

UNITED STATES PATENT OFFICE

2,266,565

HEAT TREATMENT OF STEEL

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No Drawing. Continuation of application Serial No. 153,520, July 14, 1937. This application September 19, 1938, Serial No. 230,659

4 Claims. (Cl. 148—14)

This invention relates to the heat treatment of steel, and more particularly is concerned with the heat treatment of the nickel alloy steels used in gears, driving members and the like commonly employed in automotive vehicle fields.

The present invention will be described in detail in connection with the treatment of gears and similar articles, and is a continuation of my copending application, Serial No. 153,520, filed July 14, 1937.

It has been customary, in the heat treating of gears, to heat the gears initially to a temperature somewhere around the critical temperature, after which the heated gear is quenched and then reheated up to a point slightly below the critical temperature. Such treatment heretofore appeared to be adequate for passenger car gears and the like, which have appreciably smaller loads and service requirements than the gears used in busses and trucks.

I have found that this type of treatment did not produce gears that would stand up under the required load and service demands of the larger and more powerful vehicles. An examination and study of the gears revealed that the outer surface or case of the gear was in an austenitic condition, i. e., contained an appreciable amount of austenite, which is a characteristic state of the metal which renders it soft and subject to cracking and spalling under high pressure engagement. This austenitic condition was brought about by the initial heat treatment of the gear termed "carburizing" and the subsequent quenching in oil, which provides the desired core condition in the piece. The reheating and further quenching formerly employed had little effect on this case or surface and as a result, the austenitic condition persisted in the finished article.

Heretofore it was believed that such a condition was under some circumstances desirable in gears, since it provided a more or less ductile surface which in running of the gears would work into a smooth face. However, I found that under heavy loads the austenitic condition produced scuffing and spalling of the tooth surfaces, and resulted in rapid deterioration of the piece.

In studying this condition I discovered that in attempting to convert the austenite into martensite, a harder and more durable case or surface, the molecular formation somehow changed, and there was an increase in volume which was quite appreciable. Further experimentation disclosed that while the change from austenite to martensite produced an increase in volume, the

change from martensite to troosite, sorbite and pearlite produced corresponding decreases in volume. In other words, martensite was at the upper limit of the change in volume curve for these physical states at the surface and change either toward austenite or sorbite produced a decrease in volume.

After observing this phenomenon, the recodite cause of previous gear failures became apparent. A gear as previously treated with an austenitic condition at the surface, when placed in service, would, under the pressures obtained and the temperatures at which it was run, be gradually converted toward the martensitic condition. This produced internal stresses which contributed to the deterioration of the gear surface, and at the same time, the increase in volume increased the operating pressures and thereby self-promoted spalling and cracking along the tooth surfaces.

It is therefore a primary object of the present invention to overcome the defects in gears and other members or articles subjected to high loads and operating pressures and to produce a method of heat treating such articles so that the failures heretofore found prevalent in such articles shall be eliminated.

The present invention broadly comprises the initial carburizing of a ferrous metal article at a sufficiently high temperature to relieve internal stresses in the core, refine the grain structure thereof, and effect a good depth of case for the particular article. For example, in gears the depth of the case may be from .055 to .070 inches. The article is then quenched in oil, but the rate of cooling from the carburizing temperature is such that the case contains an appreciable amount of free austenite, which is extremely undesirable.

The next step in the process consists in tempering or drawing the piece for several hours, depending upon its composition and depth of case, at a temperature which is below the critical temperature of the case and which will entirely eliminate the austenitic condition in the case, the austenite in the case changing through the martensitic condition to a lower condition such as a sorbitic or pearlitic condition, or both. The piece is then cooled down to close to room temperature prior to the next heating stage.

In the final heating the piece is brought up to a temperature approximating the critical temperature range of the case to allow the reactions in the case to take place. This produces a refinement of the grain structure in the case. The

reactions in the case during this stage produce a martensitic and probably an austenitic condition in the case, accompanied by an increase in volume such that substantially the maximum volume is obtained.

Upon quenching in oil from this final temperature, the rate of cooling is sufficiently slow to change any austenite in the case to martensite, whereby the maximum volume is obtained, and is sufficiently fast to prevent the change into a sorbitic or pearlitic condition. The piece after this final quenching, therefore, has a refined core and case grain structure, and also has the case in a substantially true martensitic condition. The article is thus provided with a hard wear-resisting case, and no growth or increase in volume is produced in use, thus entirely eliminating any inherent tendency to spall or crack.

I will now describe in detail the treatment of an article such as a gear in accordance with the disclosure of the present invention. A gear made of steel having the following composition:

Carbon	.10-.20
Manganese	.40-.60
Nickel	3.25-3.75
Molybdenum	.20-.30

is chosen in order to illustrate the invention. It falls within the groups of nickel steels identified hereinafter as the type of steels to which the invention is particularly adapted.

An article such as a gear or a similar member is first placed in a furnace and carburized at the desired temperature, which in a preferred form of the present invention is from 1650° to 1700° F. This carburizing is usually continued over a considerable period of time, such as eight hours, and in the latter part of the carburizing treatment the furnace temperature is dropped to approximately 1550° to 1575°. The length of time that the article remains in the furnace depends upon the depth of case required, but I have found that for a case depth of from 0.55 to 0.70 inches, about eight hours is the proper time at the temperatures stated.

From this last zone of the furnace, the piece or article is directly quenched from its temperature of 1550° to 1575° in a bath of oil which brings it down to approximately room temperature.

In this condition the core of the article has been properly conditioned, and a substantial portion of the internal stresses have been eliminated. At the same time, a surface layer or case has been formed upon the quenching which follows the carburizing treatment, and which produces an austenitic condition in the case. This free austenite in the case is highly disadvantageous because it is relatively soft, and under heavy loadings and high operating temperatures, has a tendency to spall off or crack, which results in rapid deterioration of the article when placed in use.

Another disadvantage of such a condition is that the operating pressures under heavy loads are sufficient to convert a portion of the free austenite into martensite, which is substantially harder and more wear resisting than the austenite. While a martensitic condition is desired in the case, the formation of such a condition during actual use is extremely disadvantageous due to the fact that in the conversion from austenite to martensite, there is an increase in volume, and as the article is in position and in being driven under load this increase in volume

will quickly result in self deterioration of the member due to the decrease in clearance caused by the increase in volume. I have found that this situation has been the recondite cause of a large number of gear failures under these conditions. It was only after appreciating the fact that the increase in volume produced by a change from the austenitic to the martensitic condition would occur when a gear having free austenite on its surface was placed under heavy load that the cause for such gear failures could be determined.

The next step in heat treatment of the piece consists of drawing or tempering the same at a temperature of approximately 1100° F. for a period of approximately two hours. I have found that drawing at this temperature results in the conversion of free austenite through the martensitic into the sorbitic condition. While slightly lower temperatures might be used in this operation, under such lower temperatures the change of state is not as rapid, and a considerably longer period would be necessary for this conversion. The drawing temperature of 1100° appears to be the most satisfactory for this purpose as the time necessary for the conversion is thereby reduced to a minimum, while no appreciable danger of going over into any of the lower states is present. However, under proper conditions, this drawing can be carried on at any temperature from 1000° to 1250° F.

While the article might conceivably be further treated by immediately reheating, under preferred shop conditions the article is then allowed to cool and is then reheated to a temperature less than the carburizing temperature and insufficient to reconvert the martensite to austenite upon quenching. I have found that the critical temperature for such reheating is between 1400° and 1450°, with best results being obtained in the range between 1425° and 1450°. This reheating is carried on only until the entire piece has been heated to this temperature, and held at such temperature for a sufficient length of time for the reactions in the case to take place. The time should be long enough to allow the entire piece to be uniformly held at the temperature desired so that any free carbon will go back into solution, as well as cementites that may be present, but not long enough to produce any grain growth. The piece is thereafter again quenched in oil and is then ready for use. I have found that the reheating temperature should be substantially equal to or preferably even slightly greater than the critical range of temperature for the metal being treated in order that the rate of cooling upon quenching be such that it is not sufficiently rapid to produce an austenite, nor sufficiently slow to produce lower sorbitic or pearlitic conditions, but provides for a martensitic condition in the case.

I have found that by such heat treatment, I am able to produce an article which may be employed as a gear or other driving or driven member which has the proper core structure, and which at the same time is capable of resisting wear on its surface even under extremely high loads and heavy pressures. This is due to the fact that a martensitic condition has been retained upon quenching of the piece subsequent to the reheating of the piece after the intermediate drawing operation, thereby insuring that the finished article will have the hard wear surface characteristic of a martensitic condition, and there will be no subsequent increase in vol-

ume due to a change of condition produced by heavy loading.

In previous types of heat treatment of gears and the like this increase in volume, together with the presence of free austenite, was sufficient to cause failure of the gear in a short time by spalling or cracking of the case surface. This has been entirely eliminated by the present process. Since any change from the martensitic condition results in a decrease in volume, it is obvious that there can be no self promotion of the spalling or cracking produced under heavy loads, and the martensite surface in itself is extremely resistant to wear.

I have found that the heat treatment described above is effective on all types of alloy steels, which are characterized in that an austenitic condition is produced in the case upon quenching from the carburizing temperature. Variations in the composition of the alloys may be made within relatively wide ranges so long as the metal retains the characteristic of producing the austenitic case condition upon the quenching after carburization. The particular treatment disclosed I have found to be extremely successful on nickel alloy steels such as the SAE-4615 or 4815 groups.

While I have described the present process particularly in connection with the treatment of gears, it is to be understood that it may be equally well applied to other similar members operating under similar conditions. It is to be understood that the particular temperature ranges given herein are illustrative only of a preferred manner of carrying out the invention, and that slight variations therein may be employed to meet special conditions without departing from the underlying principles of the instant disclosure. I therefore do not intend to be limited to the exact details shown and described, but only insofar as defined by the scope and spirit of the appended claims.

I claim:

1. The process of heat treating a gear consisting of a nickel alloy steel having 3% to 4% nickel which on carburizing and subsequent oil quenching provides an austenitic case condition, which

comprises initially carburizing said gear at a temperature of from 1650° to 1700° F., dropping said temperature in the latter portion of said carburizing to 1550° to 1575° F., quenching said gear, drawing said gear for a period of two hours at approximately 1100° F., then reheating said gear for a time sufficient to bring the gear to a temperature of from substantially 1400° to 1450° F. and re-quenching said gear.

2. The method of treating a nickel steel article containing from 3% to 4% nickel to stabilize the surface thereof to resist operating forces thereon, which comprises carburizing the article to stabilize the core and case-harden the surface, quenching in oil, heating for about 2 hours at a temperature within the range of 1000° to 1250° F. to draw the case, cooling the article from said drawing treatment, heating the article at a temperature in the range from 1400° to 1450° F. until the temperature of the article is within the said range, and quenching the article, whereby the case contains a high content of martensite.

3. The method of treating an austenitic case-hardened article of nickel steel alloy containing from 3.25 to 3.75 nickel which comprises heating the said article for about 2 hours at a temperature within the range of 1000° to 1250° F. to draw the case, cooling the article from said drawing treatment, heating the article at a temperature in the range from 1400° to 1450° F. until the temperature of the article is within the said range, and quenching the article, whereby the case contains a high content of martensite.

4. The method of treating nickel steel of the SAE-4615 or 4815 group, which comprises case-hardening and quenching to provide an austenitic case, heating the article at below the critical temperature of the case to convert the austenite in the case through martensite to sorbite and pearlite, heating the entire article to a higher temperature to reverse the case reactions in the direction toward austenite and to refine the structure, the temperature being such with relation to the heat held by the article that on quenching the austenite changes back to martensite and the latter does not change to sorbite and pearlite.

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