

[54] **METHOD AND APPARATUS FOR
QUENCHING A TABULAR SHAPED
STRUCTURE**

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[51] Int. Cl.C21d 1/66

[58] Field of Search.....148/144, 145, 148, 150-155;
266/4 R, 4 A, 4 E, 4 F

[56]

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[57]

ABSTRACT

Apparatus for continuously quenching a thick-walled tubular structure having electromagnetic induction heating means above a quench tank wherein the work-piece is rotated through the heating and quenching means.

3 Claims, 3 Drawing Figures

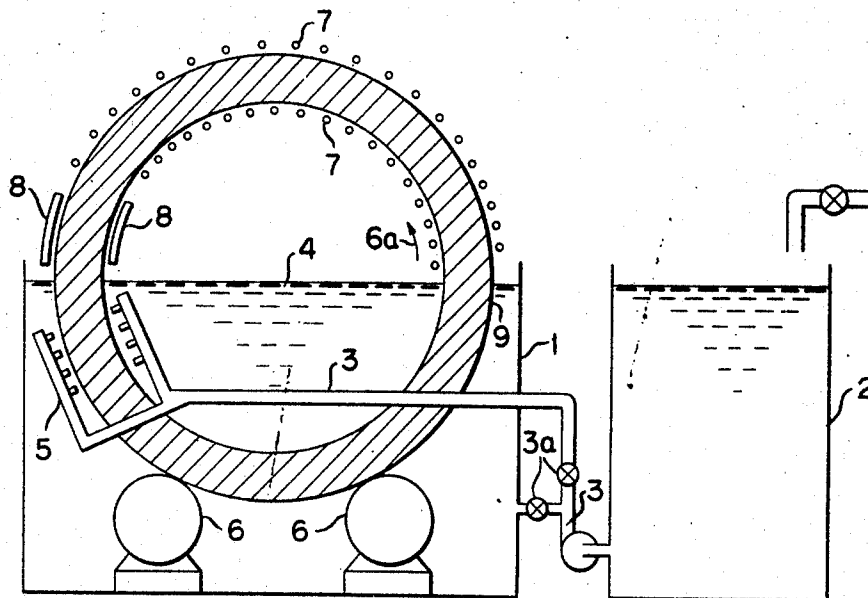
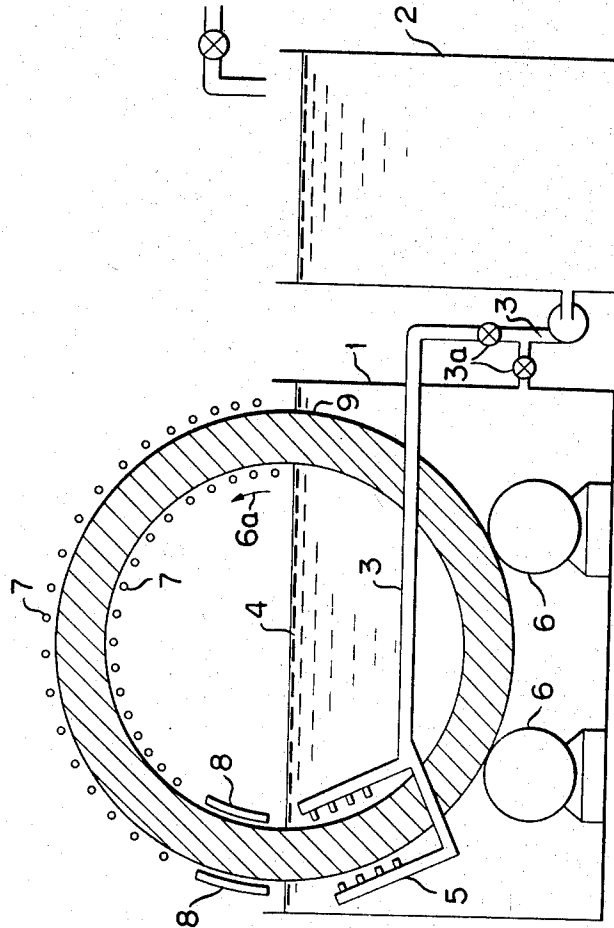
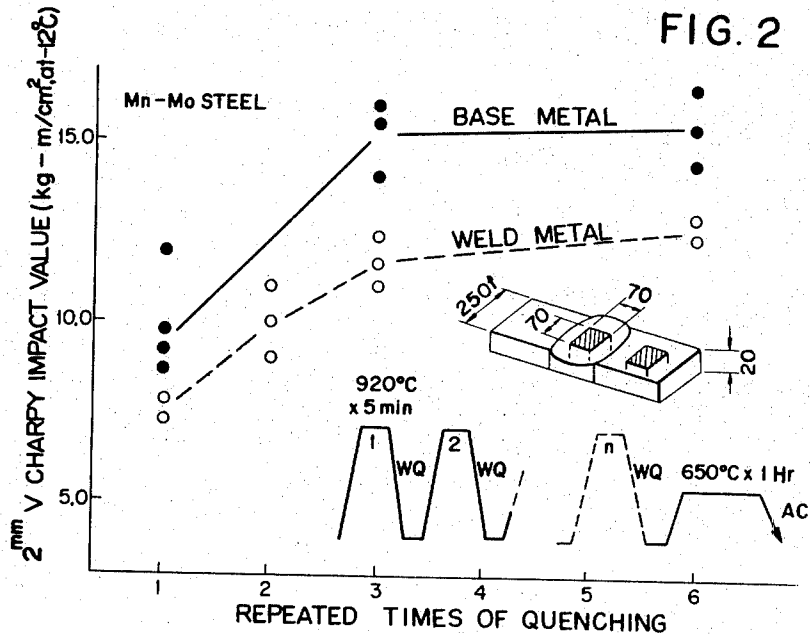
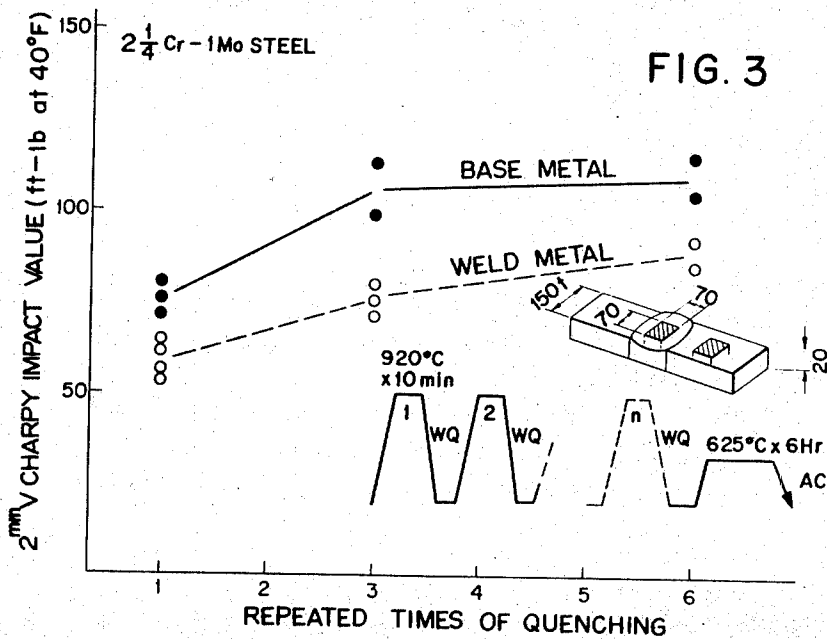


FIG. 1



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METHOD AND APPARATUS FOR QUENCHING TUBULAR SHAPED STRUCTURE

This is a division of application Ser. No. 716,646, filed on Mar. 27, 1968 and now U.S. Pat. No. 3,556,877.

The present invention relates to a method and apparatus for continuously quenching a tubular-shaped thick-walled and large-sized structure.

In the prior art, when a large-sized pressure container or vessel having a thick wall thickness and a large diameter is made of quenched and tempered high tensile strength steel plates, each steel plate is first bent into an arcuate shape, then quenched and tempered and thereafter welded together into a tubular body at a low heat input which does not adversely affect the quenched and tempered effect. Or alternatively, each steel sheet is bent and welded together into a tubular body, the whole structure of which is heated in a heating furnace and then immersed in a water tank for quenching and then tempering. In the first mentioned method, however, only the negative welding method can be utilized in order to avoid the adverse affects upon the quenched and tempered effects, so that the welding efficiency is worse and that the deposit metal must be of higher steel alloy than the parent metal for providing the same strength with the parent metal, because the deposit metal cannot be quenched and tempered and has less strength. In the last mentioned method, any suitable welding method can be applied and the deposit metal can be quenched and tempered, while a large-sized heating furnace, a hoist equipment, a water tank, etc. must be provided. Therefore, the accurate quenching of a large-sized thick-walled structure is difficult.

Bearing in mind the above, it is the object of the present invention to eliminate the above described defects encountered in the quenching method according to the prior art and to effect the positive and accurate quenching by means of a simple apparatus. Thus, the present invention is to provide a method and apparatus for quenching a tubular-shaped thick-walled and large-sized structure, characterized by that the rotating structure is at the upper half thereof continuously heated when it passes through electromagnetic induction heating means, while said structure is at the lower half thereof continuously cooled when it passes through a cooling medium tank, and that the heating and cooling are continuously and repeatedly performed so that successive superimposed quenches may be produced ranging from the skin part of the structure to the center thereof.

Now the invention will be described in more detail with reference to the accompanying drawings in which a typical embodiment of the invention is illustrated. In the drawings:

FIG. 1 is a schematic view showing an embodiment of the invention; and

FIGS. 2 and 3 are graphs indicating results of tests respectively.

In the figure, the reference numeral 1 designates a cooling medium tank; 2, an auxiliary cooling medium tank adapted to supply cooling medium 4 into the first mentioned cooling medium tank 1 through a conduit 3; 5, cooling medium injecting pipes communicated with the conduit 3 and located below the cooling medium level; 6 and 6, rotary supporting bases located on the

bottom of the cooling medium tank 1, and 7 and 8, electromagnetic induction heating coils which are disposed articuately above the cooling medium tank 1 for constructing the heating furnace, 7 being the low frequency electromagnetic induction heating coil while 8, the high frequency electromagnetic induction coil. These coils 7 and 8 are capable of heating a thick-walled tubular structure 9 to the extent that the structure can be heated up to its center by a single heating. Furthermore, the tubular shaped structure 9 to be quenched is supported by the rotary supporting members 6 with its axis being substantially horizontal in such a way that the lower half of the tubular shaped structure 9 may be immersed within the cooling medium 4 whereas the upper half thereof may be disposed above the cooling medium level. The above described electromagnetic induction heating coils 7 and 8 are disposed around the tubular shaped structure 9 in such a way that the structure 9 may be free to rotate.

With the structure described hereinbefore, when the rotary supporting members 6 are first driven in the counterclockwise direction as indicated by the arrow, the electromagnetic induction heating coils 7 and 8 are energized at the same time. Then, during the time when the portion or region of the structure 9 initially located at 3 o'clock (the position which corresponds with 3 o'clock when the tubular shaped structure is assumed to be a clock) moves within the low frequency electromagnetic induction heating coil 7 to the position of 10 o'clock, the portion will be heated by the induction coil 7 up to about 700° C. While this portion passes through the high frequency induction coil 8 from 10 o'clock to 9 o'clock, it will be further elevated to the quenching temperature of about 900° C. Thereafter, the portion is driven into the cooling medium 4 to be rapidly cooled. In this case, the cooling medium is ejected upon the structure as at 7 o'clock from the cooling medium injecting pipes 5, as needs demand, for facilitating the quenching process. The portion being quenched passes through the cooling medium 4 and finally returns to its initial position, 3 o'clock, thus completing the first cycle of quenching. Thereby, the skin part of the structure 9 is heated and quenched. In this case, the speed of rotation of the tubular shaped structure 9 can be suitably adjusted with respect to the inputs applied to the electromagnetic induction coils 7 and 8 so that the heating temperature at 9 o'clock may be adjusted to a predetermined temperature with accuracy. At the same time, the cooling speed at 8 o'clock position can be adjusted by means of the injecting tubes 5 as described above. Therefore, the precise quenching can be effected.

After the first cycle of quenching has been completed, the second cycle follows. In this cycle, more heating is applied while a rotating speed is reduced. Further, the injection of the injecting pipes 5 is adjusted. Accordingly, not only the skin part but also a part thereunder is heated and quenched. As the part under the skin one is quenched under compression stress due to the heating and quenching of the skin part, the quenching effect is good. In the same way, the third cycle continues. Repeating the cycles, successive quenches up to the central part are performed with good results. This superimposed quenching permits the thick-walled tubular structure to be improved in

mechanical properties, especially an impact test value. The test results are indicated in FIGS. 2 and 3.

According to the present invention, a rotating speed of the structure 9, an input of the electromagnetic induction coils 7 and 8, and an injection quantity of the injecting pipes 5 are adjusted in compliance with the concerned cycle of quenching. Thereby, the superimposed quenching is very accurate and effective.

According to the present invention, the heat-treatment equipment can be arranged and disposed compact in size and operated in a simple manner, as compared with the prior art equipment in which the furnace and the cooling water tank are separately disposed and the hoisting equipment must be provided, because the present invention disposes the electromagnetic induction coils 7 and 8 above the cooling medium tank 1 in which the lower half of the tubular structure 9 to be quenched is immersed in such a way that the portion of the structure 9 heated at the upper half thereof is rotated repeatedly for the successive rapid cooling and quenching.

In brief, the present invention provides a method for quenching a tubular-shaped thick-walled and large-sized structure, in which local heating and cooling is continuously performed and adjustment is easy at every quenching. Thus, the repeated superimposed quenching assures accuracy and also good mechanical properties. Furthermore, the apparatus for effecting the quenching method of the present invention is comprised of a cooling medium tank adapted to immerse the lower half of a tubular shaped structure; cooling water injection means; rotary supporting members located within said cooling medium tank for rotatably supporting said tubular shaped structure; and electromagnetic induction heating means disposed above said cooling medium tank. It will be, therefore, clearly understood that compared with the prior art apparatus in which the furnace and the cooling water tank are separately disposed and the hoisting equipment must be provided, the apparatus of the present invention can be arranged and disposed compact in size and operated in a simple manner whereby the cost of operation and installation can be much reduced. It will be readily understood that when the present invention is utilized in manufacturing a tubular shaped structure by welding, the quenching process after welding can be effected in a very simple and accurate manner so that the special operation of and consideration upon the negative welding method, the expensive high alloy welding rod, size-

ble quenching apparatus, etc., can advantageously be eliminated.

What is claimed is:

1. An apparatus for tempering a tubular shaped thick walled steel structure including a tank containing a cooling medium, variable speed-rotatable supporting means to impart rotary motion to said structure while partially immersed in said cooling medium, cooling water injection means disposed within said tank below the surface level of said cooling medium in the path of said rotating steel structure to eject additional cooling medium on said steel structure and heating means disposed above the level of said cooling medium in the path of said rotating steel structure to impart heat to said steel structure, said heating means including a first heating element to impart heat to said structure as it rotates and a second heating element to impart additional heat after the steel structure passes through said first heating element but before said steel structure is immersed into said cooling medium.

2. An apparatus for tempering a tubular shaped thick walled steel structure including a tank containing a cooling medium, variable speed-rotatable supporting means to impart rotary motion to said structure while partially immersed in said cooling medium, cooling water injection means disposed within said tank below the surface level of said cooling medium in the path of said rotating steel structure to eject additional cooling medium on said steel structure and heating means disposed above the level of said cooling medium in the path of said rotating steel structure to impart heat to said steel structure, said heating means including low frequency electromagnetic induction heating coils and high frequency electromagnetic induction coils.

3. An apparatus for tempering a tubular shaped thick walled steel structure including a tank containing a cooling medium, variable speed-rotatable supporting means to impart rotary motion to said structure while partially immersed in said cooling medium, cooling water injection means disposed within said tank below the surface level of said cooling medium in the path of said rotating steel structure to eject additional cooling medium on said steel structure and heating means disposed above the level of said cooling medium in the path of said rotating steel structure to impart heat to said steel structure, said cooling means including valves to vary the intensity of the cooling medium ejected onto the inner and outer surface of said steel structure.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,695,598 Dated October 3, 1972

Inventor(s) Akira Ujiie

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the cover sheet, the name of the inventor should read -- Akira Ujiie --.

Signed and sealed this 27th day of March 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents