Oct. 18, 1966 J. G. CAMPBELL 3,279,443

CYLINDER LINERS

Filed Nov. 2, 1964

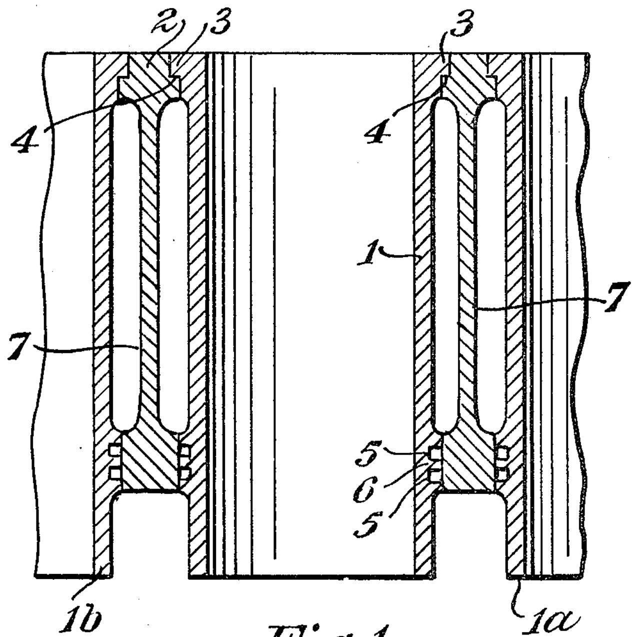

Fig.1.

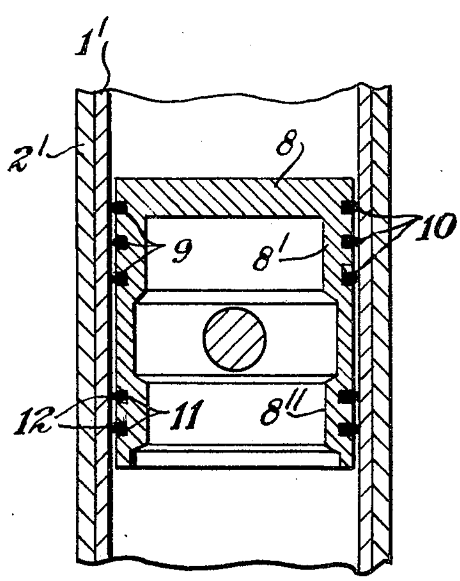

Fig.2.

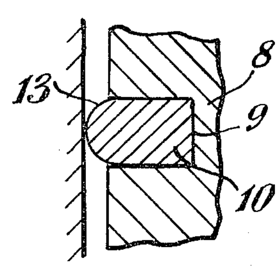

Fig.3.

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3,279,443

Patented Oct. 18, 1966

3,279,443

CYLINDER LINERS

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Filed Nov. 2, 1964, Ser. No. 408,224
Claims priority, application Great Britain, Nov. 8, 1963, 44,234/63
19 Claims. (Cl. 123—41.72)

This invention relates to internal combustion engines having cylinders and combustion chambers. The invention more particularly relates to such engines having at least one cylinder with a piston reciprocatable therein, and the invention will primarily be described in relation thereto although the cylinder could be other shapes, e.g., spherical. As will be seen, the invention has been described in the drawings with reference to the cylinder. Within the scope of the invention, however, it will be appreciated that a portion (i.e., the upper portion) of the cylinder in fact forms part of the combustion chamber due to the fact that combustion of the gases takes place partially within the cylinder. The piston is normally provided with piston rings, as is well known, to provide a seal between the piston and cylinder wall.

Considerable heat is generated in the cylinder of such an internal combustion engine, and this heat is transmitted to the piston body via the crown. It is essential to provide means for removing the excess heat produced in this manner. The engine runs more efficiently if the engine temperature is kept below a certain limit, and furthermore a substantial excess of heat can lead to serious trouble such as seizure of the engine, including something akin to fusion between the piston and cylinder liner.

Primary cooling is effected by circulation of a heat transfer medium, usually water, in the block surrounding the cylinder, or air around fins surrounding the cylinder. This is assisted by a secondary system whereby a film of oil flows over the surface of the cylinder wall. The wall of the cylinder is normally provided by a cylinder liner fitted within a cylindrical cavity in the block.

Although the cylinder liner is normally of different material from that of the block, it is theoretically possible for the inside surface of the cylinder to be of the same material as the cylinder block as a whole. Accordingly, the term cylinder liner used herein is intended to cover the inside surface portion of the cylinder, whether this be of separate material or of the same material as the cylinder block as a whole. Moreover, the liner may be a liner in the strict sense of being used inside a supporting outer wall, or it may itself constitute the whole thickness of the cylinder wall.

Up to now, cylinder liners have normally been made of metal, generally steel. These have in general proved satisfactory in service, though a number of improvements are desirable, particularly in respect of the following types of difficulties:

(1) It is quite a common experience that such engines can become too hot, resulting in the well-known phenomenon of "boiling" of the engine in automobiles and the like, thus necessitating a lengthy halt of the vehicle to await natural cooling and replacement of cooling water in the case of a water circulation system.

(2) A convenient clearance has to be provided between the piston rings and cylinder liner in order to allow for the persistence of a continuous oil film on the inner wall of the liner, and in order to allow for any expansion differentials between the piston ring on the one hand and the cylinder liner on the other hand. The size of these clearances can affect the dynamic performance of the engine.

(3) There is a certain amount of unavoidable friction between the piston rings and the cylinder liner, despite the oil film, and this not only causes wear on these coacting parts but makes it difficult to obtain the maximum number of piston traverses for a given power rating.

(4) In the event of over-heating, for example, due to breakdown of the primary and/or secondary cooling system, seizure of the engine can be caused with something akin to fusion between the piston rings and cylinder liner. This generally necessitates complete replacement of the engine, which of course is a substantial cost.

It is an object of the present invention to provide an alternative material for the cylinder liner which will provide an improvement in respect of some or all of the above listed factors.

A further object of the invention is to provide a material for cylinder liners which can be modified to suit a variety of requirements for different types of engines and different types of fuels.

According to the present invention, an internal combustion engine has a liner for the cylinder, a portion of which forms the combustion chamber, made of inpermeable graphite. By impermeable graphite we mean a graphite which has been so treated or which is of such a nature that is is substantially impermeable to the gases under pressure in the cylinder and combustion chamber and to the primary and/or secondary coolant fluids.

The graphite may be rendered substantially impermeable by impregnating it with a suitable material. Of the impregnants that may be used, phosphor-copper, cast-iron and vitreous materials are useful examples. An alternative and preferred impregnant is carbon which can be used to fill the graphite pores by, for example, deposition from an organic vapour or gas passed into the pores of a graphite material; preferably this carbon is subsequently converted to graphite by heat treatment. Similarly metallic material may be introduced into the pores in the form of low temperature volatiles such as metallic halides which are subsequently reduced to the metallic state in situ. Impregnation with materials other than carbon is very suitably performed by forcing molten or liquid impregnant into the pore system of the graphite. Alternatively the graphite may be made impermeable by coating one of its surfaces with a coherent film of metallic or vitreous material having a physical or chemical bond with compatible thermal properties. The impregnation of graphite and suitable processes for carrying it out are discussed in "Engineering" dated January 22, 1960, at pages 110 and 111, in "Atomkernenergie" dated April 1961 at pages 137 to 151, and in French Patent No. 1,276,671.

Alternatively, it may be possible to provide the impermeability by using a special densified graphite in which the size of pores is so reduced as compared with normal commercial graphite that permeation by the gases inside the cylinder is substantially prevented, without any need for impregnation.

For many purposes it is desirable that the graphite of the liner be impregnated throughout between the inner and outer walls, although such complete impregnation may not be necessary to provide impermeability. Impermeability of the graphite is of course an essential property in order to provide a cylinder and combustion chamber liner, but it has been found that the nature and extent of impregnation is also important since these can be so modified and selected as to provide a wide range of properties of the liner for suiting different engines and different fuels. Thus the impregnant can be so selected as to improve heat conductivity, anti-friction properties, strength, and surface wetting and film holding properties of the inner wall with respect to the oil lubricant.

In order to take full advantage of the benefits of using a cylinder liner of impermeable graphite, it is desirable to consider the piston rings on the piston which is to reciprocate within the liner. It is desirable to arrange the rings so that the piston will travel more truly axial in the cylinder and minimise the commonly known "slap" which imparts appreciable impact loadings in the liner wall. It is accordingly desirable to have a ring or rings in the lower part or skirt of the piston in addition to a ring or rings at the top of the piston. A suitable arrangement would be three rings at the top and two rings in the lower part. Furthermore, piston rings in common use have a square cross section, presenting a comparatively large contact area to the inner surface of the cylinder liner. With cylinder liners in internal combustion engines according to the invention it is preferred to reduce this contact area by offering a hemispherical or curved surface of the piston ring to the liner wall and thereby reduce mutual wear. Further, the wear of the ring will be of a more even nature and will maintain a more efficient seal to combustion gases, at the same time reducing the possibility of uneven wear on the liner wall, so that the true cylindrical nature of the bore may persist for a longer period of time. Very desirably the piston rings should be made of graphite, permeable or impermeable, in order to provide a graphite-to-graphite contact with the cylinder liner.

Amongst known cylinder liner arrangements is the one in which the cooling medium, such as water, acts directly on the outer surface of the cylinder liner. This system, generally known as a "wetliner," is the preferred one for the use of liners in internal combustion engines according to the invention, since it enables fullest advantage to be taken of the textural and thermal characteristics of graphite which will inhibit "film boiling," that is the persistence of a layer of coolant vapour coincident with the outer surface of the liner, which acts as a barrier to efficient heat transfer. For this system, the liner will generally be thicker than would otherwise be required, and in fact it is perhaps then no longer a "liner" in the strict sense of the word, though it will be termed such for the purposes of this specification.

Embodiments of this invention are illustrated in the accompanying drawing, in which:

FIGURE 1 is a diagrammatic view of part of a cylinder block containing a "wet liner" of impermeable graphite, shown in broken section.

FIGURE 2 is a sectional view of a piston head suitable for use with cylinder liners in a reciprocating engine according to this invention, shown in position within a cylinder having a liner of impermeable graphite, and

FIGURE 3 is a sectional view of a detail of the piston head of FIGURE 2 showing a preferred construction of a piston ring.

In FIGURE 1, a cylinder liner **1** of impermeable graphite is held supported by a cylinder block, part of which is shown at **2**, by means of a flange **3** on the liner that seats within an annular recess **4** on the cylinder block **2**. At the lower end of liner **1**, a thicker portion in contact with the cylinder block contains two annular grooves **5**. There are thus defined three annular ribs as at **6**. This means that a smaller area of accurate machining is necessary than if the grooves **5** are absent, and there is thus permitted a better fit of the liner **1** within cylinder block **2**. The cylinder block **2** comprises a plurality of spaced ribs **7**, disposed around the cylindrical outer surface of liner **4** extending parallel to its axis and spaced apart from the outer surface so as to provide for circulation of coolant fluid between the ribs **7** and around the liner. FIGURE 1 also shows in broken section parts of two adjacent cylinder lines **1***a* and **1***b*, so as to indicate the relative position of a series of liners within cylinder block **2**.

In FIGURE 2, a piston head shown generally at **8** is contained within a cylinder comprising a cylinder wall **2′** and liner **1′**. Three grooves **9** in the crown portion **8′** of

piston head **8** each contain a graphite piston ring **10**. Similarly, a pair of grooves **11** in the skirt portion **8″** of the piston head **8** contain two graphite piston rings **12**. The piston rings in this embodiment are all made so as to present a substantially hemispherical surface, when viewed in radial cross-section, to the cylinder liner. This construction is illustrated in FIGURE 3 where an enlarged view of one of the piston rings **10** is given. It will be seen that the provision of a substantially hemispherical surface **13** on the piston ring **10** results in its making what is virtually a line contact with the liner **1′**.

The advantages of using the impermeable graphite cylinder liner of the present invention are as follows:

(a) One can obtain improved heat transfer rates due to the reduction and in some cases elimination of heat transfer barriers. This allows cooler running to be obtained.

(b) One can obtain superior surface wetting and film holding properties of the inner wall of the liner, and this allows one to use a thinner oil film on the inner wall and hence allows one to use a reduced clearance between the piston rings and liner. This will improve the dynamic performance.

(c) One can obtain less friction on the liner wall, and this will provide less wear and smoother running. One will then obtain an increased number of piston traverses for the same power rating and hence improve the efficiency of the engine.

(d) Should there be a failure of the primary and/or secondary cooling systems, one will avoid the rigid seizure of the engine by way of something akin to fusion occurring between the piston rings and the cylinder lining. Overheating of the graphite liner resulting in a breakdown of the oil film, will not cause seizure as the low coefficient of friction will allow the continued operation of the engine, although naturally at a reduced efficiency accompanied by reduced compression and increased wear due to the loss of the oil seal.

(e) By suitable selection of impregnant, the liner can be made stronger and hence thinner. One can thus improve heat transfer and again obtain cooler running.

Reference herein to graphite should be construed as applying also to carbon or mixed graphite-carbon, where the context so permits. The invention is applicable to liners of carbon or mixed graphite-carbon. It will be appreciated that the principles of this invention could be applied to other parts of an internal combustion engine.

What is claimed is:

1. An internal combustion engine having a cylinder liner made of graphite wherein the graphite has been rendered impermeable by impregnation.

2. An internal combustion engine according to claim **1** wherein the graphite of the liner has been impregnated with a vitreous material.

3. An internal combustion engine according to claim **1** wherein the graphite of the liner has been impregnated with phosphor-copper.

4. An internal combustion engine according to claim **1** wherein the graphite of the liner has been impregnated with cast-iron.

5. An internal combustion engine according to claim **1** wherein the graphite of the liner has been impregnated with carbon.

6. An internal combustion engine according to claim **1** wherein the graphite of the liner has been impregnated with carbon which has been subsequently converted to graphite by heat treatment.

7. An internal combustion engine having a cylinder, a portion of which forms the combustion chamber and means for cooling said combustion chamber with coolant fluid, the combustion chamber having a combustion chamber liner made of graphite rendered impermeable by impregnation, the cooling means being adapted to provide direct contact between the outer surface of the combustion chamber and coolant fluid.

8. An internal combustion engine according to claim **7** wherein the graphite of the liner has been impregnated with a vitreous material.

9. An internal combustion engine according to claim **7** wherein the graphite of the liner has been impregnated with phosphor-copper.

10. An internal combustion engine according to claim **7** wherein the graphite of the liner has been impregnated with cast-iron.

11. An internal combustion engine according to claim **7** wherein the graphite of the liner has been impregnated with carbon.

12. An internal combustion engine according to claim **7** wherein the graphite of the liner has been impregnated with carbon which has been subsequently converted to graphite by heat treatment.

13. A reciprocating internal combustion engine having a combustion chamber and a cylinder liner, the cylinder liner being made of graphite rendered impermeable by impregnation, said engine additionally having a piston reciprocatable within the cylinder liner, the piston being provided with at least one piston ring of graphite.

14. A reciprocating internal combustion engine according to claim **13** wherein the piston ring presents a curved surface, when viewed in radial cross section, to the cylinder liner.

15. An internal combustion engine according to claim **13**, wherein the graphite of the liner has been impregnated with a vitreous material.

16. An internal combustion engine according to claim **13** wherein the graphite of the liner has been impregnated with phosphor-copper.

17. An internal combustion engine according to claim **13** wherein the graphite of the liner has been impregnated with cast-iron.

18. An internal combustion engine according to claim **13** wherein the graphite of the liner has been impregnated with carbon.

19. An internal combustion engine according to claim **13** wherein the graphite of the liner has been impregnated with carbon which has been subsequently converted to graphite by heat treatment.

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