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QUENCH HARDENING METHOD FOR RING-LIKE ARTICLES

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FIG. 1

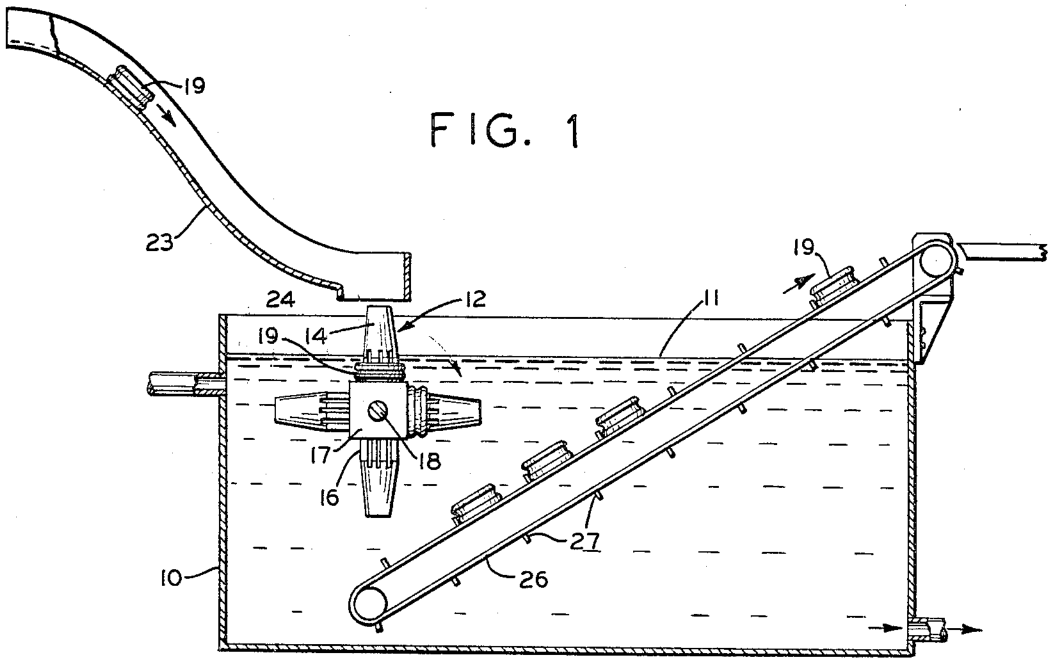


FIG. 2

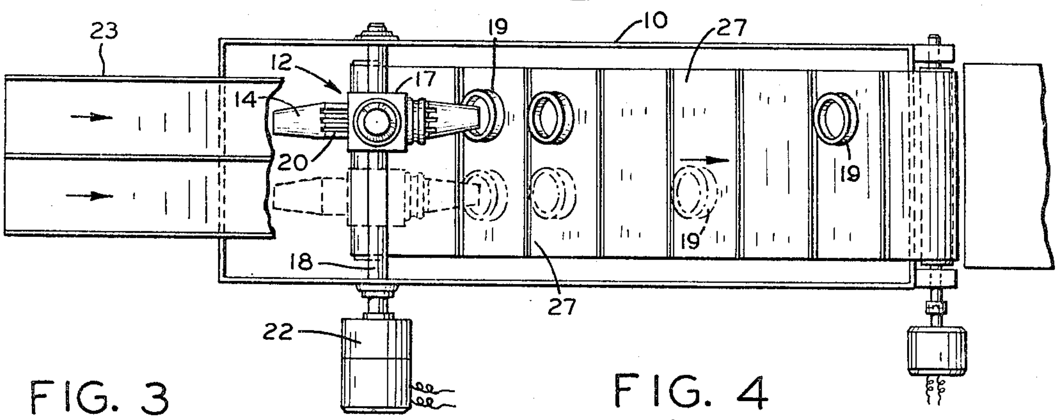


FIG. 3

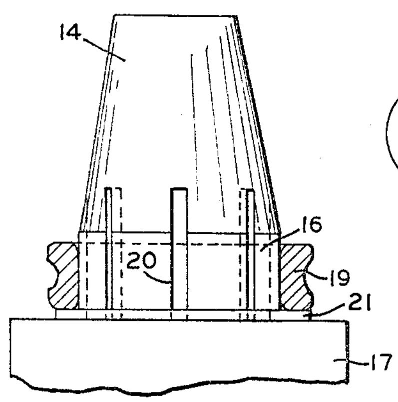
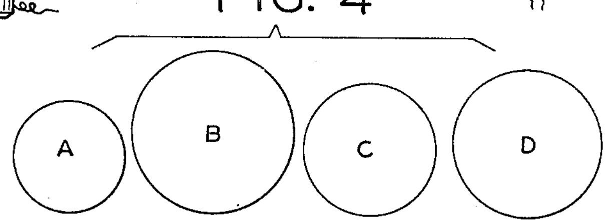


FIG. 4



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QUENCH HARDENING METHOD FOR RING-LIKE ARTICLES

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ABSTRACT OF THE DISCLOSURE

Method of hardening a bearing ring which consists in heating it to the austernizing temperature, placing it onto a solid mandrel in a quenching medium to rapidly cool it down throught the M_s point and continuing the cooling until the ring reaches the temperature of the quenching medium, during which time a compound dimensional change is occurring characterized by a thermal contraction and a simultaneous crystallographic volume increase which is greater than the thermal contraction.

The invention relates to a method and apparatus for hardening workpieces made of through-transformation-hardening steels and which are generally ring-like in shape and relates more particularly to a method and apparatus for hardening anti-friction bearing rings made from such steels.

An important object of the present invention is to provide a method for making rings for bearing races having more nearly perfect roundness than can be achieved by existing methods and at a lower cost than is possible by following conventional practices.

A transformation hardening steel is a steel which can be transformed to hard martensitic structure when cooled rapidly from the austenitic structure. Such steel generally contains 0.4% or more carbon in its chemical composition. For purposes of this invention, the term "through-transformation-hardening steel" is defined as a steel which can undergo a full martensite transformation substantially throughout the cross section of a part made of such steel.

A typical example of a through-transformation-hardening steel is AISI E52100 steel. This steel has the chemical composition, when stated in percentages by weight, as follows: carbon 0.95–1.10, manganese 0.25–0.45, silicon 0.20–0.35, chromium 1.30–1.60, phosphorus 0.025 maximum, sulphur 0.025 maximum and iron the balance.

In conventional quench hardening apparatus for ring-like workpieces, the part is heated to the austenizing temperature, transfered to a die which can be expanded and contracted by a mechanical or hydraulic device, quenched while held to the die at a pre-determined dimension, and released from the die by collapsing or expanding the same. As a result, the hardened ring-shaped part is held to roundness superior to that which can be obtained from free quenching without using any quench hardening apparatus.

The present invention employs novel principles of phase transformation, as well as expansion and contraction due to heat changes, during hardening, and utilizes the advantages of volume differences due to crystallographic and heat changes accompanying various stages of trans-

formation, thus eliminating the use of a complicated and expensive dies with an opening-closing design.

The new apparatus of the present invention includes a mandrel or die having an upper section which is tapered and acts as a guide and a lower section of uniform diameter and of true circular contour, around which the bearing race or other ring-like workpiece is constricted. The upper tapered section guides the heated ring from a feeding chute as it passes downwardly to the circular mandrel section. The latter section is initially positioned just below the level of the quenching medium and in a matter of one or two seconds the reduction in diameter of the ring as the temperature passes downwardly through the MS point causes the ring to seize the mandrel and assume a contour just as circular as the mandrel, after which the ring is lowered in the tank and is inverted. When the ring reaches the temperature of the quenching medium, it has expanded sufficiently for it to fall from the inverted mandrel and onto the bottom of the tank or onto some conveyor means within the tank.

In actual practice, it has been found expedient to mount a plurality of these mandrels on a rotatable support so that they extend radially from the axis. The uppermost mandrel in this rotatable assembly receives the ring, after which the assembly is rotated 90° in the case of a four mandrel set-up and a fresh ring is deposited on the new uppermost mandrel and the assembly rotated again through 90°. This causes the first mandrel to face downwardly and the ring promptly falls from the mandrel.

By way of explanation of the phenomenon of the present invention, it should be pointed out that in the metallurgical science, a ferrous alloy exists basically in one of three crystalline forms. In the annealed state the iron-carbon allow consists of cementite Fe_3C (or other forms of carbide if alloy elements other than carbon are present) in the matrix of ferrite, which is a body centered cubic crystalline structure. When this alloy is heated above the critical temperature (e.g. for AISI E52100 steel it is approximately 1380° F.), the ferrite transforms to austenite, which is a face-centered cubic crystalline structure, and cementile diffuses into the austenite. Accompanying the heating, there is a thermal expansion (coefficient of thermal expansion of approximately 6.6×10^{-6}IN/IN per ° F.), and a volume decrease due to phase transformation. (The volume change in percent is $-4.641+2.21\times$percent C.) Since the thermal expansion is larger than the contraction due to phase transformation, a net increase in dimension results. For simplicity of explanation, the inside diameter of the ring-shaped part in the annealed state is designated as dimension A, and the same dimension at the austenizing temperature is dimension B. From the above reasoning, it can be seen that B is greater than A.

Hardening of the steel is accomplished by rapidly cooling the austenite to a temperature at which a full martensitic condition results instantaneously, a temperature generally designated as the M_s temperature. For any specific grade of steel the M_s temperature is dependent on the austenizing temperature. For AISI E52100 steel austenized at 1550° F. the M_s temperature is approximately 480° F. The cooling rate must be sufficiently rapid to prevent austenite from decomposing into any transformation product other than martensite. During this stage of cooling from the austenizing temperature to

M_s temperature, only thermal contraction is occurring. The inside diameter of the ring-shaped part at M_s temperature is dimension C. It is therefore evident that C is smaller than B.

During quenching of the steel the cooling is carried out uninterrupted from the austenizing temperature to the temperature of the quenching medium and passes rapidly through the M_s temperature. During the imaginary second stage of cooling, i.e., cooling from the M_s temperature to the temperature of the quenching medium, a complicated volume change takes place which is effectively utilized in the process of the present invention. First, a thermal contraction is continuing, and secondly the face centered cubic crystalline austenite transforms into martensite, a body centered tetragonal crystalline structure, resulting in a volume increase of approximately (4.64–0.53 percent). The volume increase due to transformation is greater than thermal contraction in this stage. Accordingly, a net dimensional increase results.

The inside diameter of the ring-shaped part when it reaches the temperature of the quenching medium is dimension D. From calculation it can be deduced that D is greater than C, and also that D is greater than A. We have discovered that by controlling the outside diameter of the solid mandrel in the new quench hardening apparatus to a factor that is smaller than B, but equal to or larger than C, any residual out-of-roundness of the ring-shaped part is eliminated. Furthermore, since the final dimension D is larger than the outside diameter of the solid mandrel on account of the last stage volume expansion, the ring-shaped part can be stripped off the solid mandrel by its own dimensional increase without employing any mechanical or hydraulic collapsing device in the die design. In other words, the pivoted shaft carrying the mandrel is in its last mentioned position, i.e. facing downwardly, and the ring-carrying mandrel is still below the level of the quenching medium. The ring simply drops off the mandrel and onto conveyor means at the bottom of the quenching vessel or onto some conveyor means therein. The time required for the heated ring-shaped part to drop to the bottom face of the solid mandrel from the surface of the quenching medium is insignificantly small compared to the time needed to cool the part from the austenizing temperature to M_s temperature.

In the drawing:

FIG. 1 is a central section through the apparatus of the present invention;

FIG. 2 is a plan view thereof;

FIG. 3 is a side elevation of one of the mandrels with its tapered upper pilot section;

FIG. 4 is a diagrammatic showing of the respective inner diameters of the rings during the several stages, the diameter variations and differences being greatly exaggerated.

The essential details of an apparatus for carrying out the method of the present invention is shown in FIG. 1 wherein a quenching vessel **10** contains the quenching solution up to approximately the level shown at **11**. The mandrel **12** has an upper tapered section **14** and its base section **16** is of uniform diameter and as nearly round as possible. It is mounted on a frame or block **17** on a shaft **18** which is so positioned relative to the level of the quenching medium that the ring **19** is fully immersed in the quenching medium when it is first deposited, usually by gravity feed, on the mandrel. In the arrangement shown there are two banks of mandrels each having four units spaced 90° apart.

In order to assure the quenching solution of contacting a portion of inside area of the ring while at the same time assuring the maximum measure of roundness for the ring as it contracts on the mandrel, the latter is of fluted construction having a plurality of spaced canals **20** to provide for quenching medium flow to the inside of the ring. When the ring is deposited on the mandrel, it is received on a seat **21** of greater diameter than the mandrel.

Any suitable means disposed outside the vessel may be employed for intermittently rotating the mandrel in increments of 90° such as a motor **22** with a speed reduction unit.

The rings are fed, one by one, to the mandrel by an inclined feed chute **23** having a mouth **24** at its lower end and so positioned that the ring must fall substantially at the center of the tapered section **14** and move rapidly downwardly until it is seated. After contracting tightly around the mandrel and its subsequent enlargement earlier mentioned, the ring falls to an inclined moving conveyor **26** having stops **27**.

It was earlier pointed out that the diameter of the solid mandrel is critical. To illustrate the size relationship of the ring as the method proceeds through its several steps, there is shown in FIG. 4 four circles of varying sizes and it will be appreciated that the size variations are greatly exaggerated.

There is shown at A the smallest circle and this is intended to represent the inside diameter of the ring-shaped part in the annealed state. When this ring is heated to the austenizing temperature of about 1550° F. for most bearing ring steels theer occurs a thermal expansion and it achieves dimension B. When the heated ring is dropped onto the mandrel in the quenching medium, the cooling must proceed at a sufficiently rapid rate that martensite is the only transformation product produced.

As this cooling of the ring proceeds, it rapidly passes through the M_s point, which, as earlier stated, is about 480° and when that temperature is realized the ring has an inside diameter of C which is less than B and more than A. In this first cooling stage, thermal contraction only is occurring and during the second stage of cooling from the M_s temperature to the temperature of the quenching medium, the volume increases at a greater rate than the thermal contraction so that at the end of the cycle, the ring has an inside diameter of D which is greater than C.

If the mandrel diameter is equal to or slightly greater than C, the ring tightly contracts momentarily around the mandrel, producing the condition of almost perfect roundness which is not altered during the next volume increase to dimension D. This increase is large enough to cause the ring to slip off the mandrel by gravity and hence to the bottom of the tank or onto conveyor **26**.

What we claim is:

1. The method of hardening bearing rings made of through-transformation-hardening steels to a full martensitic condition by quenching to produce a high degree of roundness in the ring, which method consists in heating the ring to austenizing temperature, then placing it on a mandrel, said mandrel being positioned in a quenching medium, said mandrel having a tapered upper section to guide the ring downwardly and having a seat at the lower end of the mandrel to receive the ring, said quenching medium rapidly cooling the ring down through the M_s point at which martensite forms instantaneously and, until such point is reached, only thermal contraction is occurring, and permitting the cooling to continue for a period sufficient to enable it to reach the temperature of the quenching medium, during which period a compound dimensional change is occurring characterized by a thermal contraction and a simultaneous volume increase which is greater than the thermal contraction, and then swinging the mandrel in a downward direction to allow the ring to fall free therefrom due to gravity, the outer diameter of the mandrel being at least as large as the inside diameter of the ring when it reaches the M_s point, but larger than the outside diameter of the workpiece before it is heated, whereby the ring first contracts tightly around the mandrel to produce a high degree of roundness as the temperature is lowered to that of the quenching medium, said compound diameter change thus producing a sufficient increase in the inside diameter of the ring to cause it to readily fall from the mandrel when the latter has been swung downwardly in the quenching medium.

2. The method defined in claim 1 wherein the mandrel has spaced vertical canals to allow the quenching medium to flow to the inside of the ring.

3. The method defined in claim 1 wherein a plurality of the mandrels are mounted on a rotating shaft and extending radially therefrom are employed for a continuous, repeated operation.

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