May 31, 1960 M. M. HOLBEN ET AL 2,938,260

METHOD OF FABRICATING CYLINDER BARRELS

Filed April 2, 1954 2 Sheets-Sheet 1

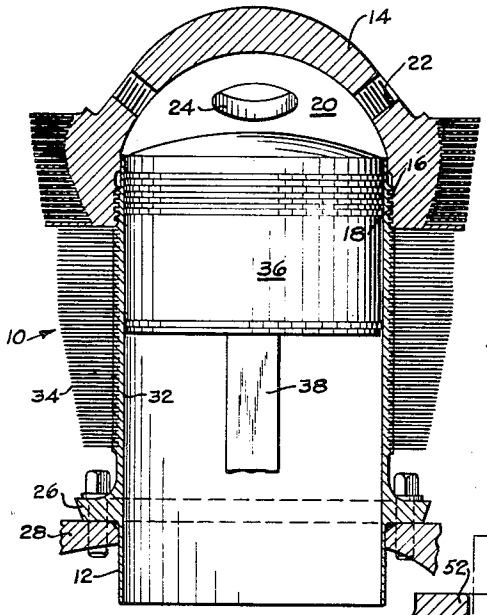

FIG. 1

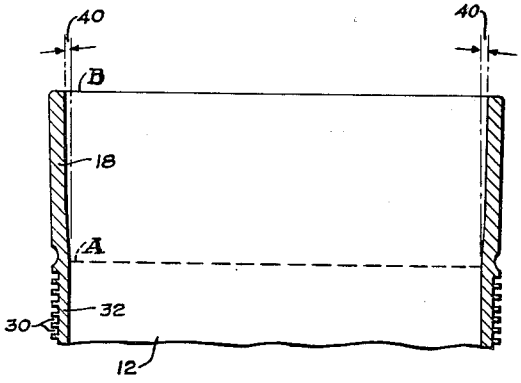

FIG. 2

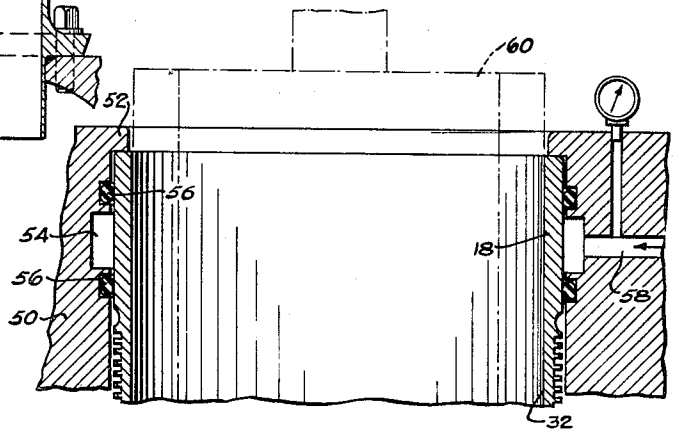

FIG. 3

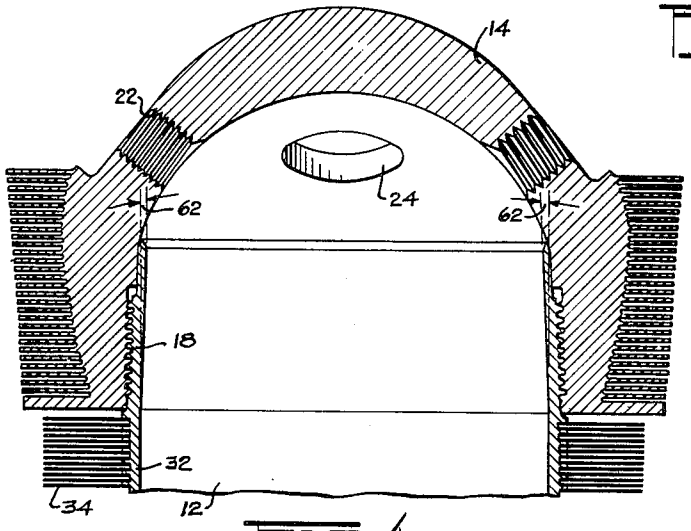

FIG. 4

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2 Sheets-Sheet 2

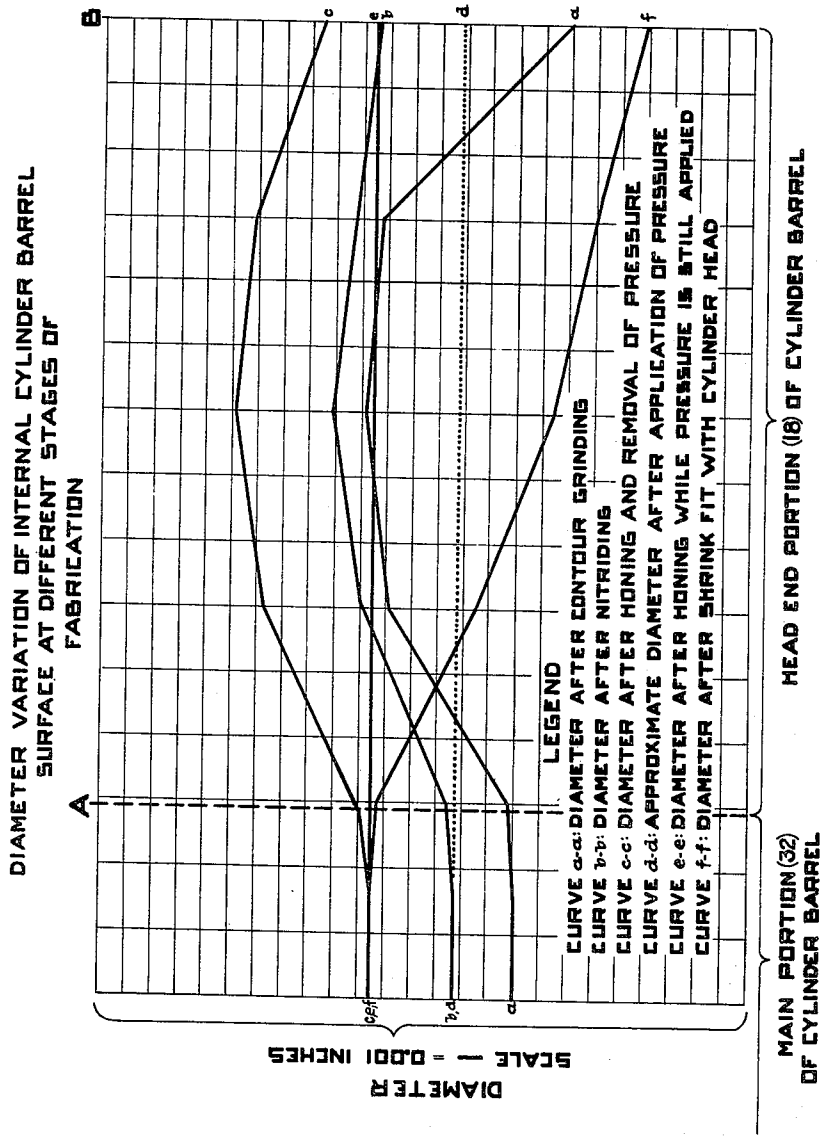

FIG. 5

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METHOD OF FABRICATING CYLINDER BARRELS

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3 Claims. (Cl. 29—156.4)

This invention relates to cylinder barrels and is particularly directed to internal combustion engine cylinder barrels and to a method of fabricating such cylinder barrels.

In the case of an internal combustion engine, during engine operation the cylinder head end (that is the end adjacent the cylinder combustion chamber) of a cylinder barrel runs hotter than the portions of the barrel more removed from the cylinder head. Hence the temperature responsive expansion of the cylinder head end of the barrel resulting from engine operation is greater than that of the adjacent barrel portion. To compensate for this uneven temperature responsive expansion it is conventional to fabricate an engine cylinder so that when the cylinder head is attached to the engine barrel the internal diameter of the head end portion of the cylinder barrel is slightly smaller, at room temperature, than that of the adjacent barrel portion. The magnitude of this choke construction of the head end portion of the barrel is such that when the cylinder reaches its operating temperature, during engine operation, the internal diameter of the head end portion of the cylinder barrel becomes approximately equal to that of the adjacent cylinder barrel portion.

It is conventional, at least in the case of aircraft engines, to attach a cylinder head to its barrel by shrinking the head on to the barrel. For this purpose, the internal diameter of the portion of the cylinder head to be connected about the head end of a cylinder barrel is provided with a room temperature diameter which is slightly smaller than that of the external diameter of the cylinder barrel head end. To connect said cylinder head and barrel, the cylinder head is heated and/or the cylinder barrel is cooled to an extent permitting a portion of the cylinder head to be disposed about the cylinder barrel head end. Said cylinder head and barrel are then restored to substantially the same temperature whereupon a tight connection is provided therebetween. Such a connection is known as a shrink fit. In order to obtain a tight shrink fit between a particular cylinder barrel head end and its cylinder head and in order that said cylinder barrel head end have the desired aforementioned choke after the head is shrunk thereon it has been found that prior to the shrink fit operation the internal diameter of the head end portion of the cylinder barrel must be made slightly larger than that of the adjacent cylinder barrel portion.

It is also conventional, at least in the case of aircraft engines, to nitride the internal surface of the cylinder barrels to provide said barrels with a hard wear resistant internal surface. This surface hardening nitriding operation is performed prior to attachment of the cylinder head to its cylinder barrel. U.S. Patent No. 2,437,249 to Floe discloses a suitable nitriding process for providing a cylinder barrel with a hardened nitrided surface layer. The specific process of this Floe patent is commonly termed a double cycle nitriding process. After the surface hardening operation the internal surface of a cylinder barrel is honed to provide the desired internal surface finish. The hardened nitrided surface is quite thin and

therefore care must be taken in the honing operation not to remove too much material. This fact coupled with the previously described enlarged diameter of the cylinder barrel head end has heretofore made it quite difficult to satisfactorily hone the internal cylinder barrel surface.

An object of the present invention comprises the provision of a novel procedure in the fabrication of cylinder barrels facilitating said honing operation. A further object of the present invention comprises the provision of such a novel procedure including the step of applying external pressure to the aforementioned enlarged diameter head end portion of the cylinder barrel to contract said head end portion to substantially the internal diameter of the adjacent barrel portion and then surface finishing (preferably by honing) the internal surface of the barrel, while said external pressure is so applied.

Other objects of the invention will become apparent upon reading the annexed detailed description in connection with the drawing in which:

Fig. 1 is a sectional view through an engine cylinder barrel and cylinder head assembly in connection with which the invention is described;

Fig. 2 is a sectional view of the cylinder barrel head end portion at an early stage of its fabrication;

Fig. 3 is a sectional view illustrating the cylinder barrel honing operation of the present invention;

Fig. 4 is an enlarged view of the head end portion of the cylinder barrel and its attached cylinder head; and

Fig. 5 is a graph showing the cylinder barrel diameter variation at different stages of its fabrication.

Referring first to Fig. 1, there is schematically illustrated a conventional metallic cylinder **10** of an aircraft internal combustion engine. The cylinder **10** comprises a cylinder barrel **12** and a cylinder head **14**, said barrel and head being secured together by a shrink fit between the meshing threads **16** of the cylinder head and the head end portion **18** of the cylinder barrel. Only the portion of the cylinder head completing the combustion chamber **20** is illustrated in the drawing, the cylinder head structure for supporting the valves and the valves having been omitted. The holes **22** in the cylinder head are for the cylinder spark plugs and the hole **24** is one of the valve ports. The cylinder barrel **12** has an annular flange **26** for attachment to an engine crankcase **28** and the barrel has external grooves **30** (best seen in Figs. 2–5) about the main barrel portion **32** within which cooling fins **34** are secured. A piston **36** is slidable in the cylinder barrel **12** and a connecting rod **38** serves to connect the piston **36** to an engine crankshaft (not shown). The cylinder and engine structure so far described is conventional.

The cylinder barrel is first fabricated with grooves **30** for the cylinder fins. Prior to securing the fins **34** in the grooves **30** and prior to machining the cylinder head attaching threads **16** on the cylinder barrel **12**, the internal surface of the cylinder barrel is ground, by means of a cam controlled contour grinding operation, so that the profile of the head end portion **18** of the barrel deviates from the adjacent constant diameter of the main portion of the cylinder barrel. The magnitude of this deviation is clearly shown by curve *a—a* in Fig. 5. In Fig. 5 stations A and B along the cylinder barrel are at the two ends of the head end portion of the barrel and these same stations are also indicated on Fig. 2. Hence it is clear from Fig. 5 that, as contour ground, the diameter of head end portion of the barrel progressively increases from the constant diameter of the adjacent main barrel portion **32** to a maximum diameter approximately midway between stations A and B and then progressively decreases so that at station B the diameter is actually slightly less than said constant main portion diameter. The magnitude of the deviations in diameter illustrated

are for a cylinder barrel having a diameter of approximately six inches and, as indicated by the diameter scale on Fig. 5, said deviations are highly magnified in Fig. 5.

After the cylinder barrel internal surface is contour ground to the diameters indicated by curve *a—a* in Fig. 5, said internal surface is treated to provide a hard surface layer. For this purpose the internal surface of the cylinder barrel may be treated by a nitriding process and preferably by a double cycle nitriding process such as disclosed in the aforementioned Floe patent. Such a nitriding operation results in an increase in the internal diameter of the cylinder barrel particularly at the extreme head end of the barrel (station B). The new diameter variation along the barrel is indicated by curve *b—b* in Fig. 5. From said curve *b—b* it is apparent that the cylinder barrel main portion **32** now has a slightly larger constant internal diameter and the internal diameter of the barrel head end portion **18** increases from said constant diameter at station A to a maximum value at a point between stations A and B and then is approximately constant to station B. Fig. 2 illustrates the cylinder barrel after the nitriding operation, reference numeral **40** designating said enlarged diameter condition of the cylinder head end portion. Remembering that the diameter scale is highly magnified in Fig. 5 it is apparent that the enlarged diameter condition of the head end portion **18** of the barrel is greatly exaggerated in Fig. 2.

The hardened nitrided internal surface layer of the cylinder barrel is now honed to provide the desired surface finish. Curve *c—c* of Fig. 5 shows the desired diameter variation after the honing operation. Because of the thinness of said nitrided surface layer it is essential that no more than a predetermined depth of material be removed by the honing operation from any portion of the internal surface of the barrel. Heretofore the enlarged diameter head end portion of the barrel was honed by a contour honing operation. Considerable difficulty, however, was experienced in removing just the right amount of material at all points during the honing operation. If too much material is removed at any one point the relatively soft material under the hard nitrided surface layer would be exposed thereby materially reducing the useful service life of the barrel. On the other hand if too little material is removed at some region, this region may constitute a high spot after the cylinder head is shrunk on to the barrel such that during subsequent engine operation the barrel would scuff in this region. Furthermore a nitrided surface layer has a brittle outer film which, if not entirely removed from the cylinder barrel nitrided surface by the honing operation, tends to break loose during subsequent engine operation to cause scuffing. Also this brittle outer film, if not removed, appears to promote corrosion of the cylinder barrel. It is apparent therefore that the depth of material removed by the honing operation must be carefully controlled. If the internal surface of the barrel has been nitrided by the double cycle nitriding process of the aforementioned Floe patent then the honing operation should remove material to a depth of at least 0.0002 inch to insure removal of said brittle surface film but, to prevent exposure of the relatively soft material under the hard nitrided layer, the honing operation should not remove material to a depth of more than 0.002 inch. These dimensions may vary somewhat if a different form of nitriding process is used.

In accordance with the present invention the barrel to be honed is first placed within the cylindrical bore of a fixture **50**. This fixture has a flange **52** or other means for accurately locating the barrel therein and has an annular groove **54** which, when a barrel is supported within the fixture **50**, is disposed approximately midway between the ends of the head end portion **18** of said barrel. The fixture **50** also includes seal rings **56** which engage said barrel on each side of the annular groove **54**. A suitable liquid, such as oil, is supplied under a predetermined pressure to the groove **54** by a passage **58**. This oil pressure acts inwardly on the enlarged head end portion **18** of the barrel to contract said end. It has been found that by properly selecting the magnitude of said pressure the enlarged head end **18** of the barrel can be contracted inwardly, within the elastic limits of the cylinder barrel material, so as to provide a right-circular cylindrical continuation of the main barrel portion. That is, the head end portion **18** of the barrel and the main portion **32** of the barrel now form one continuous cylinder of substantially constant diameter as indicated by the approximate line *d—d* of Fig. 5. While the internal surface of the barrel is thus contracted by the hydraulic pressure of the fixture **50** to a cylinder of substantially constant diameter, its internal surface is honed by a conventional cylindrical honing operation. Obviously, with a conventional hone schematically indicated at **60**, the amount of material removed by the honing operation can more readily be controlled with such a cylindrical honing operation compared to the difficulty experienced with the contour honing procedure previously employed. Line *e—e* of Fig. 5 indicates the constant internal diameter of the cylinder barrel after the honing operation and while the barrel is still in the fixture **50** and the head end of the barrel is elastically contracted by the pressure in the annulus **54**.

The honed barrel is then taken out of the fixture **50** whereupon, because of the relief of the external pressure against the head end portion **18** of the cylinder barrel, said portion elastically springs out to an enlarged diameter condition so that the internal diameter variation of the barrel is now as indicated by curve *c—c* of Fig. 5. Threads **16** are now machined on the external surface of the head end portion of the barrel. During the threading operation the diameter of the barrel head end portion increases slightly apparently as a result of the working of the material. The cylinder head **14** has mating threads **16** of somewhat smaller pitch diameter and the cylinder head is now secured to the barrel by means of a shrink fit connection between the cooperating threads **16** of the head and barrel as illustrated in Fig. 4. This shrink fit contracts the head end portion of the barrel to provide the desired choke at the cylinder barrel head end. The decrease in diameter or choke of the barrel head end portion is shown by curve *f—f* in Fig. 5 and has been exaggerated for purposes of illustration at **62** in Fig. 4.

As herein used a "surface finishing" operation is one, such as honing which removes a small controlled amount of surface material to provide the desired surface finish. In the case of a cylinder barrel having a nitrided surface layer obtained by the aforementioned double cycle nitriding process, the surface finishing operation preferably should remove material to a depth of no more than 0.002 inch and no less than 0.0002 inch from any portion of the nitrided surface layer.

While we have described our invention in detail in its present preferred embodiment, it will be obvious to those skilled in the art, after understanding our invention, that various changes and modifications may be made therein without departing from the spirit or scope thereof. We aim in the appended claims to cover all such modifications.

We claim as our invention:

1. The method of fabricating a cylinder barrel for an internal combustion engine; said method comprising the steps of forming a barrel with the head end portion of the barrel having an internal diameter which progressively increases from the adjacent barrel portion to a maximum value and then progressively decreases so that the extreme head end of the barrel has a diameter substantially equal to that of said adjacent portion; nitriding the internal surface of said barrel, the internal diameter of said head end portion, and particularly that of said extreme head end, increasing relative to that of

the adjacent barrel portion during said nitriding operation; applying hydraulic pressure inwardly against the head end portion of the barrel so that the internal diameter of said head end portion is elastically decreased approximately to that of said adjacent barrel portion; and then, while said hydraulic pressure is applied, honing the internal surface of said barrel.

2. The method of fabricating a cylinder barrel for an internal combustion engine; said method comprising the steps of forming a barrel with the head end portion of the barrel having an internal diameter which progressively increases from the adjacent barrel portion to a maximum value and then progressively decreases so that the extreme head end of the barrel has a diameter substantially equal to that of said adjacent portion; nitriding the internal surface of said barrel, the internal diameter of said head end portion, and particularly that of said extreme head end, increasing relative to that of the adjacent barrel portion during said nitriding operation; applying hydraulic pressure inwardly against the head end portion of the barrel in an annular zone spaced from the ends of said head end portion so that the internal diameter of said head end portion is elastically decreased approximately to that of said adjacent barrel portion; and then, while said hydraulic pressure is applied, honing the internal surface of said barrel.

3. The method of fabricating a cylinder barrel for an internal combustion engine; said method comprising the steps of forming a barrel with the head end portion of the barrel having an internal diameter which progressively increases from the adjacent barrel portion to a maximum value and then progressively decreases so that the extreme head end of the barrel has a diameter substantially equal to that of said adjacent portion; nitriding the internal surface of said barrel, the internal diameter of said head end portion, and particularly that of said extreme head end, increasing relative to that of the adjacent barrel portion during said nitriding operation; applying hydraulic pressure inwardly against the head end portion of the barrel so that the internal diameter of said head end portion is elastically decreased approximately to that of said adjacent barrel portion; and then, while said hydraulic pressure is applied, honing the internal surface of said barrel so that the depth of the material removed by the honing operation is no more than 0.002 inch and is no less than 0.0002 inch.

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