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CASE HARDENING

This invention relates to the case hardening of steel.

Low surface hardnesses and commensurately poor
5 wearability have resulted chiefly from procedures
employed in the manufacture of prior art steel bearing
surfaces, and particularly in those of trunnions of
universal joint cross members. Such members have
been traditionally formed from steel forgings, the
10 forging being heat treated prior to all grinding or
other metal removal steps. It is common knowledge
that such grinding, buffing, or similar finish
machining steps remove, at least in part, several
thousandths of an inch of the hardened surface achieved
15 from heat treatment and subsequent quenching operations.
In fact, the effect of such post heat treatment
machining or metal removal steps has been to remove
any retained austenite in such case hardened surface.
Retained austenite has been regarded as undesirable
20 because of its tendency to be readily transformed
into untempered martensite under conditions of work
hardening, or even the flexure of parts under conditions
of extremely cold temperatures. The general thinking
in the industry has been that untempered martensite
25 is to be avoided at all costs, as the latter has been
associated with dimensional changes of finished parts,
as well as brittleness and associated cracking.

Prior art trunnions have therefore been subjected to grinding steps after heat treatment and quenching procedures to remove substantial portions of case hardened layers typically having only 0 to 5 percent retained austenite. The deliberate avoidance of virtually all untempered martensite in the final product has thus resulted in bearing surfaces having less than desirable case hardnesses, along with associated relatively lower resistances to abrasion and deformation.

According to the present invention there is provided a method of case hardening a surface of a component made from a carburizing grade of steel, the method comprising a treatment step, which results in a surface layer of the component having not less than 10% austenite, and a subsequent work hardening step which transforms the austenite to result in the surface layer containing at least 5% untempered martensite.

In preferred practical forms of the method, the case hardened surfaces are achieved by machining, carburizing, quenching, tempering, and work-hardening steps, whereby a relatively high percentage of the austenite achieved during carburizing is retained through quench. A significant percentage of the retained austenite is then deliberately transformed into untempered martensite by the work hardening step.

A preferred form of the method comprises the steps of: (1) completing all machining, grinding, and similar operations involving metal removal steps, (2) carburizing the machined component to achieve a surface carbon concentration in the range of 0.9 to 1.3 percent, (3) direct quenching the component in oil by means resulting in the retention of 10 to 30 percent austenite in a case depth of at least 0.25 millimetres (ten thousandths of an inch), (4) time tempering the part in a controlled furnace environment

at constant temperature, and (5) work hardening the part to transform a portion of the retained austenite into untempered martensite, resulting in the case depth having a composition including at least 5 to 5 20 percent untempered martensite.

For a better understanding of the present invention and to show how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawing, which is a view of a case hardened universal 10 joint cross member.

The method which will now be described is applicable to the case hardening of bearing surfaces of steel parts, for example, the surfaces of trunnions 12 of the universal joint cross member 10 shown in the 15 drawing. The trunnions 12, which extend radially of a center body portion 14 of the cross member, are each disposed for rolling contact with needle bearing elements (not shown). The surfaces of the trunnions should ideally have high abrasion and deformation 20 resistance, but yet have sufficient strength to resist rolling contact fatigue.

The case hardening consists of five basic steps, and the table on the next page displays a preferred sequence of the steps as employed in the method.

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TABLE

STEPS: (For SAE 8617 Steel)

1 <u>Machining</u>	2 <u>Carburizing</u>	3 <u>Direct Quench</u>	4 <u>Tempering</u>	5 <u>Work Hardening</u>
Rough Turning	Temperature: 840-940°C (1550-1740°F)	Temperature: 815-900°C (1500-1650°F)	Temperature 149-205°C (300-400°F)	Technique: Shot Peen
Grinding or other Finish Machining	Duration: 3 - 6 hours	Quenchant: Oil at 27-54°C (80-130°F)	Duration: 1 - 1½ hr	Material: ASTM 390: chilled steel shot
	Effective case depth: At least 0.25 mm (10 thousandths of an inch)	Duration: 3-7 minutes		Intensity: Almen Strip "A" arc height 0.41-0.66mm (0.016 to 0.026 inches)
Case Hardness (Rockwell C):		63-67	59-64	59-68
<u>Compositions</u>				
Austenite Retained:		10-30%	10-30%	5-10%
Tempered Martensite:		0%	70-90%	70-90%
Untempered Martensite:		70-90%	0%	5-20%

In more detail, the method proceeds as follows. First, the trunnions 12 of the member 10 are fully machined. An important feature of the method is that all machining procedures are carried out in an initial phase, so as to avoid any subsequent removal of resultant case hardened surface material. Referring to the chart, the cross member 10 is thus initially machined, the machining procedure comprising rough machining, such as lathe turning, immediately followed by all finish metal removal operations such as grinding to final dimension and tolerances, as or if required. The cross member 10 is preferably stamped as a forging, and the trunnions 12 are subsequently machined to final tolerances for proper operation in roller contact bearing service.

Next the member 10 is carburized at a temperature in the range of 840 to 940°C (1550 to 1740°F). This procedure is carried out for 3 to 6 hours under the preferred practice of this method. The carburizing furnace may, for example, be of the "pusher type continuous", wherein an endothermic gas may be used as a carrier in the production of a controlled environment for achieving a high carbon potential. The carrier is preferably enriched with one of the hydrocarbon gases, for example a methane gas as will be appreciated by those skilled in the art. The preferred surface carbon concentration is in the range of 0.9 to 1.23 percent. Under the aforesaid conditions, this concentration will ensure that the case depth subject to carbon penetration will be at least 0.25 millimetres (ten thousandths of an inch). It should be noted that these conditions will in some regions of the affected surface areas result in case hardened depths up to as much as 1.25 millimetres (fifty thousandths of an inch). The object of the carburizing procedure is to ensure that a substantial amount of austenite is retained in the case hardened surface of the member 10.

Depending on the carbon content of the steel, as will be understood by those familiar with heat treatment of steels, the austenitic phase of steel is reached at 723°C (1333°F) for the eutectoid composition of 0.80% carbon, and at higher temperatures for any other carbon percentage values. It should be noted that of all steel phases, the austenite phase has the greatest affinity for receiving carbon atoms, yet only approximately two percent carbon can be absorbed within the steel, under ideal conditions. After carburization, if the steel is cooled slowly, the carbon atoms will migrate out of the crystalline structure of the austenite, and the composition will degenerate into an undesirable brittle structure, such as "cementite". Thus, a rapid quench is employed to effect a "freezing" of the austenitic structure before the carbon atoms have had a chance to migrate. The result is preferably a phase having a stronger, hence more desirable, crystalline structure at low temperatures, for example, martensite which is much more stable at lower temperatures than austenite, while only slightly differing from the latter in metallurgical properties.

Contrary to the present method, wherein a deliberate effort is made to assure the greatest feasible amount of retained austenite (approximately 10-30 percent upon quench), prior art efforts have been directed to minimizing retained austenite (and hence resultant martensite), primarily to avoid brittleness and cracking of parts. As a result, the prior art techniques employed a carbon concentration in the range of only 0.8 to 1.0 percent to minimize the amount of retained austenite. The present method, however, limits the problems of the prior art by tempering the member 10 after quench in order to reduce the unsatisfactorily large amount of untempered martensite produced by the quenching step, as further explained

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hereinafter.

Referring to the chart, in order to effect carburization, the steel member 10 must be made of a carburizing grade of steel. Obviously, the lower the carbon content of the steel, the more easily saturated the member will become in a comparatively shorter period of time. For example, a nickel-chromium steel of low carbon content, as SAE 8617, will achieve a carbon concentration of 0.9 to 1.3 to a minimum case hardened depth of at least 0.25mm (ten thousandths of an inch) at 900°C (1650°F) in 3 to 6 hours. An SAE 8610 steel, which has an identical composition except for lower carbon content, will absorb carbon more readily under the same conditions, while an SAE 8620 steel having higher carbon content will absorb correspondingly less carbon. (SAE 8617 steel has a carbon percentage of 0.17).

Upon removal of the member 10 from the carburizing furnace, allowing for but a slight drop in temperature down to a range of 815 to 900°C (1500 to 1650°F) the member is "direct quenched" in oil which is maintained at a temperature of 27 to 54°C (80 to 130°F), for three to seven minutes. A direct quench is more desirable than an indirect quench in the preferred procedure as an indirect quench results in a lesser amount of retained austenite. An indirect quench procedure, as "austempering" (more frequently utilized in the case of high carbon steels), involves quenching, then reheating the quenched member to a temperature slightly below the austenitic phase, then cooling more slowly to allow the austenite to transform to bainite, a softer ferritic phase having malleable characteristics unsuitable for bearing surfaces, as will be appreciated by those skilled in the art.

As shown in the chart, the direct oil quench results in a retained austenite percentage of approximately ten to thirty, and a Rockwell C hardness

in the range of 63 to 67 over the case hardened surface of the member 10. It will be appreciated that an oil quench procedure provides for a substantially greater time control of the quench as compared to

5 a water quenching procedure, which from high temperatures tends to more readily subject the member to surface cracking during the rapid cooling associated therewith.

A tempering procedure, next conducted, involves are-heating operation to relieve undesirable and
10 fairly substantial tensile surface stresses induced by the direct quench operation. Thus the member 10 is reheated and held for approximately $1\frac{1}{2}$ hours at a constant temperature in a range of 149 to 205°C (300 to 400°F). During this period, the Rockwell
15 C hardness decreases from 63 to 67 to a range of 59 to 64. Although a relatively high Rockwell C hardness is achieved upon quench, the amount of untempered martensite (70-90% - see Table), is extremely and unsatisfactorily high as earlier noted, and would
20 result in the prior art problems related to fatigue and brittleness. Such a high percentage of untempered martensite must therefore be substantially reduced in order to enhance the strength of the part, and to avoid brittleness. Moreover, as the oil quench step
25 also results in an uneven distribution of hardness over the surface, the tempering step also produces a more uniform hardness over the surface.

After tempering, the final operation comprises a work-hardening of the case depth. The work hardening
30 procedure allows for a smaller and more desirable amount of untempered martensite within the surface of the part. It will be appreciated by those skilled in the art that only retained austenite is capable of being transformed into untempered martensite by
35 work hardening. This is because once converted during the tempering step, the tempered martensite cannot be transformed back into untempered martensite by

work hardening procedures. Thus, the retained austenite becomes the only source of untempered martensite after the quench and tempering steps.

The presently preferred work hardening procedure is shot peening, as for example achieved by the use of ASTM 390 chilled steel shot. The shot peening procedure converts a substantial portion of the residual retained austenite into untempered martensite, resulting in a composition having 5 to 20% untempered martensite in an effective case hardened depth of at least 0.25 millimetres (ten thousandths of an inch), and achieving a Rockwell C hardness of 59 to 68. To effect this hardness level, the shot peening must be of an intensity sufficient to produce an Almen test strip "A" arc height of 0.41 to 0.66 millimetres (16 to 26 thousandths of an inch), as will be fully appreciated by those skilled in the art.

It should be further noted that an additional benefit of work hardening the case hardened depth is the inducement of compressive stresses into the surface, thus also inherently enhancing the fatigue life of the part. The stresses result from the fact that the crystalline structure of untempered martensite is slightly larger than that of austenite. Thus there is a slight expansion of the surface case depth as a substantial portion of the retained austenite is transformed into untempered martensite by the shot peening procedure. The combination of the greater case hardness and the surface compressive stresses provides for an improved bearing surface for use in high stress contact roller environments, for example, those to which the trunnions 12 are subjected.

Other benefits are also realized in the practice of the above-described method of this invention, although not all are readily apparent. For example, the higher carbon concentration as employed herein is believed to produce a small percentage of carbides

in the case hardened surface which also contributes to the improved wear resistance of the member 10.

The above-described preferred practice of this method is exemplary only, and numerous variants there
5 of are envisioned as falling within the scope of the appended claims. For example, the method could also be applied to other bearing parts, such as the inner race of a universal joint bearing cap as used to support the trunnion, or even to bearing portions of axle
10 shafts and the like.

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CLAIMS

1. A method of case hardening a surface of a component made from a carburizing grade of steel, the method comprising a treatment step, which results
5 in a surface layer of the component having not less than 10% austenite, and a subsequent work hardening step which transforms the austenite to result in the surface layer containing at least 5% untempered martensite.
- 10 2. A method as claimed in claim 1, in which, after the treatment step, the surface layer contains not more than 30% austenite.
3. A method as claimed in claim 1 or 2, in which, after the work hardening step, the surface
15 layer contains not more than 20% untempered martensite.
4. A method as claimed in any one of claims 1 to 3, in which all metal removal operations on the surface are completed prior to the treatment step.
5. A method as claimed in claim 4, in which
20 the metal removal operations comprise (1) a rough turning step, and (2) a finish machining step.
6. A method as claimed in any one of the preceding claims, in which the treatment step comprises a carburizing step.
- 25 7. A method as claimed in claim 5, in which the carburising step is conducted at a temperature in the range of 840 to 940°C (1550 to 1740°F).
8. A method as claimed in claim 6 or 7, in which the carburizing step is conducted for a time
30 not less than 3 hours and not more than 6 hours.
9. A method as claimed in any one of claims 6 to 8, in which, after the carburizing step, the carbon concentration in the surface layer is in the range 0.9 to 1.3%.
- 35 10. A method as claimed in claim 9, in which the carbon concentration in the range 0.9 to 1.3% is maintained to a depth of at least 0.25 millimetres



(ten thousandths of an inch).

11. A method as claimed in any one of claims 6 to 10, in which the carburizing step is followed by a quenching step effected when the component is at a temperature of at least 815°C (1500°F), the quenching step comprising immersing the component in oil for not less than three minutes, the oil having a temperature in the range of 27 to 54°C (80 to 130°F).

12. A method as claimed in claim 11, in which the quenching step results in the surface layer containing 70 to 90 percent untempered martensite, and 10 to 30 percent retained austenite.

13. A method as claimed in any one of claims 6 or 12, in which the carburizing step is effected in a carburizing gas furnace, wherein an endothermic carrier gas is enriched with a hydrocarbon gas.

14. A method as claimed in any one of the preceding claims, in which a tempering step is effected between the treatment step and the work hardening step, the tempering step comprising maintaining the component at a temperature in the range of 149 to 205°C (300 to 400°F) for not less than 1 hour and not more than 1½ hours.

15. A method as claimed in any one of the preceding claims, in which the work hardening step is achieved by shot peening.

16. A method as claimed in claim 15, in which the shot peening step is conducted with chilled steel shot.

17. A method as claimed in any one of the preceding claims, in which the surface has a hardness of a magnitude represented by an Almen test strip "A" arc height of 0.41 to 0.66 millimetres (sixteen to twenty-six thousandths of an inch).

18. A method as claimed in any one of the preceding claims, in which after the work hardening step, the surface layer comprises 70 to 90% tempered



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martensite and 5 to 20% untempered martensite to a depth of at least 0.25 millimetres (ten thousandths of an inch).

19. A method of case hardening as claimed in claim 1 and substantially as described herein.

20. A component which has been case hardened by a method in accordance with any one of the preceding claims.

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