

April 14, 1970

R. H. HAYS ET AL
DIE-QUENCHED CRANKSHAFT

3,506,501

Filed May 26, 1966

3 Sheets-Sheet 1

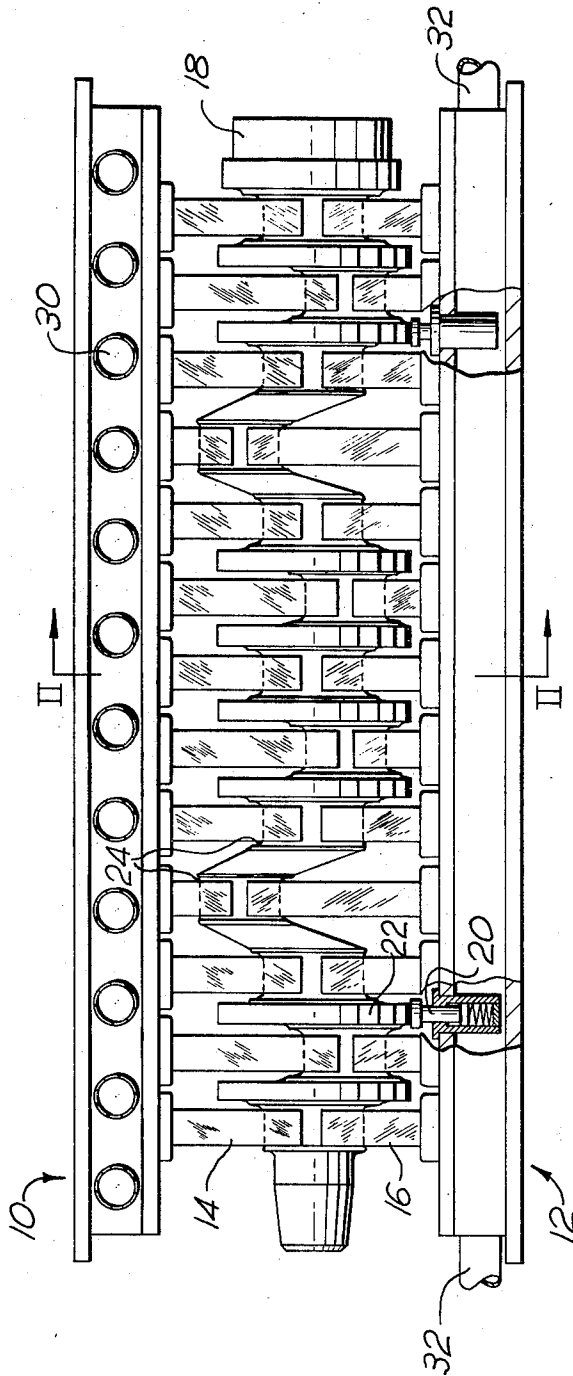


FIG. 1

INVENTORS
RAYMOND H. HAYS
JACK E. SANSON
KENNETH D. GLADDEN

BY
Fryer, Binnwald, Fox & Phillips
ATTORNEYS

April 14, 1970

R. H. HAYS ET AL
DIE-QUENCHED CRANKSHAFT

3,506,501

Filed May 26, 1966

3 Sheets-Sheet 2

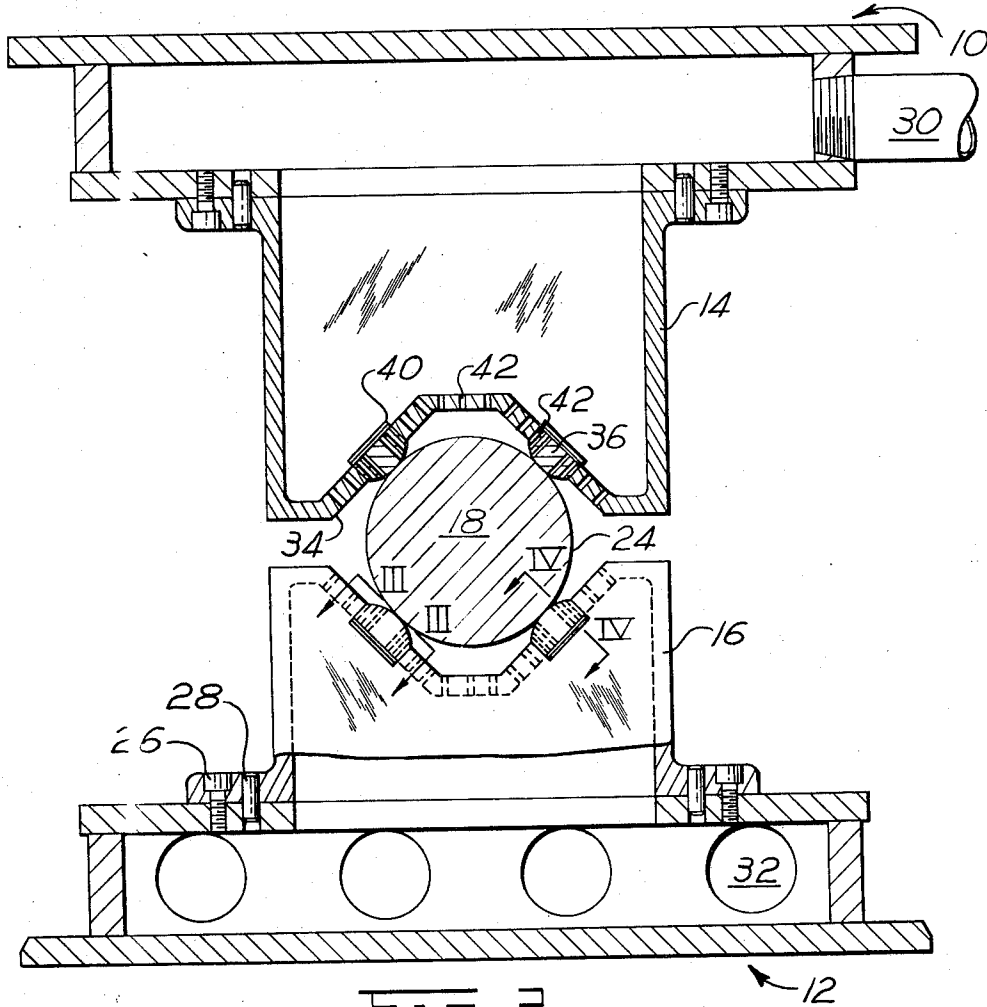


Fig. 2.

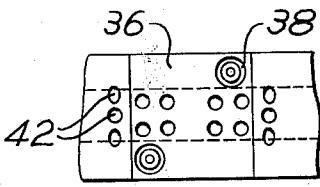


Fig. 3.

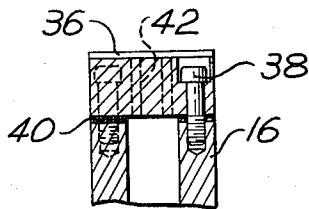


Fig. 4.

INVENTORS

RAYMOND H. HAYS
JACK E. SANSOM
KENNETH D. GLADDEN

BY
Fryer, Ginnard, Gier & Phillips
ATTORNEYS

April 14, 1970

R. H. HAYS ET AL

3,506,501

DIE-QUENCHED CRANKSHAFT

Filed May 26, 1966

3 Sheets-Sheet 3

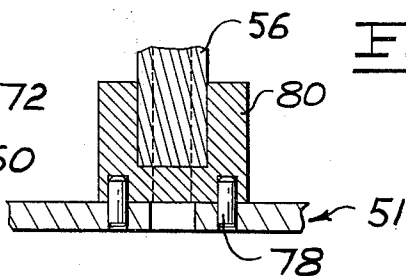
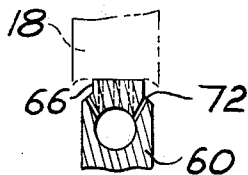
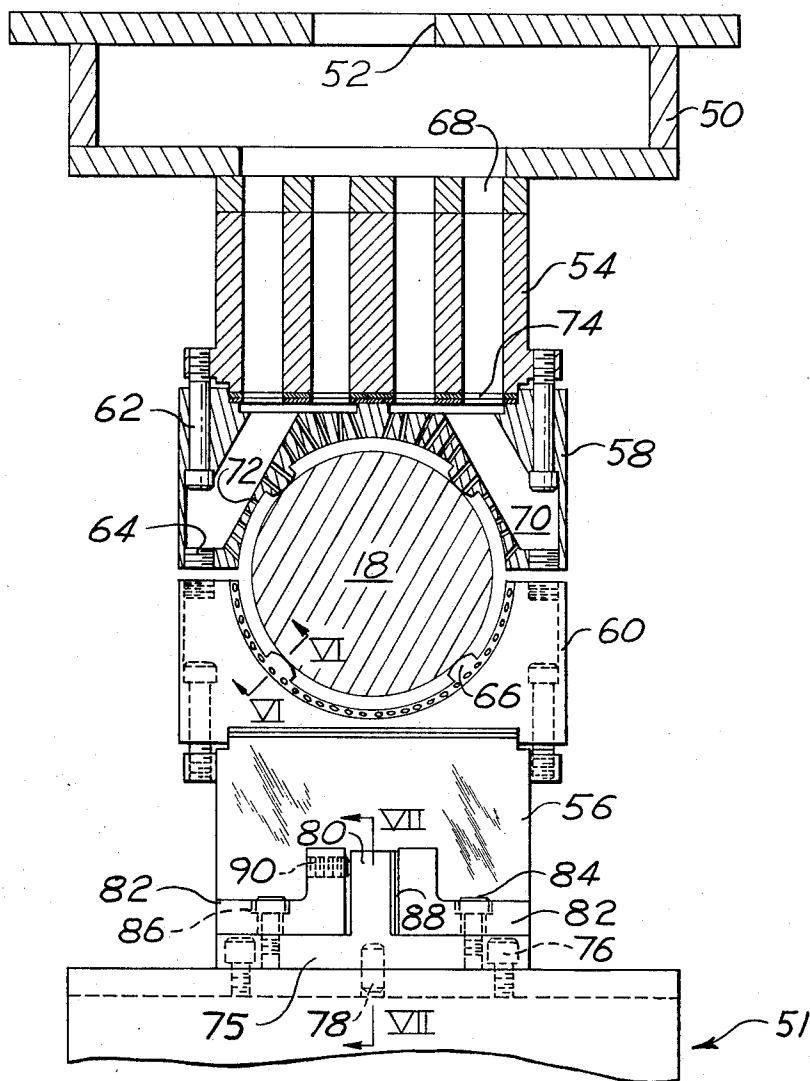


FIG. 5.

FIG. 6.

FIG. 7.

INVENTORS

RAYMOND H. HAYS

JACK E. SANSOM

KENNETH D. GLADDEN

BY

Fryer, Bynum, Kirk & Phillips
ATTORNEYS

1

2

3,506,501

DIE-QUENCHED CRANKSHAFT

Raymond H. Hays, Peoria, Jack E. Sansom, Eureka, and Kenneth D. Gladden, Washington, Ill., assignors to Caterpillar Tractor Co., Peoria, Ill., a corporation of California

Filed May 26, 1966, Ser. No. 553,142

Int. Cl. C21d 1/00, 1/62

U.S. Cl. 148—131

4 Claims

ABSTRACT OF THE DISCLOSURE

A multi-throw crankshaft is produced by a novel heat treating method which results in a finished crankshaft having a carbon content of .24-.40% case hardened to a substantially martensitic case over substantially its entire outer surface to a surface hardness of Rockwell C 44-54; and having a depth of hardness of .060-.200 inch.

This invention relates to a new improved die-quench hardened crankshaft and die-quenching apparatus and method for producing the same.

The current commercial practice of processing forged steel crankshafts is to heat and quench the entire surface for grain refinement and subsequently temper for producing a machineable hardness. After cold straightening and basic machining, the bearing surfaces are induction hardened, reheated to tempering temperature, and then finally finish ground. In some cases the bearing fillets are shot peened prior to final finishing to increase fatigue strength.

Several problems have led to the need for the present invention, each of which has more or less intensified the other. The first of these is the rapidly increasing gas pressures in modern diesel engines as a result of the constant demand for increased horsepower from an engine of given size. These pressures not only add further loading to the crankshaft but also excite more rigorous vibrations which add to crankshaft fatigue. It is, therefore, desirable to provide a crankshaft which would be stronger at its present size and weight without using more expensive alloy steels. Toward this end, attempts have been made to provide the stronger crankshaft by heat treatment.

Unfortunately, heat treatment per se causes several problems, especially with an article of such irregular shape as a crankshaft. One such problem is that in the use of existing induction heat treating methods, it is necessary to use a steel of high carbon content to get the depth of hardness which is needed for overall shaft strength and proper bearing life. A phenomenon which may be termed "longitudinal cracking" has occurred in engines utilizing relatively high carbon crankshafts. Such longitudinal cracks develop in the journal surface of the crankshaft during engine operation as a result of the adverse stresses produced from heat generated during bearing seizures. These cracks start a stress point which can lead to ultimate failure of the crankshaft.

During the past few years, the tempering temperature of the crankshafts has been raised from 540° to 740° F. to increase the ductility in the crank surface to prevent longitudinal cracking in field service and, unfortunately, the hardness level has been lowered from Rockwell C 49-57 to the present Rockwell C 40-46. This in turn has reduced the fatigue strength and wear-life of the crankshafts.

A further problem is that if a complete crankshaft is heated and immediately quenched in an open quenching tank, distortion is so great that considerable time is consumed in straightening the cold crankshaft to make it usable. This is not only objectionable from a cost standpoint but it has been proven that when a piece of steel

is straightened following heat treatment, some areas are structurally weakened. In many cases, the distortion is so great that it cannot be corrected within the desired limits.

Also in present induction hardening processes it is often necessary that oil holes in the crankshaft be plugged to prevent cracks from forming therein during the quenching operation. After the subsequent induction hardening process, the crankshafts are again straightened and a peening operation is done in the area of the pin and main journals. This operation is necessary on present production crankshafts to alleviate undesirable residual stresses caused by the sharp transition between the hardened and relatively unhardened portions of the crankshaft formed by the induction hardening in the fillet area. This tends to relieve the stressed area between the hardened portion of the bearing surfaces and the fillets and eliminate cracks that generally start in this area if no peening is done.

The present invention provides a low carbon content crankshaft which is completely die-quench hardened after substantially all machining operations have been performed thereon and which eliminates the need for the straightening process previously required, the shot peening operation, and the plugging of the crankshaft oil holes. Since low carbon quenched and tempered steels are tougher than high carbon steels at the same hardness level, it is possible to use a low carbon steel at a higher hardness level with no increase in susceptibility to longitudinal cracking, but with marked improvement in fatigue life. As a result of the invention, the final crankshaft hardness is of a higher value, such as Rockwell C 49-54, than that attainable previously without encountering cracking problems, etc. Further, as a result of the novel die-quenching apparatus of the present invention, it is possible to harden the entire surface of the crankshaft since when placed within the die the crankshaft is straightened and properly held while jets of water under pressure drastically quench the journals, thereby achieving an excellent surface hardening pattern. While the quenching process is taking place, the entire fixture and crankshaft are submerged and, due to the greatly agitated water from the jets, the hardness pattern is continued out into the cheeks and/or throws of the crankshaft.

The previously required cold straightening operation, the shot peening operation, and the need for plugging the oil holes have all been eliminated as a result of the invention. The straightening operation has been eliminated as a result of the novel die-quenching apparatus which properly retains the crankshaft during the quenching operation. The various other operations are eliminated since the extreme agitation of the water and jets against the retained crankshaft distribute the heat treat pattern evenly throughout the entire exposed surfaces of the crankshaft. Any changes between the hardened surfaces and relatively unhardened surfaces are gradual so as to eliminate the sharp stress concentrations known to crankshafts produced by prior art procedures.

In addition to the advantage of eliminating such previously required operations as straightening after quenching, shot peening and oil hole plugging, the low carbon content die-quench hardened crankshaft of the present invention has numerous other advantages such as increased fatigue life, higher surface hardness, elimination of longitudinal stress cracking, greater core strength and quench hardened fillets. Moreover, a more economical grade of steel can be used than was previously possible.

Other objects and advantages of the invention will become more readily apparent from the following detailed description when taken in conjunction with the accompanying drawing.

In the drawing:

FIG. 1 is a side elevation of one embodiment of die-

quenching apparatus constructed in accordance with the invention;

FIG. 2 is a partial cross section taken on the line II—II of FIG. 1;

FIG. 3 is a plan view taken on the line III—III of FIG. 2;

FIG. 4 is a cross sectional view taken on the line IV—IV of FIG. 2;

FIG. 5 is a longitudinal view, partially in section, of a modified embodiment of die-quenching apparatus constructed in accordance with the invention;

FIG. 6 is a cross sectional view taken on the line VI—VI of FIG. 5; and,

FIG. 7 is a cross sectional view taken on the line VII—VII of FIG. 5.

Referring now to FIG. 1, the die-quenching apparatus of the invention comprises a movable upper platen 10 adapted to cooperate with a work supporting lower platen 12. The platens 10 and 12 are respectively provided with a plurality of upper 14 and lower 16 die blocks which are adapted to receive therebetween a cylindrical workpiece such as the multi-throw crankshaft 18, on which the quenching operation is to be performed. It is to be noted that although the die blocks are of like construction, they are of different heights and in different locations, to secure the respective journals of crankshaft 18 in proper position. The lower platen 12 is provided with a plurality, preferably four, of spring loaded buttons 20 which support the crankshaft by its cheeks 22 when it is first placed in the apparatus. The buttons 20 prevent the crankshaft journals 24 from coming into contact with the cold metal of the die blocks 16 until the upper platen 10 is lowered into place for commencement of the straightening and quenching operation. Contact of the hot journals with the relatively cold die blocks for any length of time prior to application of the quench water effects a mild quench of the contact area and is detrimental to the quenching operation.

Referring now to FIG. 2 in conjunction with FIG. 1, it can be seen that the platens 10 and 12 and die blocks 14 and 16 are of hollow construction, the die blocks being secured to the platens by suitable retaining means 26 and alignment pins 28. A plurality of conduits, as indicated at 30 and 32, are connected to the platens allowing water under pressure to be directed through the platens to the die blocks.

As shown in FIGS. 2, 3 and 4, the upper die blocks 14 and lower die blocks 16 have generally cylindrical shaped opposed surfaces 34 for substantially surrounding the crankshaft 18 when the platens are in closed position. Two or more protruding pads 36 are suitably spaced about each die block surface for contact with and support of the crankshaft journals 24. Suitable retaining bolts 38 (see FIG. 4) are provided for securing and adjusting the pads 36 with respect to their respective die blocks. Shims 40 can be removed or added between the pads and their respective blocks so as to shift the workpiece either laterally or vertically. As shown, a plurality of small passageways 42 are provided in both the cylindrical surfaces 34 of the die blocks and the pads 36 to allow jets of water during the quenching operation to contact as much of the crankshaft journal surfaces as possible. It is important that the external surfaces of the pads 36 be shaped so as to make minimal contact with the journals during the quenching operation. Although the pads are shown with arcuately shaped external surfaces, these surfaces could be of any other suitable shape such, for example, as triangular with radiused corners providing the support for the various journals.

In the modified embodiment shown in FIG. 5-7, the upper platen 50 and lower platen 51 receive water through ports 52. Suitably secured to each of the platens, and in fluid communication therewith, are supporting blocks 54 and 56. Upper and lower die blocks 58 and 60 are

secured to their respective supporting blocks by retaining bolts 62, the bolt heads of which are accessible through normally plugged apertures 64. It should be noted that the pads 66 are an integral part of the die blocks 58 and 60. During the quenching operation, water under high pressure enters port 52, flows through drilled passages 68 into the die block cavity 70 and outwardly through holes 72 to spray against the crankshaft journals.

Since the pads 66 are integrally formed on the die blocks, lateral and vertical adjustment thereof must be made via the die blocks 58 and 60. The die blocks are adjusted vertically by changing shims 74 located between the die blocks and their respective supporting blocks. As best shown with reference to the lower platen 51 (FIGS. 5 and 7), an inverted T-shaped bracket 75 is fastened to the lower platen by means of bolts 76 and alignment pins 78. Located at the mid-portion of the bar of the T-shaped bracket is a bifurcated leg 80 which closely receives the support block 56. Integrally formed on the support block 56 are a pair of spaced arms 82 which straddle the leg 80 of bracket 75. The support block 56 is adjustably secured to the bracket 75 by means of fasteners 84 adapted to be received in oversized holes 86 formed in the arms 82. It will be readily understood that after loosening fasteners 84 the support block 56 and its associated die block 60 may be shifted horizontally by removing or adding shims 88 and loosening or tightening an adjusting screw 90.

Multi-throw crankshafts having a substantially martensitic case may now be produced with the following properties and characteristics; carbon content: .24-.40% C.; surface hardness: Rockwell C 44-55; depth of hardness: .060-.200 inch (as measured five Rockwell C points below the surface hardness). Test results have indicated that the above crankshafts, when die-quenched in the apparatus of the invention, have a Total Indicator Runout of less than .020 inch.

In operation, immediately after the crankshaft has been furnace heated to its austenitizing temperature, it is placed in the lower platen and supported above the lower die blocks by the spring loaded buttons. The buttons prevent the crankshaft journals from coming into contact with the die pads until a very short time prior to the beginning of the quenching cycle. The upper die is then moved into position forcing the spring loaded buttons downwardly which allows the crankshaft to be clamped in position as shown in FIGS. 2 and 5.

With the crankshaft clamped in position and with the entire quenching apparatus placed in a tank (not shown), fluid quenchant, preferably water under very high pressure, is directed through the hollow platens and sprayed through the many passages in the dies against the crankshaft journals and fillets. Immediately following the beginning of the quenching spray, the entire crankshaft is submerged and subjected to a drastic-quench so as to cause the hardness case to be extended over the entire crankshaft. Due to the extreme agitation of the water against the retained crankshaft, the heat treat pattern is distributed evenly throughout the entire exposed surfaces of the crankshaft including the oil hole surfaces inside the crankshaft. It is to be understood that the submersion process could be eliminated by providing sufficient water jets in the die-quenching apparatus to spray the entire crankshaft.

We claim:

1. Method of heat treating a steel multi-throw crankshaft containing about .24-40% carbon comprising: furnace heating the entire crankshaft to its austenitizing temperature; placing said crankshaft in a die-quenching fixture; closing said dies about said crankshaft and establishing minimal surface contact between said crankshaft journals and said dies while firmly maintaining said crankshaft in fixed axial alignment; and drastically quenching said crankshaft by spraying fluid quenchant under high

5

pressure through said fixture and over substantially the entire surface thereof to produce an essentially martensitic case over the surface of said multi-throw crankshaft.

2. Method of heat treating a multi-throw crankshaft as in claim 1 wherein, prior to closing said dies, said crankshaft is supported in said fixture only by the cheeks thereof, and wherein said crankshaft is drastically quenched by spraying water through said dies onto said crankshaft journals and fillets and immediately submerging said entire crankshaft and fixture in a water filled quench tank.

3. A carbon steel multi-throw die-quenched crankshaft having a carbon content of about .24-40%; case hardened to a substantially martensitic case over substantially its entire surface to a surface hardness of Rockwell C 44-54; and having a depth of hardness of .060-.200 inch.

4. A multi-throw crankshaft as set forth in claim 3 having in its unstraightened condition a total indicator runout of less than .020 inch.

6

References Cited

UNITED STATES PATENTS

| | | | |
|-----------|---------|----------------|----------|
| 1,742,739 | 1/1930 | Urschel | 266-6 |
| 2,255,103 | 9/1941 | Denneen et al. | 266-4 X |
| 2,343,889 | 3/1944 | Denneen et al. | 266-4 X |
| 2,492,434 | 12/1949 | Mueller | 266-6 X |
| 2,599,575 | 6/1952 | Morgan | 148-39 X |
| 2,709,077 | 5/1955 | Allen | 266-6 |
| 3,108,913 | 10/1963 | Sommer | 148-39 |
| 3,305,409 | 2/1967 | Cary | 148-146 |
| 1,924,296 | 8/1933 | Stoffel et al. | 148-151 |

CHARLES N. LOVELL, Primary Examiner

U.S. Cl. X.R.

74-595; 148-39, 147

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,506,501 Dated April 14, 1969

Inventor(s) Raymond H. Hays et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

CLAIM 1, line 2, "40%" should read -- .40% --.

CLAIM 3, line 2, "40%" should read -- .40% --.

Signed and sealed this 4th day of August 1970.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents