Jan. 22, 1957 N. BREDZS 2,778,756

PROCESS FOR HARDENING STEEL

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FIG. 1

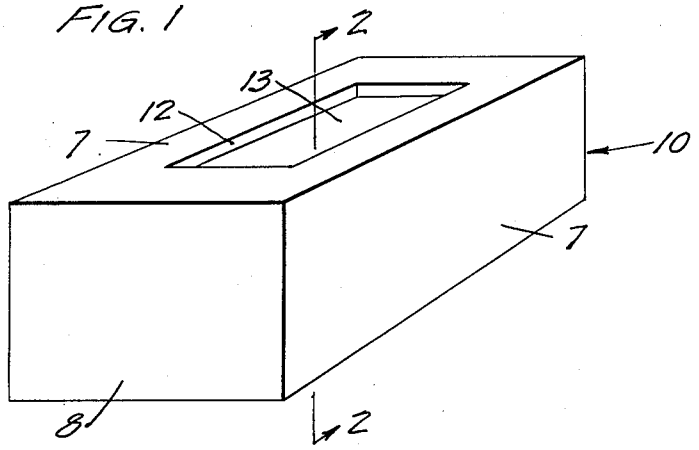


FIG. 3

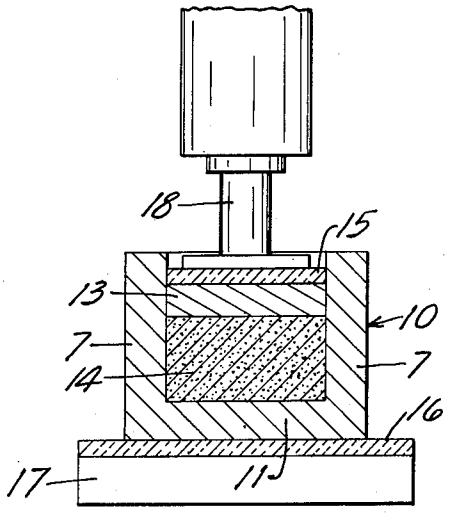
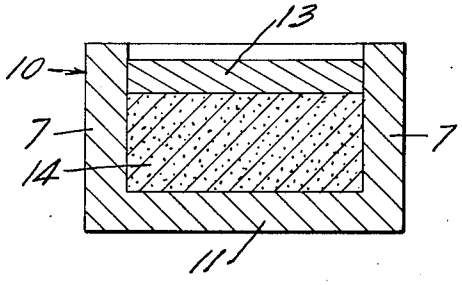


FIG. 2



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PROCESS FOR HARDENING STEEL

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2 Claims. (Cl. 148—21.5)

This invention relates to a method and to apparatus for hardening steel.

This application is a continuation-in-part of my copending application, Serial Number 198,111 filed November 29, 1950, now abandoned.

The steel referred to herein is that having a percentage of carbon normally lying in the range between 0.3% and 1.0%. The invention is intended to include those hardenable alloys of carbon steels which are of a nature such that the alloying metal is present in small quantity and does not fully compensate under ordinary conditions for the deleterious effect of a delayed rate of cooling upon the steel during the hardening process. One of the objectives of my invention is to acquire in ordinary steel a uniformity of high quality hardening comparable to that obtained in an alloy steel having a high percentage of chromium, vanadium, molybdenum, tungsten, manganese, and the like, without the expense of adding any, or only nominal amounts, of such alloying material. I am therefore not concerned with alloy steels excepting those in which the amount of expensive alloying metal compensates only partially for the lack of uniformity throughout the body of the steel after it has been hardened. In the case of conventional carbon steels, a percentage of carbon less than 0.3% will produce a material approaching the qualities of pure iron. That is to say, pure iron of itself is not capable of being hardened at all. Steels having an amount of carbon under 0.3% will not be capable of hardening sufficiently to fall in the category of hardenable steels. On the other hand, steels which contain over 1.0% carbon fall in the category of gray cast irons and these may become so brittle upon hardening that the benefits of hardening will be overshadowed by the breakability of the material. Insofar as the hardened product having a carbon content over 1.0% is useful, my invention applies also to the hardening thereof.

The steel product within the scope of this invention, as above specified, undergoes a transformation when it is heated upwardly through a red heat. The usual transformation temperature of carbon steels lies close to 1333 degrees F., although it is to be understood that the transformation is not a sharp and instantaneous phenomenon. The structure of the steel above the transformation temperature is known as austenite. Austenite exists only at the hot temperature and is a solid, homogeneous solution of carbon in iron. The iron is not necessarily heated to the point where it becomes fluid, but nevertheless is capable of holding in homogeneous solution all of the carbon present in a carbon steel of the class described.

Now, however, when the austenite steel is allowed to cool, it may form one of several chemical and physical structures or a combination of the structures. A portion of the carbon present in the austenite will form iron carbide having a molecular formula Fe_3C. This material is known as cementite and, if the crystals of cementite are large, the steel will be soft and ductile. The steel having a matrix composed of iron with cementite crystals interspersed is known as pearlite. Where the hardest steel is

desired from a given carbon steel formula, it is the desire of the metalurgist to reduce to a minimum the formation of pearlite. Heretofore, the formation of pearlite has been suppressed or eliminated by one of two commonly employed means.

The first is the addition of one or more alloying metals, such as those mentioned above, in quantities sufficient to achieve improved hardening despite variations in the rate of cooling during the hardening process. As pointed out previously, such alloys with steel are expensive, yet have been deemed necessary in achieving uniform hardness throughout thick sections.

The other method of preventing the formation of pearlite has been known for centuries and constitutes a chilling or quenching of the hardenable steel from the austenitic condition down to a condition at a lower temperature incapable of reforming the iron-cementite mixture known as pearlite. It is understood, of course, that the metallurgist can acquire various degrees of hardening by the rate of chilling or quenching as well as by varying the composition of the steel. The ideal conditions under which the cooling or quenching occurs is a rapid and instantaneous cooling without the development of internal strains and with a perfect preservation of uniform structure approaching, in a cold state, the homogeneous structure of the high temperature austenite. This ideal cold structure of hardenable steels is known as martensite but the relative amount and uniformity which are desired are seldom obtained. For example, if the steel body has a thickness of four or five inches, the outer surface to a depth of about one inch will quickly chill under quenching to give a substantial proportion of the martensite structure. The internal portions of the body will cool at a slower rate and, hence, will form some cementite and iron. Pearlite has a lesser density than martensite at the same temperature. The steel body will thus have a hard case with strains set up throughout the structure and have a certain portion of pearlite medially of the body which will not give the maximum hardness throughout. My invention is directed toward the elimination of the above noted disadvantages through a new and improved method of hardening steel. It is understood that I make no claim for a new type of microscopic or chemical structure within a hardenable steel, nor do I add to, detract from or otherwise adjust the elements and their percentage relationship so as to deviate from ordinary conventional steel formulae.

It is a general object of my invention to provide a new and improved method and apparatus for hardening ordinary steel in a cheap and relatively simple manner and with a high degree of efficiency.

A more specific object of the invention is to provide a novel method and apparatus for hardening carbon steel to achieve a uniform, high-quality permeation of martensitic structure, yet employing a low rate of cooling heretofore deemed incapable of hardening an ordinary carbon steel.

Another object is to provide a new and improved method and apparatus for deeply hardening carbon steel which, through the use of controlled pressure and temperature, will achieve results comparable to those obtained through the use of expensive alloying metals as ingredients for the steel.

Another object is to provide a method and apparatus for hardening carbon steels, the use of which will result in substantially uniform and entire hardening by the formation of martensite throughout the mass of steel.

It is a further object to provide a method and apparatus for hardening carbon steels which will eliminate or greatly reduce internal strains normally set up by case-hardening effects in conventional hardening processes when applied to masses of steel of a magnitude such that

the rate of cooling in the central portions is substantially less than that at the outer or case portions.

A still further object of the invention is to provide for hardening carbon steel at a reduced rate of cooling and without quenching in an immersion bath regardless of the size and shape of the steel object to be hardened.

These and other objects and advantages will more fully appear from the following description made in connection with the accompanying drawings wherein like reference characters refer to the same parts throughout the several views and in which:

Fig. 1 is a perspective view of my molding or encasing structure with the steel body to be hardened disposed internally therewithin;

Fig. 2 is a cross section of the apparatus illustrated in Fig. 1 taken on the line 2—2 therein; and

Fig. 3 is a diagrammatic representation of the apparatus shown in Figs. 1 and 2 with pressure applied between a ram and a base structure, unessential details of the apparatus being cut away.

When eutectoid, hypereutectoid or hypoeutectoid steel has been heated to a temperature above its transformation and then is cooled, considerable alterations in volume result from such cooling. As previously noted, when the steel is quenched, a martensitic structure is attained, at least in the casing depth of the steel article which is quenched. The martensitic structure has a density considerably greater than that of the austenite structure. On the other hand, if the steel is allowed to cool slowly, as by exposing to atmospheric air, there will be considerable pearlite formation during the cooling process. The pearlite structure has a density less than the martensite. Because of these alterations in volume, the transformation from austenite to the stable form is sensitive to pressure.

I have discovered that by applying pressure to the steel while at or above its transformation temperature, it is possible to get a good yield of martensite structure at a much slower rate of cooling. Furthermore, this formation of hard martensite will be uniform throughout the entire mass of the steel and, hence, will eliminate strains normally set up by non-uniform transformation. Obviously, where the casing portion of a steel article has one density and the internal portions of the article has another density, the uneven shrinking of the metal will result in stresses and strains deleterious to the strength of the hardened steel article.

Thus, by practising my invention, I can transform small or large bodies of steel of the class described into hard steel having uniform structure throughout. Furthermore, I accomplish this by applying high pressures and by employing a rate of cooling slow enough to prevent case hardening or the transformation of only a shell portion of the steel body while the internal portion still remains in austenitic form. The rate of cooling which I employ is such as would result in a substantial formation of pearlite if the pressure were not applied, other conditions remaining the same.

My process thus completely eliminates quenching by immersion in a liquid bath and not only causes the same or a greater hardness than by liquid quenching, but will permeate the entire mass of the steel body without setting up internal stresses and strains.

Bodies of ordinary eutectoid, hypereutectoid or hypoeutectoid carbon steel in the order of four inches in diameter, for example, will acquire a hardened shell of about one inch when quenched in a liquid bath. The internal body will have an increasingly greater amount of pearlite toward the center because of the lag in cooling. The outer portions are chilled quickly but, since the thickness of the material progressively delays the transfer of heat from the central portions, the pearlite is allowed to form. This formation of pearlite cannot be avoided except by changing the formula of the steel. Alloying metals such as molybdenum have been successfully employed to harden carbon steels at a slower rate so that a steel having one percent of molybdenum will have its hardening depth increased from one inch to two inches. Where thicker sections are to be tempered or hardened, a four percent molybdenum alloy will generally achieve a homogeneous hardness throughout. The molybdenum steel alloys are very expensive, however, and obviously the greater percentage of molybdenum, the greater the cost of fabrication thereof. My invention will achieve hardening characteristics in carbon steel bodies which closely simulate those of expensive alloyed steels with the addition of minor amounts, or no amount at all, of such alloying elements.

Apparatus which may be utilized to facilitate the formation of hard steel by my method is shown in the accompanying drawing. The apparatus may include an encasing structure or mold indicated generally at **10** and having a floor **11**, side walls **8** and end walls **9**. Internally of the structure is an encasing chamber **12** within which a cover **13** closely fits. The cover **13** is removable from the encasing structure and is adapted to slide downwardly in closely interfitting relation. The entire encasing structure, including the cover must be formed of heat resistant material which can withstand deformation at temperatures above the transformation point, namely in the range of from 1350 to about 1500 degrees F.

In carrying out my process or method, a steel article to be hardened is indicated at **14** and is placed in the encasing or mold **10** in close contacting relation with the internal walls thereof with the cover **13** placed in position thereover and likewise in contact therewith. The entire encasing structure, together with the steel article, is subjected to a temperature in excess of the transformation point of the carbon steel article. I prefer to heat the entire mass to about 1500 degrees F., being sure that the temperature is uniform throughout. I then place a heat insulating member **15** upon the movable or cover portion **13** and a similar heat insulating member **16** in opposed relation beneath the encasing structure **10**. The assembly is then placed between converging compression members such as fixed base **17** and a ram **18**. Pressure is applied between the compression members until the desired ultimate pressure is acquired. I then prefer to maintain this pressure throughout the remainder of the process. In the simplest form of my process, the encasing structure is merely allowed to stand at ordinary room temperature while the heat is dissipated evenly and uniformly from the steel article and from the steel encasing structure. The rate of cooling which I prefer to attain is not so rapid as will cause case hardening of the steel article and on the other hand is not so slow as to render the process uneconomical from the standpoint of time. In the broadest sense my process consists merely in maintaining a high enough pressure throughout the uniformly heated hardenable steel body from above the austenitic transformation point down to a point where the steel body has cooled to a stable form typified by substantially a martensitic structure. The pearlite formation will thus be minimized or avoided irrespective of the rate of cooling.

I have found that pressures in the neighborhood of 18 or 20 tons per square centimeter will give me the results which I desire. I do not have sufficient experimental data to show how the minimum pressure may vary from one steel composition to another but I do have sufficient data to show the general effect of pressure upon the transformation characteristics of plain carbon or eutectic steel.

One very important feature of my invention is the prevention of the formation of a skin casing around my steel article during the hardening process. Thus, even if the article were to be heated well above the transformation temperature, say 1500 or 1600 degrees F. and the apparatus by which compression was applied was not heated to a comparable degree, there would be a quick heat exchange to the encasing to the mold or encasing

structure which would bring a thin layer of the article down below the transformation point. Since only a few thousandths of an inch of hard skin can resist a tremendous amount of pressure, it will thus be seen that the hydrostatic pressure effects which I desire could not be readily achieved. It is for this reason that I heat the article to be hardened directly within the mold structure and, when applying pressure, employ heat insulating devices to prevent too rapid a transfer of heat from the mold or mold cover to the converging elements of the compression device. As previously pointed out, the mold structure must be constructed of a heat resistant material which will not deform under the pressures applied.

By way of example a specific procedure which I have employed utilized a mold or encasing structure having a thickness of 1 inch throughout. The encasing structure was constructed of a high chrome steel having 18 percent of chromium in the alloy. This composition gave satisfactory results and showed no deformation at temperatures in the neighborhood of 1500 degrees F. The mold cavity accommodated in closely fitting relation a bar of carbon steel having a cross section 3 inches square, the carbon steel subject to my process at a composition just above the eutectoid, namely 0.9 percent carbon.

The mold and the carbon steel body were then heated in a furnace until the entire mass of both the steel body and the encasing structure together with its cover had attained 1500 degrees F. At this point, Transite insulating sheets were laid upon a press base and upon the mold cover and the compression ram was brought down upon the cover of the mold in opposed relation to the base of the press. The compression was then increased until a pressure of 18 tons per square centimeter was reached. The mold and its compressed body were then allowed to cool in atmospheric air, the rate being calculated at 300 degrees F. per minute. Pressure was maintained at 18 tons per square centimeter until the steel body had cooled to a stable condition. Upon examination of the internal structure of the carbon steel body there was no pearlite present at all, the body being strictly martensitic.

The process of the foregoing example was repeated at higher and lower pressures, from which it was ascertained that it was not necessary under the conditions stated to use a pressure in excess of 20 tons per square centimeter. On the other hand, if the pressure were

decreased to 15 tons per square centimeter the results were only partially satisfactory. Undoubtedly, further tests will show that alloys and carbon steels of different composition will require different amounts of pressure. The crux of my invention, however, is the discovery that pressure per se can prevent the formation of pearlite during a rate of cooling considerably less than that attained by liquid quenching.

It will, of course, be understood that various changes may be made in the form, details, arrangement and proportions of the parts without departing from the scope of my invention.

What I claim is:

1. The method of treating a mass of hardenable steel consisting in heating the mass to a temperature at least slightly above its transformation temperature to form a homogeneous austenitic structure, maintaining said article at such temperature throughout while simultaneously applying a pressure amounting to at least 15 tons per square centimeter over the surface of said mass to minimize the formation of a pearlite structure upon cooling, and permitting said article to cool at a moderate rate under the influence of said pressure whereby the steel will be transformed directly from an austenitic structure to substantially a martensitic structure.

2. The method set forth in claim 1, wherein said mass is rigidly mold-encased throughout the heating, pressurizing and cooling steps.

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