Aug. 29, 1933. O. STOFFEL ET AL 1,924,296

HEAT TREATMENT OF CRANK SHAFTS

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Fig.2

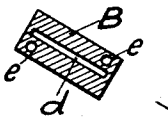


Fig.1

Fig.3

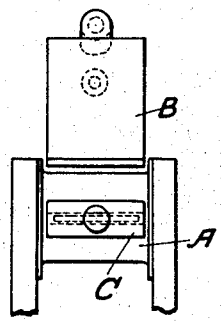
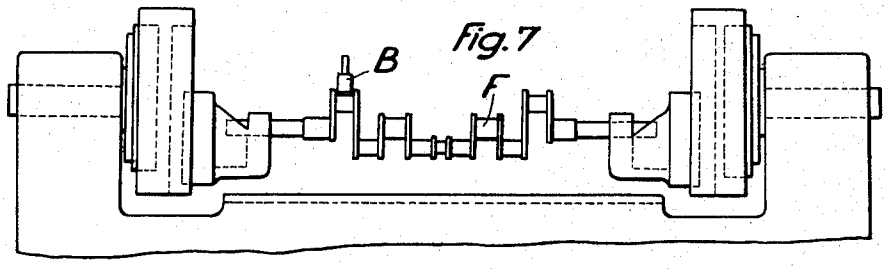


Fig.7



Inventors
OTTO STOFFEL,
CARL ROESCH,
CARL SUDHAUS,

ATTORNEY

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Fig. 4

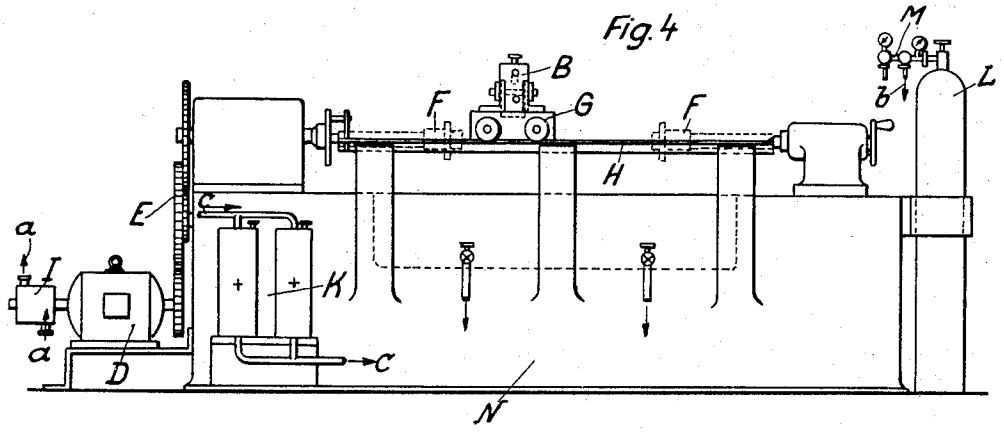


Fig. 6

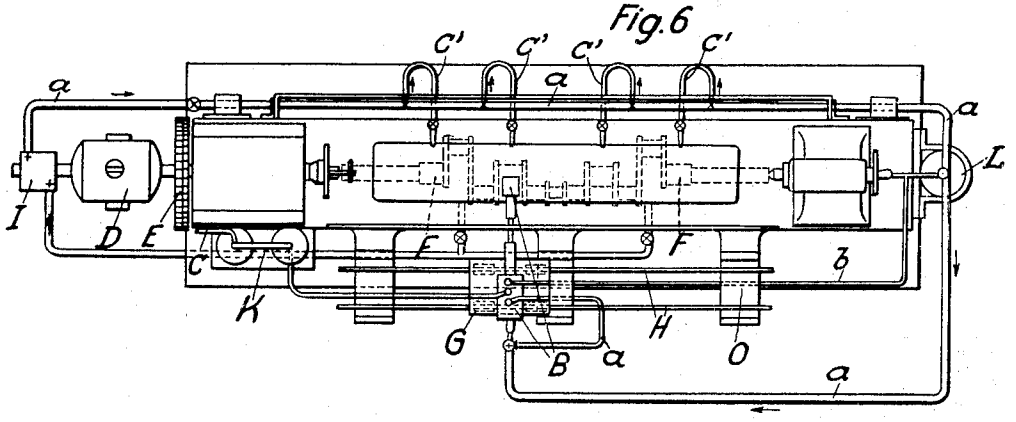
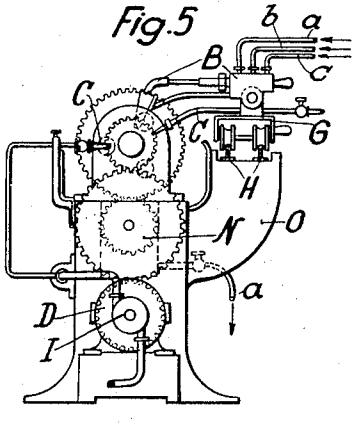


Fig. 5



Inventors
OTTO STOFFEL,
CARL ROESCH,
CARL SUDHAUS,
By
ATTORNEY

Aug. 29, 1933. O. STOFFEL ET AL 1,924,296

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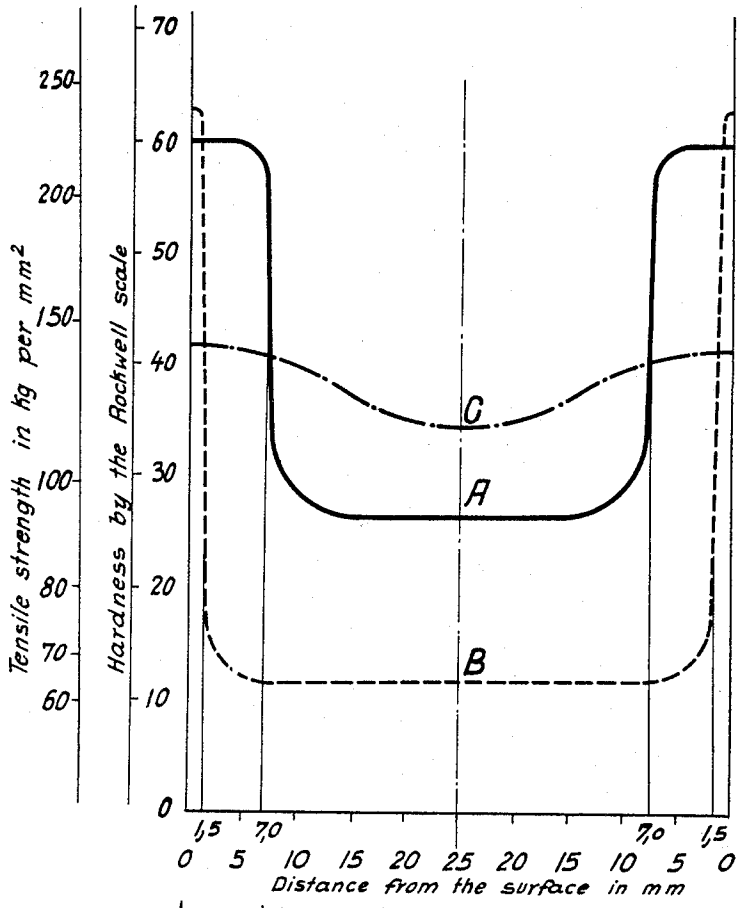


Fig.8

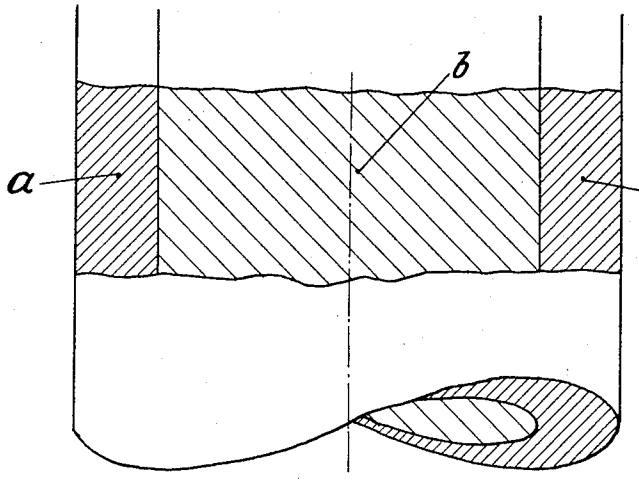


Fig.9

Inventors
OTTO STOFFEL,
CARL ROESCH,
CARL SUDHAUS,

ATTORNEY

Patented Aug. 29, 1933

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HEAT TREATMENT OF CRANK SHAFTS

Otto Stoffel, Carl Roesch, and Carl Sudhaus, Remscheid, Germany, assignors to The Linde Air Products Company, a corporation of Ohio

Application August 20, 1930, Serial No. 476,654, and in Germany February 11, 1929

2 Claims. (Cl. 148—21)

This invention relates to an improved heat treatment of crank-shafts, whereby it is possible to obtain not only safety against fracture under static and dynamic stresses but also high resistance to wear.

In order to attain both these desiderata it is essential that crank-shafts should exhibit on the one hand a certain tenacity and toughness, properties which can be imparted by the process of normalizing, that is to say, hardening followed by suitably controlled annealing, and on the other hand, the entire piece, or at least, its superficial stratum, must possess a high degree of hardness in order to present high resistance to wear. Both properties, namely high tenacity coupled with good ductility, and high superficial hardness, cannot, however, be concurrently obtained in the case of crank-shafts by the processes hitherto known, since improvement as regards the one property is not attended by a similar improvement of the other. Hence, in many instances, the requirement of safety against fracture predominating, the production of a specially hard superficial stratum is dispensed with, and normalized steels, with a carbon content ranging in general between 0.2 and 0.5%, are employed for highly stressed crankshafts. Since the normalizing process precedes the machining of the work, and the result obtained can be checked by testing the strength of each piece, for example by Brinell and like tests, it offers a certain advantage over the other heat treatments hereinafter described. It is also attended by the advantage that, in the case of continuous production, the further treatment is not interrupted by protracted heat treatment.

Latterly, however, high resistance to wear or attrition has become more and more important, in consequence primarily of the development of internal combustion engines operating at high speed and with high compression (as employed for instance in Diesel-engines) and casehardened steels are being more extensively employed for crankshafts. Owing, however, to their low carbon content (below 0.2%) these steels are of low tenacity, and the crankshaft has accordingly to be given increased dimensions, the unfavourable result of which is an increased cost and a weight which is unsuitable for motor vehicle and aircraft engine crankshafts.

The conditions are similar when superficial hardening is effected by nitrification.

These processes, moreover, are attended by the special drawback that they entail a chemical change in the superficial stratum. The composition of the superficial stratum no longer possesses the character of a so-called structural steel, but that of a brittle tool steel displaying modified coefficients of expansion, as compared with the core material, so that rejections due to stress cracks are increased.

Moreover, in this process, it is impossible within economic time limits to increase the carbon content in a stratum several millimetres in thickness, or that of the nitrogen in a stratum only 0.5 millimetre thick, without at the same time exceeding the permissible concentration (free cementite or Braunite) here and there. Hence only thin superficial strata can be produced by this means. Nevertheless, in the final grinding which succeeds the hardening process, it is often necessary not only to shape the crank pin cylindrically, to gauge but also—especially in the case of multiple-crank shafts—to rectify any eccentricity or lack of parallelism that may have arisen through distortion. If, in such cases, the hardened superficial stratum is already comparatively thin in itself, it may readily happen that, in the grinding, the hardened stratum becomes unduly weakened in places, or even removed altogether, thus spoiling the entire crankshaft. In order to avoid rejections of this kind, it is therefore necessary to true the shafts up carefully after hardening and before grinding, an operation that is not only troublesome, requiring considerable skill, but also entails unavoidable stresses in the crankshafts. Such stresses manifest themselves, in a particularly adverse manner, by becoming cumulative due to the divergent composition of the shell and core, and consequently favouring the exfoliation known in connection with casehardened pieces. Moreover, these stresses cannot be eliminated by subsequent heating to redness, or annealing, without, at the same time, impairing the quality of the casehardened stratum. The insufficient thickness of the casehardened stratum has the further unfavourable result that, in the event of heavy surface pressures, a partial flattening into the core may occur, in consequence of which the member itself, or, in certain circumstances, the entire machine might be ruined.

Finally, a further disadvantage of this process is that the protracted heat treatment involved therein cannot be made to fit in with series production, but necessitates an interruption in the progressive manufacture of the individual pieces, and the accumulation of a large number of the latter. This considerably increases the total number of pieces simultaneously in course of production.

Another process which also aims at imparting greater hardness at the surface of the crankpin than in the core, consists in employing an air-hardened steel for the crankshafts and in raising the crank pins alone to the hardening temperature—for example by means of blowpipe burners—and subsequently cooling more or less rapidly, so that the hardening diminishes towards the centre. In this process, however, which entails the employment of an expensive material, with lower damping properties to oscillation stresses, the desired properties on the surface and in the core can only be imperfectly obtained, the surface being not so hard, and the core not so tough, as would be desirable. Moreover, there is no means of testing the resulting tenacity of the core material.

Although it has been proposed to heat steel journals on the surface only, by rotating them in a furnace, followed by quenching of the articles before the heating has extended into the core, this process is cumbersome and is inapplicable to crankshafts, if it is not desired to harden the crank cheeks as well. Moreover, in the case of crankshafts, the heating and quenching of the entire surface would lead to extensive distortion.

The primary object of our invention is an improved method of treating crankshafts wherein all of the disadvantages explained hereinabove are eliminated, and a crankshaft which is superior to any crankshafts known prior to our invention with regard to its tenacity and its resistance to wear.

A process for hardening the tires of railway wheels has also been suggested (British Patents Nos. 144,532 and 225,333 which specifications were completely accepted June 17, 1920, and December 4, 1924) which comprises raising the superficial strips which are to be hardened to hardening temperature by a single passage of a welding burner over the same, followed by immediate quenching before the heating has extended to the interzones of the piece. It has been proposed (Austrian Patent No. 86,662 dated December 10, 1921) to harden the heads of railway rails in a similar manner, slot burners being suitably employed.

Our invention is based on the discovery that, given a suitable temperature of the welding burner and a suitable duration of exposure of the surface which is to be hardened to the action of the burner, this process affords the possibility of hardening a superficial stratum of any convenient thickness, such as 3–8 mm., without, on the one hand, burning the material and, on the other, prejudicially affecting the mechanical properties of the deeper zones, i.e. the core. According to the invention, by the application of this process, a crankshaft with superficially hardened journals—especially crank pins—can be produced which consists of material of identical chemical composition at the core and surface, and having, on the surface, a shell of uniform hardness, and in the interior a core which has remained unaffected by the hardening treatment applied to the surface.

We have found that precisely such normalizable steels as have proved most suitable for crankshafts display the very hardness after severe quenching which is most suitable for the surface. This hardness is the same as that which has been found most suitable in the case of hardened roller-bearing races, for example without it being necessary to have their usual higher content of carbon and chromium which entails a milder form of oil quenching in order to prevent the formation of hardness cracks. Hence, in hardening crankshaft pins according to our invention it is important to establish conditions of such a kind that, although the surface of the pins is so hot that the subsequent cooling will produce hardness, the core remains substantially cold. For this purpose we preferably employ a burner with, for example, a slot nozzle. This burner is disposed in such a manner that the slot is parallel to the axis of the crank pin, and the surface of the pin is gone over with said burner one or more times, preferably once, the pin itself being rotated the while. The heated surface is quenched immediately, before the heating has extended into deeper zones. Of course, it would be equally feasible to move the burner round the pin, or effect the heating in other ways, such as by electricity. The cooling is effected either by the surrounding air alone, by jets of air—artificially cooled if necessary—directed on to the pin in the rear of the burner, by jets of liquid, or by means of a bath.

A preferred method of carrying out the invention and an example of the apparatus employed for that purpose will now be described with reference to the acompanying drawings, in which Fig. 1 is a diagrammatic representation of the burner and cooling nozzle in relation to the pin, Fig. 2 is a section along the line 2—2 of Fig. 1, Fig. 3 is a side elevation viewed from the left in relation to Fig. 1. Fig. 4 is an elevation of a complete machine serving to carry out the process. Fig. 5 is a corresponding end elevation. Fig. 6 is the plan corresponding to Figs. 4 and 5. Fig. 7 is a side elevation of the upper part of the machine, to show the chucking of the crankshaft for the purpose of hardening the crank pins. Fig. 8 is a diagram representing the distribution of the hardness throughout the cross section of the pin, in accordance with the invention, and Fig. 9 is a diagrammatic axial section through the pin.

In Figs. 1 and 2, A denotes a slowly revolving crankshaft pin, and B a blowpipe burner with slot nozzle, the latter being shown in section in Fig. 2. Apart from the shape of the nozzle, the burner is designed as an ordinary water-cooled welding burner. The three pipe connections *a*, *b* and *c*, fitted with shut-off valves, serve to admit water, oxygen and acetylene respectively. The oxygen and acetylene are mixed in the usual manner in the mixing tube *g* and burn at the mouth *h* of the burner. The water entering at *a* is conveyed through a tube *e'* and the bores *e* in the burner head, for the purpose of cooling the latter, and leaves the burner by way of the tube *e''*. The bore *f* serves for the purpose of mounting the burner on the carriage (described later) and enables the burner to be pivoted round said point. The nozzles C and C' enable the cooling medium (usually water) to be sprayed over the crankshaft pin which is to be hardened.

Figs. 4, 5 and 6 represent the complete arrangement for hardening crankshafts in accordance with the invention. A machine standard N—an old lathe being suitable—supports, by means of brackets O, two rails H, on which a carriage G, supporting the burner B, is adapted to travel to and fro. The crankshaft F to be hardened has been normalized in known manner in a preceding operation. If this shaft is made, for example, of steel with 0.35% of C, 0.8% of Cr and 0.2% of Mo, the normalizing is effected by hardening at

830° C., quenching in water and subsequently annealing at 630° C. The crankshaft F normalized in this manner is chucked in the machine in the way that is customary in ordinary turning lathes. Since, in order to turn the crankshaft, only the frictional forces in the machine have to be overcome, a small driving motor D will suffice, the speed of which is reduced by the disconnectible gear E.

For ordinary motor crankshafts, with crank pins 40–75 mm. in diameter, a speed of one revolution per minute has been found the most suitable, and the reducing gear E is designed accordingly in relation to the speed of the motor D. The burner B, mounted on the carriage G, is now adjusted and fixed, in relation to the journals or crank pins to be hardened, so that it does not impede the rotating crank arms of the revolving crankshaft.

The burner is connected with a gas supply pipe, such as an acetylene pipe *c*, by means of flexible tubing or the like. Said acetylene pipe is fitted with a water seal K, to prevent backfiring. The oxygen is admitted to the burner B at *b*, through flexible tubing which comes from the oxygen cylinder L, fitted with a reducing valve M. The medium for cooling the burner and quenching the crankshaft to be hardened is preferably employed in circulation, and maintained under a pressure of about 15 lb. per sq. inch by a pump I driven by the motor D. For the acetylene, a pressure of 10 lb., and for the oxygen one of 55–70 lb. is suitable.

The hardening is effected in the following manner: The burner is placed in position in the above described manner, so that the nozzle is situated about 10 mm. from the crank pin. The gear E is put out of operation, and the motor D and water pump are started. After turning on the acetylene valve *c*, the burner is lighted, and the oxygen valve is opened, in the same way as with an ordinary welding burner. In a few seconds, that side of the crank pin which faces the burner will have attained bright red heat, whereupon the gear 3 is thrown in. The crank pin A then revolves past the burner, and the strip which has thus been heated to redness passes in front of the main cooling nozzle C and is quenched, whilst the material coming in front of the burner, for the time being, is heated, the operation being continuous. Preferably after one revolution has been completed, the oxygen and acetylene are turned off, but the shaft is allowed to turn a little further, so that the parts last heated before shutting-off the burner can be quenched by the jet of water issuing from the cooling nozzles C. This done, the carriage is shifted into position facing the next bearing journal, and the operation is repeated.

The crankshaft is chucked in the hardening machine in the same manner as in a lathe. Fig. 5 shows the crankshaft chucked for hardening the intermediate journal, and Fig. 6 the shaft in position for hardening the crank pins.

Our method of operating and the resulting product offer the following advantages, which have not hitherto been concurrently obtained by any known process:

1. The possibility of choosing the steel to be used, with sole reference to the expected stresses, that is, of using both high-alloy and also unalloyed steels, or normalizable steels with only a small amount of alloy.

2. Normalizing the core in the manner found most suitable for work of the kind in question.

3. The possibility of checking the tenacity of the core by tests on the finished product after normalizing.

4. Obtaining a hardened outer shell of the same tenacity and hardness as have been found suitable for resisting wear in bearings.

5. The possibility of adapting the thickness of the hardened shell to the stresses which will occur.

6. The possibility, owing to the thicker hardened shell, of attaining the desired final dimensions by simple grinding, without previous trueing up.

7. The possibility of applying the hardening process to single pieces and performing it in a time corresponding to the rhythm of the flow production.

8. Substantial reduction of the stresses between the hardened shell and unhardened core, inasmuch as the shell and core material are of identical chemical composition.

9. Increased toughness and damping capacity, that is to say, lessened risk of cracks in the hardened stratum, as compared with those in which the hardening is based on modification of the chemical composition, and

10. Reduced distortion of the entire piece, inasmuch as only an insignificantly small portion is heated at any one time during the hardening treatment.

The manner in which the hardness is distributed through the cross section of a crankshaft pin hardened in accordance with the invention is plotted, as curve A, in Fig. 8. Curve B shows the course of the hardness in a case-hardened pin, and curve C in a pin of air-hardened Cr-Ni steel. The abscissæ represent distances from the centre pin (in millimetres) and the Rockwell hardness and the tensile strength in kg. per sq. mm., are plotted as ordinates (right and left hand scales respectively).

Curve A shows that, to the depth of about 7 mm, the hardness in the outer shell of the pin corresponds to 60° Rockwell, that is to say, is of the same tenacity as is usual for roller-bearing races, whereas the core has a uniform hardness of about 27° Rockwell, equivalent to 95 kg. per sq. mm., tensile strength, which corresponds to that of a properly normalized crankshaft steel for high stresses.

By comparison, curve B has a very hard shell, but one that is much thinner (only about 1.5 mm.) whilst the tenacity of the core is substantially inferior to that of curve A, owing to the low carbon content. Similar results to curve B are obtained in pins superficially hardened by nitrification, in which case the outer stratum, though still harder is nevertheless thinner than is obtainable in case hardening.

Curve C shows that a pin of air-hardened Cr-Ni steel exhibits merely slight differences in the hardness of the shell and core. By comparison with A and B, its resistance to attrition is considerably slighter, whilst the core is more brittle.

The tenacity values given as examples in the curves can, of course, be influenced, in all three cases, by the composition of the steel used. The typical distribution of the hardness remains, however, the same.

Fig. 9 represents the cross section of a crank pin according to the invention, *a* being the hardened shell and *b* the normalized core.

What we claim is:—

1. Process of producing a relatively deep wear-

resistant outer layer of uniform high hardness on a cylindrical bearing surface of a steel shaft while preserving the initial chemical composition and the initial core hardness thereof, which comprises maintaining a ribbon-type flame of a width equivalent to the length of the surface to be treated and so positioned with respect to said surface as to apply uniform heat thereto along a line parallel with the axis thereof, causing a relative movement between said flame and said surface of uniform angular velocity, and applying a quenching liquid to said surface immediately following its contact with said flame.

2. A steel shaft comprising a cylindrical bearing element having an integral case of uniformly high hardness and of a thickness not less than 3 millimeters over the bearing surface thereof, said case and the core of said element being of the same chemical composition and said core having a hardness at least as great as that of the metal of the shaft in normalized condition but materially less than that of the case.

OTTO STOFFEL.
CARL ROESCH.
CARL SUDHAUS.