Feb. 27, 1968 O. R. CARPENTER ET AL 3,370,993

HEAT TREATMENT OF METALS

Filed March 18, 1965

FIG. 1

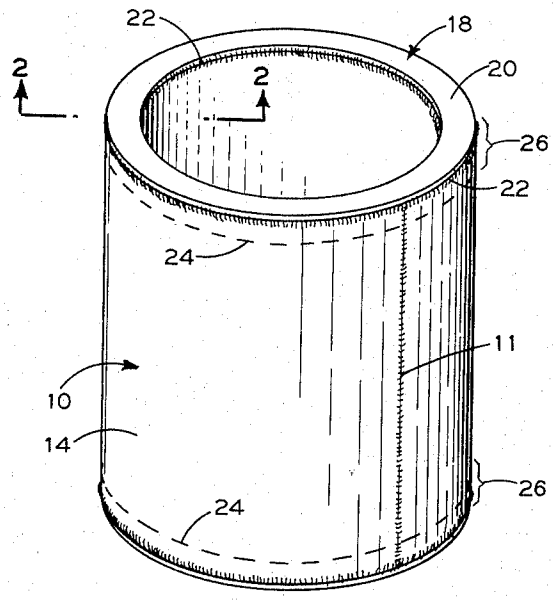
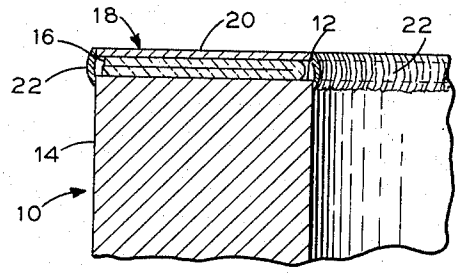


FIG. 2



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HEAT TREATMENT OF METALS

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ABSTRACT OF THE DISCLOSURE

A heat treatment method whereby a more nearly uniform heat transfer is achieved during the heat treating process by insulating the end surfaces of the article and enclosing these insulated end surfaces with metal covers. The inclusion of this step in the heat treatment procedure ensures more uniform cooling of the article and thus achieves more uniform heat treatment of a finished article, thereby affecting economies by reducing scrap losses.

This invention relates to the heat treatment of metals, and it has for a general object to obtain uniform mechanical properties in heat treated articles. Mechanical properties are the characteristic responses of a material to applied forces.

Heat treatment to improve mechanical properties may involve quenching and/or tempering, e.g., heating the article to a selected temperature for a predetermined period and then cooling it rapidly. However, if the article has surfaces which provide increased heat transfer in one portion thereof, there will be accelerated cooling in such portion and the article will be nonuniformly heat treated. It follows that test specimens taken from the more rapidly cooled portions of the article do not give a true indication of mechanical properties throughout the article; and it also follows that the more rapidly cooled portions of the article may have to be removed and scrapped in any situation where it is necessary to produce an article with uniform mechanical properties.

Therefore, the present invention is directed to providing more nearly uniform heat transfer throughout an article, all to the end of minimizing the nonuniform heat treatment of a finished article and thereby effecting economies by reducing scrap losses.

According to the present invention, disadvantages of conventional heat treatment procedures are minimized and objects of the present invention achieved, by insulating end surfaces of an article to be heat treated. The inclusion of this step in the heat treatment procedure ensures more uniform cooling of the article and thus achieves more uniform heat treatment thereof.

Quenching involves heating the object to be treated to a selected temperature above the upper critical temperature of the material, as defined by its phase diagram, and then cooling it rapidly. Steel is strong after quenching, but tempering is frequently employed to improve other desirable qualities, such as ductility. Tempering consists of reheating the quenched article to a selected temperature below the lower critical temperature of the material, next maintaining the article at such temperature for a prescribed period of time, and then cooling it at a predetermined rate. It should be recognized that when one portion of an article cools more rapidly from the quenching temperature than another portion, nonuniform heat treatment results. For example, the end surfaces of an elongated object are equivalent to extended heat transfer surfaces which provide more rapid cooling, with consequent nonuniform heat treatment because heat is transferred at end portions of the object to the cooling medium from the end and side surfaces thereof at the same time, whereas the intermediate portion of the article is cooled by a transfer

of heat to the cooling medium only from the side surfaces thereof.

It is well known that, after heat treatment, end portions of an elongated object do not have the same mechanical properties as the intermediate portion because of the different grain structure produced by the more rapid cooling at the end portions. Thus, experience has shown that in order to obtain a test specimen which gives a typical indication of the mechanical properties of the main intermediate portion of the article, it has been necessary to take test coupons or specimens from the parent metal at a distance equivalent to 1 to 1⅛ times the thickness of the object, measured from the end surfaces. The end portions, between each end surface and its adjacent test location, subsequently are removed and scrapped. By following the teachings of the present invention, however, the test locations may be disposed closer to the insulated end surfaces because the nonuniformly heat treated end portions are shorter; and scrap losses are reduced.

Various other objects, features, and advantages of the invention will appear more fully from the detailed description which follows, taken in connection with the accompanying drawings, forming a part of the present application and in which:

FIG. 1 is a perspective view of an upright tubular article provided at each annular end surface with insulation and a cover therefor according to the invention; and

FIG. 2 is an axial sectional view of an end portion of the article shown in FIG. 1, taken along line 2—2 of FIG. 1.

The invention, as described herein, is applied to the heat treatment of a tubular article; but it is to be understood that the invention is not so limited. The invention is especially advanageous in the making of large pressure vessels wherein a series of tubular shell courses are joined end-to-end by butt welding, since any large reduction of scrap loss at the ends of each shell course results in appreciable savings of both material and labor.

In FIG. 1 of the drawings is shown an upright, vertically elongated tubular article 10 which may be a forging or casting, but preferably it is rolled from plate stock into cylindrical shape and then butt welded along a longitudinal seam 11. The tubular article 10 has annular end surfaces 12 at opposite ends thereof, and also a cylindrical outer side surface 14 disposed about the longitudinal tube axis.

After fabrication of an article, the former practice was to heat treat the article and determine its mechanical properties by removing test specimens or coupons at a distance of 1 to 1⅛ times the thickness of the article from the end surfaces 12.

To illustrate why this former practice of taking specimens at a distance remote from the end surfaces has been followed, and 8 foot long hollow cylinder of Croloy 2¼ grade steel, with a wall thickness of 6 inches and an outside diameter of 12 feet, was heat treated and test specimens were taken at locations 3 inches and 8 inches from an uninsulated end of the cylinder. The mechanical properties of the specimens were determined by mechanical testing, with results given in the following Table A:

TABLE A

Distance of Test Location From End of Article	Tensile Strength, p.s.i.	Impact Strength Charpy V-Notch Test, ft. lbs.
8 inches	124,500	23, 25, 27
3 inches	128,500	31, 31, 34

It can be seen from Table A that the test specimens from the location 3 inches away from the end of the hollow cylinder have greater tensile strength and greater impact strength than the test specimens from the location 8 inches from the end of the cylinder. This difference in

mechanical properties is attributed to the more rapid cooling experienced at end portions of the hollow cylinder because heat is transferred on cooling both from the exposed annular end surfaces of the cylinder, as well as the side surface; and, as previously explained, more rapid cooling during the heat treatment steps would account for the greater tensile strength and greater impact strength of test specimens from locations closest to the end of the cylinder, e.g., at the 3 inch location.

The results set forth in Table A can be given even broader interpretation. It is well known in the art that, in respect of mechanical properties of the intermediate portion of the article, specimens taken at a distance equivalent to 1 to 1⅓ times the thickness of the article from its end surfaces are representative of the intermediate portion. Thus, with a 6 inch thick article, the specimens taken at an 8 inch test location are representative of the entire intermediate portion of the article. Therefore, the results given in Table A indicate that the mechanical properties of the article at 3 inches, or ½ the thickness of the article, from the uninsulated end surface, are appreciably different from the mechanical properties of the intermediate portion of the article. The results also indicate that the end portions of the article must be removed and scrapped if the finished product is required to have uniform mechanical properties, even if the defacement suffered by the removal of test specimens did not already render the end portions unusable for nearly all applications.

It should be appreciated that the removal of an 8 inch long portion from each end of an article 8 feet long, or an aggregate length of 16 inches, produces a scrap loss amounting to approximately 16% of the article as fabricated. As mentioned previosly, the present invention is directed to reducing this scrap loss. And, as will appear more fully hereinafter, such scrap loss can be reduced 60% by practicing the present invention.

Proposed heat treatment method

The present invention proposes insulating of the annular end surfaces 12 by applying insulating blank 16, preferably asbestos material, to the annular end surfaces 12 of the tubular article 10. Of course, the invention is not limited to any particular kind of insulating material, but it is necessary to provide insulation capable of withstanding the highest temperatures experienced during quenching; for example, 1600 to 1800° F. when steel is heated to a temperature above its upper critical temperature. It is also desirable to enclose the insulating blanket 16, as shown, with a cover 18 comprising an annular member 20 of sheet steel, which may be 10 gauge material, circumferentially welded at the inner and outer edges thereof to the adjacent end portions of the article 10. The welds are designated by the numeral 22.

A watertight cover 18 is desirable so that during heat treatment the article may be cooled rapidly by immersion in a liquid coolant without the coolant filling the voids or interstices of the insulation and thereby impairing its effectiveness.

After heat treatment test specimens are taken from a hollow cylinder at test locations disposed along an annular line, designated by a broken line 24 in FIG. 1, and which line 24 is contiguous to both the intermediate portion and the end portion. The end portions removed after heat treatment are designated by the numeral 26, and they extend from the end surfaces 12 to and including the test locations along adjacent line 24.

In carrying out the present invention, therefore, the following steps are employed:

(1) The end surfaces 12 of the article 10 are covered with insulating material 16, preferably in the form of asbestos blanket.

(2) The insulating material 16 is enclosed in covers 18 which, in turn, are secured in watertight sealing relation to the respective ends of the article 10.

(3) The article 10 is heated to a selected temperature above its upper critical temperature for a specified time period.

(4) The article 10 is cooled rapidly.

(5) The article 10 may be tempered next, as by heating it for a given time at a temperature below its lower critical temperature and then cooled.

(6) Test specimens are taken at a distance of approximately half the thickness of the article 10 from the end surfaces 12 for determination of the mechanical properties thereof.

(7) If the mechanical properties are unsatisfactory, then steps 1 to 6 are repeated, and new coupons obtained for testing.

(8) However, if the mechanical properties are satisfactory, then the end portions 26 of the article including the test locations are removed.

A test was conducted on a heat treated hollow cylinder similar to that tested to obtain the results given in Table A, except that portions of the end surfaces were insulated according to the invention, in order to compare the mechanical properties of test specimens taken 8 inches from an uninsulated end surface with the mechanical properties of test specimens taken from the same object at locations 3 inches and 8 inches away from an insulated end surface. In this instance the insulating blanket was asbestos material having a thickness of approximately 3/32 inch and a density of about 62 pounds per cubic foot. The test results are given in Table B.

TABLE B

Test Location	Tensile Strength, p.s.i.	Impact Strength, ft. lbs., Charpy V-Notch Test
3" from insulated end	130,000	[1] 23, 38, 30
8" from insulated end	130,750	[2] 24, 25, 29
8" from uninsulated end	130,750	[2] 22, 27, 30

[1] Average=27.
[2] Average=26.

The results of the tests summarized in Table B clearly show aproximately the same mechanical properties for all three test specimens and, more specifically, that by insulating an end surface of the test object the mechanical properties were approximately the same at 3 inches from the insulated end as at 8 inches from either the insulated or the uninsulated end. It therefore follows that with the proposed method, 5 inches at each end, or 10 inches in all may be saved in the as manufactured overall length of the object, thereby effecting at 62.5% reduction in metal scrapped.

From the results given in Table B, it can be seen that an article 6 inches thick which is subjected to usual heat treatment techniques will, if the ends are insulated, have substantially uniform grain structure of the metal except for an end portion less than 3 inches long, a longitudinal or axial distance equivalent to ½ the wall thickness of the cylinder.

The invention is not limited to any particular kind of insulating material, but asbestos blanket is preferred because it is readily and conveniently available in inexpensive laminated felt or blanket form. Furthermore, asbestos can endure temperatures above the upper critical temperatures for steel, such as 1800° F.; also it can withstand the thermal shock which accompanies rapid cooling by immersion in a cool liquid; and yet it has low thermal conductivity, 1% or less that of most steels.

Although the invention has been specifically described, it will be obvious to those skilled in the art that the invention is not so limited, but that it is susceptible of being practiced with various changes and modifications without departing from the spirit thereof as covered by the following claims.

What is claimed is:

1. A method for heat treating an object having end surfaces, including the steps of:

covering said end surfaces with insulating material, heating said object to above its critical temperature for a predetermined period of time, and then rapidly cooling said object, wherein the improvement comprises enclosing said insulating material and said end surfaces with metal covers.

2. In a method for heat treating by heating and rapidly cooling an object having end surfaces, the step of covering said end surfaces with insulating material, wherein the improvement comprises enclosing said insulating material and said end surfaces with metal covers.

3. In a method of uniformly heat treating an article having surface portions thereof which are equivalent to extended heat transfer surfaces, said article being heated to a temperature above its critical temperature and then cooled rapidly, the step of insulating said surface portions for at least the rapid cooling of said article, wherein the improvement comprises enclosing said insulating material and said end surfaces with metal covers.

4. In a method for heat treating an elongated object having end surfaces and end portions, each end portion extending from an end surface of said object in longitudinal direction for a distance less than the thickness or diameter of said object, said object being heated to a temperature above its critical temperature and cooled rapidly, the steps of insulating said end surfaces at least for the time said object is being cooled rapidly, removing test specimens from said end portions, and removing said end portions, wherein the improvement comprises enclosing said insulating material and said end surfaces with metal covers.

5. In a method for heat treating an elongated object having end portions, each end portion including an end surface and extending from said end surface in longitudinal direction for a distance less than the thickness or diameter of said object, said object being heated to a temperature above its critical temperature and cooled rapidly, the steps of insulating said end surfaces prior to heating the object, removing test specimens from said end portions, and removing said end portions subsequent to the removing of said test specimens, wherein the improvement comprises enclosing said insulating material and said end surfaces with metal covers.

6. In a method of heat treating an elongated metal article including end surfaces and having end portions, each end portion extending longitudinally from an end surface for a distance not exceeding one-half the thickness of said article, including the steps of:

covering said end surfaces with insulating material,

heating said article to a selected temperature above its critical temperature for a predetermined period of time,

rapidly cooling said article by placing it in a body of fluid at low temperature,

removing a specimen from at least one of the end portions of said article,

testing said specimen to determine the mechanical properties, thereof,

repeating the previous steps if the desired mechanical properties are not obtained until such desired properties are obtained, and

removing said end portions from said article, wherein the improvement comprises enclosing said insulating material and said end surfaces with metal covers secured in sealing relation to said end portions.

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