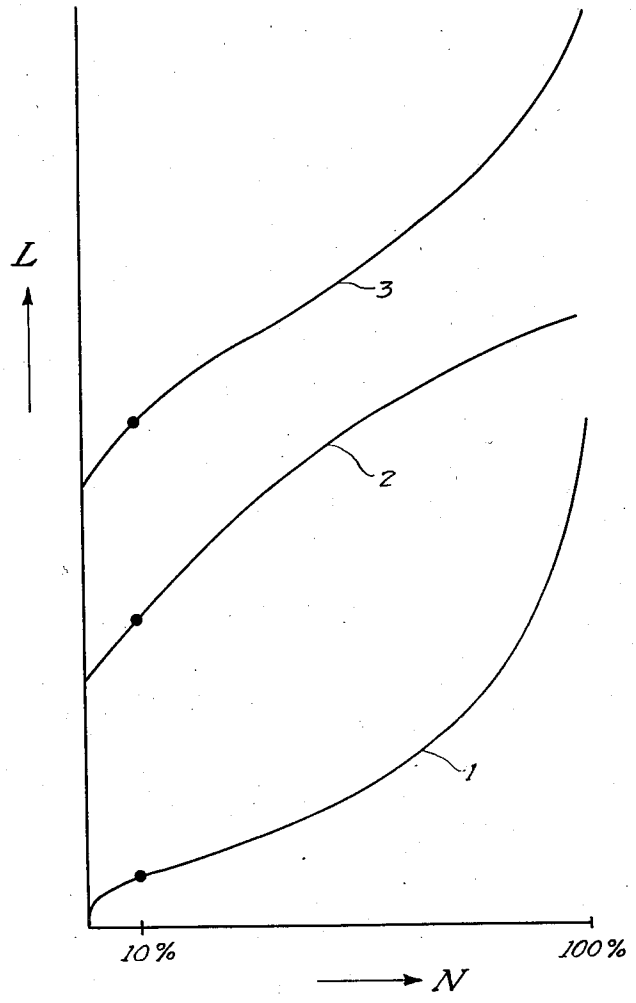
April 16, 1940. B. A. KJERRMAN 2,197,365

METHOD OF PRODUCING A HARDENED STEEL ARTICLE

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Fig. 1.



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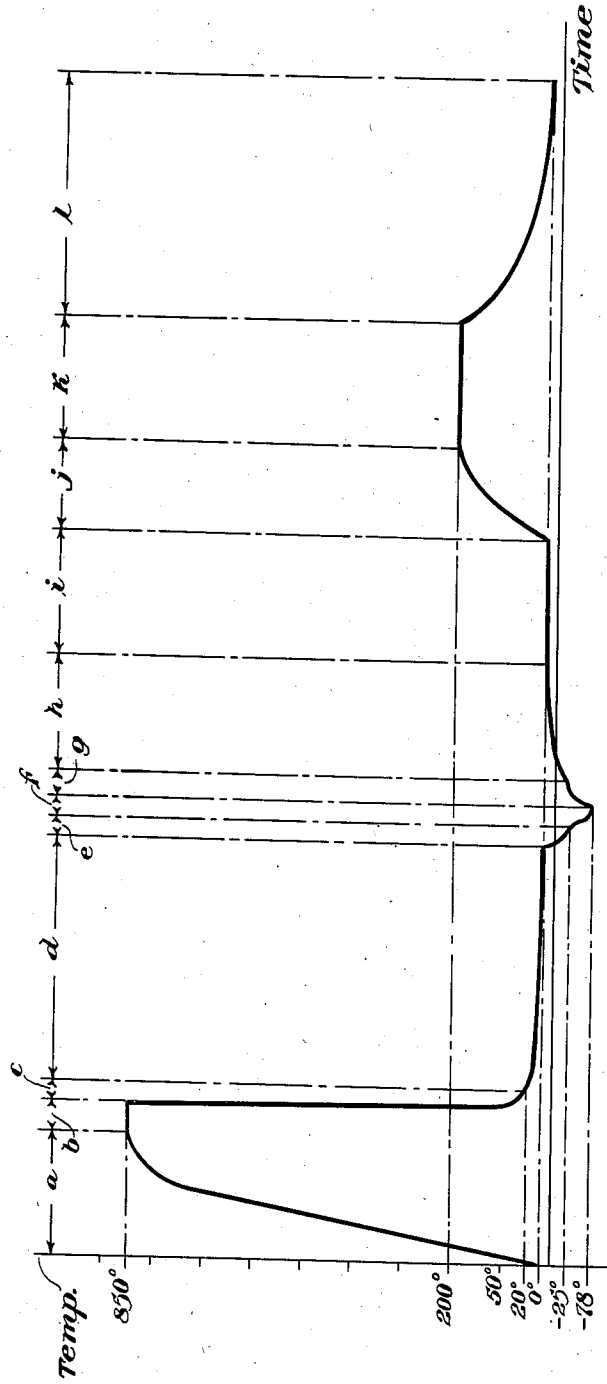


Fig. 2.

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Patented Apr. 16, 1940 2,197,365

UNITED STATES PATENT OFFICE

2,197,365

METHOD OF PRODUCING A HARDENED STEEL ARTICLE

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Application February 5, 1937, Serial No. 124,284
In Sweden February 5, 1936

3 Claims. (Cl. 148—21)

This invention is based on the discovery that certain internal stresses in hardened steel superimpose themselves upon certain internal stresses emanating from external forces in such a manner that the capacity of the material for withstanding the external forces is increased, while certain other internal stresses have the opposite effect. This is especially the case when the external forces are concentrated on a limited area of the surface so that the stress conditions are changed to a considerable extent only in certain parts of the body of the member.

Figure 1 of the drawings represents the Cartesian co-ordinates of some of the bearings and Figure 2 shows the temperature outlined for the heat treatment of a ring.

In carrying out the invention according to the chart represented in Figure 1, the ring is first heated from indoor temperature, that is about plus 20° C., to the hardening temperature of plus 850° C. This is the step *a* in the diagram and takes about one hour. The ring is then allowed to soak at this temperature for ten to fifteen minutes, step *b*, after which it is quenched in oil of plus 50° C. temperature, step *c*. The ring remains in the oil bath four or five minutes after which it is removed and, in accordance with the practice at our works, it is allowed to cool in the atmosphere. This is the step *d* and during this period the work piece slowly cools down to indoor temperature of about plus 20° C. The length of this step *d* varies considerably with the amount and character of the work on hand and may be from about two or twenty four hours. The ring is then immersed in a bath of trichlorethylene having a temperature of about minus 25 to minus 30° C. and is allowed to remain in this bath for about ten minutes. The temperature of this bath, minus 25 to minus 30° C., is obtained by immersing in the bath still colder rings obtained from the following operations. The length of time during which the rings are allowed to remain in the bath *e* is about ten minutes. This length of time is determined by the working conditions and it has been found that the workman can keep things going smoothly by allowing the piece to remain in the bath for this length of time. The ring is then removed to a bath having a temperature of about minus 78° C. where it is allowed to remain for a further ten minutes, step *f*. From this bath the cold ring is again transferred to the original bath, thereby cooling this bath and the rings in the bath which are to be cooled to the aforementioned temperature of about minus 25 to minus 30° C. The rings remain in this bath for another ten minutes, step *g*, after which they are removed and absorb heat from the atmosphere until they assume the indoor temperature, which requires about another hour. This is the step *h* in the diagram. Depending upon working conditions they will remain at indoor temperature from one to ten hours, *i*, after which they are tempered by being heated to a temperature of plus 200° C., step *j* which requires about 45 minutes. The rings are retained at a temperature of plus 200° C. for one hour, step *k*, after which they are removed and allowed to cool in atmosphere and gradually assume indoor temperature after about two hours, step I. The heat treatment of the rings is now finished.

One of the objects of the invention is to furnish a hardened steel article for supporting heavy loads and the method of producing it.

Examinations of the stress conditions in members of hardened steel having a Brinell hardness number of more than about 600, have shown that the internal stresses are of two kinds, namely the so called micro-stresses which keep each other in equilibrium within each element of the material, and which constitute the physical properties of the material, especially the hardness, and partly so called macro-stresses, which are substantially uniformly directed within a greater volume of the material, and which are held in equilibrium by forces in other volumes of the material. The macro-stresses are, therefore, of the same character as stresses caused by external forces.

Examinations of the distribution of the macro-stresses and their direction have shown that the material at the surface of the body and in the neighborhood thereof is subjected to considerable tensile stresses and the material in and about the innermost parts of the body is subjected to corresponding compressive stresses. It has furthermore been found that the stresses at and in the neighborhood of the surface have substantially different magnitudes in different directions. Thus the stresses directed parallel with the surface are considerable, while those directed perpendicular to the surface are small. No internal stresses perpendicular to the surface can, of course, exist at the surface itself.

When external forces are applied to a limited area of the surface of a body, for example by applying a load to a ball resting upon the body, the most dangerous stress in the material will be along a line perpendicular to the surface at the center of the pressure area, probably at a

short distance under the surface, no matter whether the most dangerous stress condition is characterized by the greatest shearing stress or by the greatest shear strain energy. At this most dangerous point, the stress condition of which determines the strength of the material under the load under consideration, there will be compressive stresses in all three directions, but the compressive stress in a direction perpendicular to the surface is considerably greater than in the other directions (as a rule about three times greater). It is this difference in the magnitude of the stresses which causes the danger of exceeding the strength of the material.

If the body when in unloaded state has macro-stresses of the character of tensile stresses in the neighborhood of the surface and parallel therewith, the dangerous stresses will be increased in a high degree, since the difference between the stresses in perpendicular and tangential directions after loading will be greatly increased. Macro-stresses having the character of tensile stresses only in a direction perpendicular to the surface, on the other hand, decrease the dangerous stresses. This theoretical analysis thus provides an explanation of the phenomenon which has been discovered, namely that it is of advantage for the strength of the material subjected to a concentrated load that tensile stresses should be lacking at the surface, and still more advantageous that there should be compressive stresses acting at the surface parallel therewith before the external load is applied.

The purpose of the present invention is to make use of the knowledge of the decisive influence of the macro-stresses on the dangerous material stresses in a body subjected to concentrated loads. A typical example of this kind of great practical importance is the ball or roller bearing. The invention is characterized mainly in that in a member of hardened steel, in which a certain portion of the surface is intended to be subjected to heavy stresses from external forces, especially for ball or roller bearings, the material in the member, which is subjected to the stresses of the external forces has, when in unloaded condition, Brinell hardness number of at least 600, and practically lacks marco-stresses of the character of tensile stresses in directions parallel with the surface of the member.

When testing a large number of ball or roller bearings the life hitherto attained by different bearings subjected to the same load has varied considerably for different specimens of the same type of bearing. This dispersion is represented in Figure 1 of the accompanying drawings by the curve 1. The number of bearings tested is plotted along the horizontal N-line. The vertical L-line represents the life of the different bearings. The dispersion curve 1 which, when based on a sufficient number of bearings, has hitherto always had the same basic form independent of the design and size of the bearings and relatively independent of all hitherto known qualities of the material in the bearing shows that there is a very great difference between the greatest and the shortest life and further that the life of the greater part of the bearings is less than the mean life. The dispersion is usually 30 to 100 or still more.

When testing ball bearings having race rings according to this invention and practically lacking in macro-stresses a dispersion according to curve 2 was obtained. This curve shows that there is considerably greater uniformity as regards the different specimens of the bearing (dispersion 2 to 3) and further that the life of the bearing has been considerably increased. The relatively high values which have been obtained in exceptional cases according to curve 1 without doubt depend thereon that the macro-stresses of the character of tensile stresses in these bearings have accidentally been exceptionally small or have happened to be localized or directed in such a way that they have only to a less degree taken part in causing the material stresses which are decisive for the fatigue effect. It is natural that the dispersion curve 2 should not be fully horizontal, since the material still contains heterogeneities which do not have any connection with the macro-stresses.

When testing ball bearings according to this invention, the members of which bearings had macro-stresses of the character of compression stresses on the material at the surface, a dispersion according to curve 3 was obtained. The lives of the bearings in this case are still higher than those obtained with material lacking in stresses. Compared with the best bearings at present known the life was about ten times as great or the load carrying capacity more than twice as great respectively. (Life and carrying capacity as used here refer to the life and the carrying capacity which is exceeded by 90% of all bearings of the size in question and which has been marked by a dot on each of the curves).

The presence of macro-stresses and their character of compressive or tensile stresses can be ascertained in different ways, for instance by X-ray examination of the lattice distortion or by measuring the alterations in the dimension or shape of the body after locally removing a portion of the material.

The method of obtaining the desired characteristics of the material consists in principle therein that the internal stresses on the material augmented by suitable means are permitted to accomplish by themselves alterations in the material to such an extent that the macro tensile stresses at the surface can be caused to disappear without at the same time diminishing the micro-stresses to an undesirable degree. This can take place if the material is cooled from the hardening temperature sufficiently to set up strong internal stresses, after which these stresses are allowed to act during a certain time before the temperature is raised. The time during which the stresses should act depends very greatly upon the temperature at which the body is kept. If the body is cooled after hardening to about 0° C., a very long time is required for the accomplishment of the work of the internal stresses with a subsequent tempering to a relatively high temperature. If, on the other hand, the body is cooled to a much lower temperature, eventually after having first been cooled to indoor temperature and having been kept at that temperature for a longer or shorter time, the time required for accomplishing the desired effect will be decreased. If the body is cooled to minus 50° C. or more, the effect of the stresses will be almost immediate, and the desired stress condition can be obtained after raising the temperature to a degree at which the micro-stresses remain high.

When treating bodies having a suitable shape and analysis they can be quenched directly from the hardening temperature, for example +850° C. down to a temperature of, for example, minus 100° C. As a rule, it is however, necessary to cool the body by stages and retain it at one or more

of the intermediate temperatures during a certain time. This method has been found to give considerable economical advantage.

Sufficient activity of the internal stresses can be obtained by adding to them stresses resulting from external forces, for instance omnilateral pressure, a vibration or the like. A very powerful effect can be obtained by a suitable combination of cooling and the application of external forces.

A simple method of obtaining ball bearing parts, according to this invention, made of a material containing about 1% C, 1% Cr and 1% Mn is by quenching the body from about +850° C. to about indoor temperature in oil in the usual manner and then further cooling the body in a suitable liquid, for instance alcohol to −30° C. The body is then immediately transferred to another similar bath, cooled to −78° C., in which it remains until it has assumed the temperature of the bath. From this bath it is transferred back to the first bath, from which it absorbs heat, whereby the first bath will not require any separate cooling means. A suitable cooling means for the second bath is solid carbon dioxide. After the cooling operation the body is tempered at a temperature and during a length of time which gives a Brinell hardness number of about 660 to 670, if practically complete freedom from macro stresses is desired. As a rule the tempering temperature will be between +200° and +250° C.

The length of time required for this tempering operation required to give a Brinell hardness number of about 660 to 670 depends on the tempering temperature and for a tempering temperature of about 200° C. will be about 1 hour. This is the method, which is employed by me at present in carrying out the invention.

A more effective method is to cool in stages to temperatures of −25, −50, −75 and −100° C. after hardening. In order to attain the lowest temperature in these series an interrupted Linde-process may be suitably used. It is then possible to attain greater hardness and greater load carrying capacity with the same tempering temperature as in the above mentioned case.

It is especially advantageous to retain the body at indoor temperature during quite a length of time after quenching and before further cooling. After cooling it is also of advantage to proceed in the same manner before tempering.

The augmentation of the internal stresses by the application of external forces can take place simultaneously with, after or before the cooling. When applying this method the body can be connected in an electro-magnetic oscillation circuit so that the body will be heavily vibrated. The most simple method of maintaining this vibration is to make the frequency of the electro-magnetic oscillations equal to the frequency of the mechanical vibrations of the body. The apparatus required for this method is an ordinary tone frequency generator, in which the body is included as a tuning-fork.

It is apparent that the method of treating the body can be varied in many different ways. The alterations in stress condition and structure during the treatment according to the different methods are, of course, too complicated in their details to be exactly determined. The most suitable method for each special case can, however, be determined by a thorough examination, in accordance with principles known in the art, of the results obtained by different methods.

It must be borne in mind that the times, temperatures, etc., herein given are only to be regarded as examples, since the values may vary considerably with different steel analyses and depending upon the purpose to which the object is intended to be put.

This invention is, of course, not limited to parts for ball bearings and roller bearings, but can be applied to many other members which are subjected to similar loads, for instance pintle bearings for sluice gates, bridge supports, dies, percussive tools, etc.

Having thus described my invention, I claim and desire to secure by Letters Patent:

1. The method of producing a hardened steel part for an antifriction bearing which consists in raising it from indoor temperature of about +20° C. to the hardening temperature of about +850° C., after which the part is quenched in oil of about +50° C. and then allowed to slowly cool to indoor temperature, then cooled in a bath to −25 to −30° C., then placed in a bath of about −78° C., then transferred to the original bath of about −25 to −30° C., after which it is removed from the bath and exposed to indoor temperature, and then subjected to a heat of about +200° C. after which it is allowed to regain indoor temperature.

2. The method of producing a hardened steel part for an antifriction bearing which consists in raising it from indoor temperature of about plus 20° C. to a hardening temperature of about plus 850° C. in about one hour allowing it to soak at this temperature for ten or fifteen minutes after which the part is quenched in oil of about plus 50° C. for four to ten minutes, after which it is removed from the oil and allowed to cool in the atmosphere, or to indoor temperature, the length of this step consuming from two to twenty-four hours, then cooling it in a bath of about minus 25° to minus 30° C. for about ten minutes, then placed in a bath of about minus 78° C. where it is allowed to remain for about ten minutes, then transferred to the original bath of about minus 25° to minus 30° C. for about ten minutes, then it is removed from the bath and absorbs heat from the atmosphere until it assumes indoor temperature which requires from one to twenty-four hours, then subjected to a temperature of about plus 200° C. for about sixty minutes after which it is allowed to assume indoor temperature in about two to four hours.

3. The method of producing a hardened steel article intended to be subjected to heavy external forces acting upon a certain portion of the surface, as for instance a ball or roller bearing member, characterized thereby that that part of the material in the member, which is intended to be subjected to the stress of the external forces, when in unloaded state, has a Brinell hardness number of at least 600 and is practically free from macrostresses of the character of tensile stresses in directions parallel with the surface of that part of the member which consists in heating the article to about +850° C., then cooling the article to about indoor temperature, and thereafter further cooling the article in two stages, first, to about minus 30° C. and then to about minus 78° C., and then tempering at +150° C. to +250° C.

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