goods such as oil well casing, could not be so treated due to the distortion resulting from quenching causing ovality and cracking of the pipe walls. While it has been proposed to round up casing after quenching and tempering to remove the ovality, such cold work unduly hardens the casing and lowers its ductility in amounts impairing its usefulness for casing oil wells.

It is accordingly an object of this invention to provide an improved method of producing round and round, quenched and tempered oil well casing.

It is another object of this invention to remove distortion resulting from quenching pipe without impairing the desired physical properties obtained by the quenching and subsequent tempering.

The foregoing and further objects will become apparent from the following specification when read in conjunction with the attached drawing, wherein:

Figure 1 is a graph showing the effect on compression yield strength of compressing quenched steel of various amounts at various tempering temperatures, wherein the ordinate shows compression yield strength in 1000 p.s.i. and the abscissa the percent of compression.

We have discovered that the harmful cracking effect resulting from quenching can be overcome in pipe having a D/t ratio between 10 and 25 by restricting the analysis of the steel within the ranges hereinafter set forth and by applying the quenching medium to the exterior only of the casing as a spray while preventing the quenching medium from contacting the interior thereof.

We have further discovered that quenched steel can be removed without substantially impairing the quenched and tempered physical properties by reducing the diameter of the casing to a predetermined amount while the casing is within a certain range of tempering temperatures. That is, the reduction must take place within the critical temperature range hereinafter described.

In general, the teachings of this invention are applicable to casing composed of steel which can be quenched as described without cracking of the pipe walls and which can be sufficiently transformed to martensite to effect an increase in strength and hardness which can be regulated in a subsequent tempering operation. Such a steel has the following chemical ranges:

- .15 to .50% carbon
- .50 to 2.00% manganese
- .01 to .15% phosphorus
- .06% max. sulphur
- Nil to 1.00% silicon
- Nil to .15% molybdenum
- Nil to .006% boron
- Balance iron, impurities and residual amounts of other elements such as nickel, chromium and copper.

To demonstrate the improved results obtainable by application of this discovery, the data obtained from a series of experiments using steel containing .30% carbon, 1.58% manganese, .015% phosphorus, .019% sulphur and .18% silicon, balance iron, impurities and residual amounts of other elements and forming a graph as in Figure 1 of the drawing. Specimens of about 3/4" diameter by 3/4" in length were machined from plates of this steel and quenched from above the upper critical at sufficiently rapid rate to produce a substantially 100% martensitic structure. These quenched specimens were then heated to various tempering temperatures between 500 and 1000° F. and subjected to various amounts of compression as indicated by the drawing. For any temperature shown, all the specimens subjected thereto were exposed to temperature for approximately 30 minutes regardless of the amount of compression. After normal cooling to room temperature, the specimens were finish machined and the compression yield strengths thereof determined. These also are shown on the graphs of the drawing.

Hithertofore, it has been generally believed that working steel of the general type set forth above at any temperature below its lower critical temperature had a hardening effect thereon. However, a review of the curves of the attached drawing shows a critical temperature range wherein a slight working, i. e., up to about 1/4% compression shows such work hardening and beyond which an unexpected work softening is obtained whereby it is possible to work pipe and casing in amount which does not substantially change the quenched and tempered physical properties. In general, this is an amount in excess of about 1/4% and which does not substantially exceed about 3% at temperatures over 600° F. and below 1000° F. Preferably the steel should be compressed between about 1/4% to 2% while at tempering temperatures of about 700 to 950° F. By working such amounts at such temperatures any cold work or work hardening effects are avoided and at which the quenched and tempered physical properties are substantially undiminished.

This lack of substantial effect by working quenched martensitic material within the foregoing amounts at temperatures below the lower critical is contrary to prior metallurgical teachings and expectations based thereon.

This method of producing tubular goods of a chemical composition which quenches to martensite is particularly adapted to the manufacture of oil well casing. As before stated, it has heretofore been largely impossible in pipe making to take advantage of the quenching and tempering method of improving physical properties of pipe, particularly pipe having a high D/t ratio, such as casing, due to distortion causing ovality thereof. Ovality is a very serious defect in oil well casing, since the collapsing or external hydrostatic pressures it will withstand is dependent to a considerable extent on the roundness thereof.

If the roundness is restored by conventional cold work, the ductile properties are deleteriously affected and the casing rendered unfit for many applications. However, in accordance with the teachings of our invention, casing of the foregoing steel composition and D/t ratio can, after quenching as described, be rounded up by reducing the diameter thereof at least about 1/4% and preferably not over about 3% and more specifically by reducing the diameter by about 1/2 to 2% without materially affecting the quenched and tempered physical properties thereof. If the diameter reducing is done at temperatures above about 600° F. and below about 1000° F. It is of course desirable to regulate the temperatures and amount of work to avoid lowering the ductility.

As illustrative of the foregoing steel composed of .32% carbon, 1.52% manganese, .017% phosphorus, .021% sulphur and .149% silicon was formed into 7" O. D. oil well casing having a nominal .362" wall thickness. Thus
the casing had a D/r ratio of slightly over 19. The formed casing was heated to 1550° F. and water spray quenched, with care being taken to prevent any of the water getting into the interior thereof. Although the casing was somewhat distorted, i. e., oval after such quenching, it was sound, showing no evidence of cracking. The casing was then tempered by heating it to 900° F. Certain sections of the casing were thereafter cooled and tested and showed an average compression yield strength of 138,500 p. s. i., a tensile yield strength of 134,700 p. s. i. and an elongation of 22% in 2". The remainder of the casing was treated to remove the ovality by reducing the diameter thereof about 2.4% while at about the tempering temperature of 900° F. After cooling the casing had an average compression yield strength of 125,900, a yield strength of 124,600 p. s. i. and an average elongation of 22.2% in 2". Thus the ovality was removed without work hardening the steel and with only a slight reduction in the yield strength together with a slight single increase in elongation.

This application is a continuation-in-part of our co-pending application Serial No. 74,578, filed February 4, 1949.

While we have shown and described several specific embodiments of our invention, it will be understood that these embodiments are merely for the purpose of illustration and description and that various other forms may be devised within the scope of our invention, as defined in the appended claims.

We claim:

1. The method of producing heat treated pipe having a D/r ratio in excess of 10 comprising forming pipe of steel containing

   .15 to .50% carbon
   .50 to 2.00% manganese
   .01 to .15% phosphorus
   .06% max. sulphur

   Balance iron and other elements in amounts which do not adversely affect the properties.

   heating said pipe to above the upper critical temperature thereof, quenching said heated pipe to obtain in said steel a martensitic structure which when compressed at a temperature above 600 and below 1000° F. will first increase in compression yield strength and upon further compression within said temperature range will then decrease in compression yield strength, the quenching of said pipe causing ovality therein, heating the quenched pipe to a temperature within the aforementioned range, reducing the diameter of said pipe an amount sufficient to remove said ovality but not over 3% by compression while in said temperature range to first increase the compression yield strength of the pipe and then decrease the same, and regulating the amount of compression within said range to an amount insufficient to reduce said yield strength substantially below the value of the same if the quenched pipe were simply tempered at the temperature of said heating and compression.

2. The method of producing heat treated pipe having a D/r ratio in excess of 10 comprising forming pipe of steel containing

   .15 to .50% carbon
   .50 to 2.00% manganese
   .01 to .15% phosphorus
   .06% max. sulphur
   Nil to 1.00% silicon
   Nil to .15% molybdenum
   Nil to .006% boron

   Balance iron, impurities and residual amounts of other elements,

   heating said pipe to above the upper critical temperature thereof, quenching said heated pipe to obtain in said steel a martensitic structure which when compressed at a temperature between 750 and below 950° F. will first increase in compression yield strength and upon further compression within said temperature range will then decrease in compression yield strength, the quenching of said pipe causing ovality therein, heating the quenched pipe to a temperature within the aforementioned range, reducing the diameter of said pipe between at least 14% and not over 3% by compression while in said temperature range to remove said ovality and to first increase the compression yield strength of the pipe and then decrease the same, and regulating the amount of compression within said range to an amount insufficient to reduce said yield strength substantially below the value of the same if the quenched pipe were simply tempered at the temperature of said heating and compression.

3. As a new article of manufacture, a round pipe produced in accordance with the method of claim 1.

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