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PROCESS FOR ULTRASONIC QUENCHING OF STEEL ARTICLES

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This invention relates to the quenching of steel, and is especially directed to improvements in this operation based on the utilization of ultrasonic waves in the quenching liquid.

In hardening steel by heat treatment followed by quenching, the importance of maintaining uniform cooling throughout the entire surface at the desired rate during quenching is generally recognized, since uneven cooling of different parts of the surface results in softer areas that are subject to greater wear and corrosion.

An object of this invention is to provide a novel method of improving the uniformity of quenching. This is in general accomplished by utilizing the action of ultrasonic waves transmitted through the quenching liquid to the surface of the article being quenched.

A factor which seriously affects the quenching rate and therefore the hardness of the steel is the fact that a vapor layer or blanket tends to form at the surface of the hot steel. The rate of heat conduction by the vapor being substantially different from that of the liquid, the cooling rate is necessarily affected. Moreover, the blanket varies widely in thickness due to differences in the contour of the steel, thus producing different cooling rates at different points, and the liquid tends to break through the vapor blanket unevenly, resulting in further unevenness in quenching. Isolated vapor areas or bubbles also tend to produce soft spots, while agitation of the liquid is desirable, it serves primarily to keep warmer quenching liquid from building up around the steel, and is not effective in breaking up the vapor blanket so as to prevent uneven hardening, especially when the steel piece has blind holes or other recesses that tend to retain the vapor.

An object of the invention is to provide a novel method for substantially eliminating or preventing the formation of the vapor blanket. A related purpose is to accomplish this object by the use of ultrasonic waves. Such waves may be transmitted through the metal; but this practice has two disadvantages. It tends to affect the crystalline structure of the steel that is being quenched, and it is not adequately effective in breaking up the vapor blanket. This is believed to be due at least in part to the fact that waves traveling to an interface between metal and vapor are largely reflected back into the metal. An object of the invention is to provide more efficient dissipation or prevention of the vapor blanket by transmitting ultrasonic waves through the quenching liquid to the metal surface during quenching.

A further object is to provide an improved process of the indicated type in which the action of the ultrasonic waves is enhanced by agitation of the liquid. It has

been found that such agitation cooperates with the ultrasonic wave action in eliminating the vapor blanket and maintaining liquid at uniform temperature in contact with the steel, and that the combination is unexpectedly effective.

Quenching oils are produced in different grades which vary widely in effectiveness and correspondingly in cost. An object of the invention is to provide a process which will produce, with lower grade and cheaper quenching oil, quenching results comparable to those which heretofore required higher grade, more expensive oils. A related object is to produce better quenching, and specifically harder steel, by the use of the same oil.

In heat treatment operations a surface oxide deposit, referred to as scale, will form on the metal surface if exposed to air before immersion in the quenching liquid. This is generally objectionable, since a bright surface is usually desired, and it will also have some effect on the quenching rate. Processes for scale removal and brightening are well known, but involve considerable trouble and expense. A purpose of the invention is to provide an improved process for scale removal, and specifically for removing scale by ultrasonic wave action.

It has been discovered that when the scale is subjected to ultrasonic waves before the metal has cooled, scale is removed to a substantial extent or completely. This may be due to the structural condition of the freshly formed scale, to the fact that it has not had an opportunity to form the bond with the metal surface that takes place when both the metal and the scale have cooled, or for other reasons. In any event, factors aside from temperature are present which make removal by ultrasonics during quenching unexpectedly advantageous; for if the metal is allowed to cool and then reheated to quenching temperature the scale is materially harder to remove by the same process.

Another object is to improve quenching by the removal of scale in the early stages of quenching, thereby exposing the bare metal to the quenching liquid. A further object is to provide a process that will improve quenching by both removing scale and eliminating the vapor blanket through the same continuing procedure, and specifically, by the use of ultrasonic waves.

When steel articles are quenched by ordinary procedures the hot metal breaks up a certain amount of the oil, freeing carbon which forms an objectionable coating at the surface of the metal. It has been found that this effect can be prevented by subjecting the articles to the action of ultrasonic waves in the manner already indicated. An object of the invention therefore is to inhibit the formation of a carbon coating on steel during quenching, and specifically to accomplish this object by the use of ultrasonic waves in the quenching liquid.

A further object is to provide an improved process for brightening steel. This is in general accomplished by scale removal in the manner indicated, and is advantageous partly because of the greater ease with which scale is removed before the steel cools, but mainly because it eliminates in many instances the separate operation of removing scale from quenched steel to brighten it that is now required in many instances.

When quenched articles are removed from the liquid a certain amount of the quenching liquid, commonly oil, adheres to them and must be removed. In large operations the amount of oil lost in this manner, known as

"drag-out," may be of substantial value. An object of this invention is to reduce substantially the quantity of quenching liquid, and specifically oil, that is removed from the bath on the quenched articles. An ancillary purpose is to provide a process utilizing ultrasonic waves to accomplish the latter object.

A further general object is to provide an improved process in which a single set of operating conditions which establish ultrasonic wave activity in the quenching liquid may be utilized to accomplish any two of the above indicated operations, or all three of them, in combination, without materially changing such conditions. More specifically, descaling and vapor blanket elimination, or blanket elimination and drag-out reduction may be accomplished in combination by successive stages of the same ultrasonic wave conditions according to this invention. A related object is to effect these results by continuous operation.

Other objects and advantages will appear from the following description and examples; but it is to be understood that the examples are given to illustrate the practice of the invention, and not by way of limitation.

The process is carried out in a container for the quenching liquid, connected to a source or sources of ultrasonic waves in such manner that waves of the required energy are transmitted through the liquid to the surface of an article immersed therein. Various arrangements of this type are known, generally including a wave generator engaging a wall of the container, though immersion generators have also been developed. Moreover, magnetostrictive transducers are particularly suited for use as wave generators in this process, due to the power they can develop and the fact that the frequencies at which they operate efficiently and satisfactorily, ranging from sixty kilocycles down to fifteen kilocycles per second, have been found especially effective in the process herein set forth, with unexpectedly good results between fifteen and twenty-two kilocycles.

A type of apparatus that has been found to be eminently adapted to the practice of the present process is illustrated in United States patent application Serial No. 405,756, Brown, filed January 25, 1954, now Patent No. 2,815,193. It includes one or more magnetostrictive transducers rigidly connected to the bottom of the container. The wave generating apparatus, whatever the type, must develop in liquid in the container ultrasonic waves that will produce cavitation along substantially the entire surface of a heated article immersed for quenching. With apparatus of the indicated type a frequency of approximately 18 kilocycles and sufficient energy to produce cavitation throughout the quenching zone have been found effective.

Procedures and precautions normally observed in quenching should be employed. Scale formation is rapid when the heated article is in air between the furnace or other heating apparatus and the quenching bath; but the present invention minimizes the effect of such scale. In the examples the specimens were in air between two and three seconds, paralleling a known commercial quenching operation. The articles being quenched should of course remain in the liquid until the effect of quenching is complete, in accordance with standard practice. In the examples the specimens remained in the liquid for ten minutes.

The process is illustrated by the following examples:

Example 1

Cylinders of 1095 steel approximately 1 cm. in diameter and 4.5 cm. long are heated in a suitable furnace, such as a Lindburg furnace, at 1550° F. for one hour. They are then quenched in mineral oil at 120° F. for ten minutes. The oil is contained in a Bendix ultrasonic unit, type UTL2–UG2, made at Pioneer-Central Division of Bendix Aviation Corporation, Davenport, Iowa, having a magnetostrictive transducer suspended in coolant from the bottom of a container supported by its upper rim, corresponding generally to the disclosure of the above-mentioned Brown application. The hardness of the quenched steel cylinders will be substantially greater than that of identical cylinders treated in exactly the same manner except that they are quenched without ultrasonic wave activation. In one series of tests, for example, the cylinders quenched in ultrasonically activated oil had an average surface hardness of 48.2 on the Rockwell "C" scale, while the control cylinders had an average surface hardness of 35.2 on the same scale, tests being made with a Rockwell hardness tester.

Example 2

The quenching and testing procedure of Example 1 is followed, the only difference being that the quenching oil is Quenchol 521, marketed by Sinclair Oil Co., a petroleum oil characterized by a flash point of 355° F., fire point 410° F., viscosity at 100° F. 90–110 SSU (Saybolt seconds universal), viscosity index 115, and ASTM color dark green. The average hardness of the ultrasonically quenched cylinders was 58.6, while that of the control cylinders was 53.3.

Example 3

Cylinders of 874C steel one inch long and one inch in diameter are heated for one hour in a Lindburg furnace at 1425° F. They are then divided into four groups. Group A is immersed in quiescent oil, while group B is immersed in oil violently agitated by an impeller. Known types of agitation may be used, one effective arrangement employing an axial shaft driven at 12,000 r.p.m. with an impeller located near the bottom; and an impeller with four blades, an inch and a half in diameter with a 15° pitch, provides sufficient agitation in a small container. Group C is immersed in oil that is ultrasonically activated, that is, oil carrying ultrasonic waves of sufficient energy to produce cavitation at the cylinder surfaces, but otherwise quiescent; and group D is immersed in oil that is similarly ultrasonically activated and also violently agitated in the same manner as group B. The oil in every case is paraffin oil, and the cylinders are immersed for ten minutes. Each cylinder is then cut transaxially in half, exposing the center cross-section, and hardness readings were made at the center of such section and radially at one-eighth inch intervals, with a Rockwell hardness tester. The readings will show progressively greater hardness in the four groups, with group B cylinders (agitation alone) harder than group A, group C (with ultrasonics alone) harder than group B, and group D (ultrasonics and agitation) harder than group C. In each case the hardness measurement at the outer point, one eighth inch below the original surface, will be greater than the hardness at the center, with intermediate hardness values at test points between the outer point and the center.

Example 4

The quenching and testing procedure of Example 3 is followed, the only difference being the use of a high grade quenching oil, specifically Super Quench Oil, marketed by Gulf Refining Co., a petroleum oil characterized by a flash point of 345° F., fire point 385° F., viscosity at 100° F. 88.4 SSU, viscosity index 105, API gravity 31.7, pour point 20° F., and ASTM color NPA dark.

The test results on the four groups will have the same relationships as those of Example 3, though the hardness of all points in a particular group will be greater than the hardness of homologous points in the same group in Example 3, and the difference between the hardness of group C and that of group B will be much greater, indicating greater superiority of ultrasonics over agitation with this type of oil.

The types of steel employed in the examples are iden-

tified by SAE numbers, and are described in publications of the Society of Automotive Engineers, including their 1955 Handbook, pages 51–55.

I claim:

The method of reducing quenching liquid loss in quenching steel objects in such liquid which comprises passing ultrasonic waves through the liquid at an energy level sufficient to produce cavitation at the surface of the steel objects during the removal of the quenched steel objects from the quenching liquid.

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