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None

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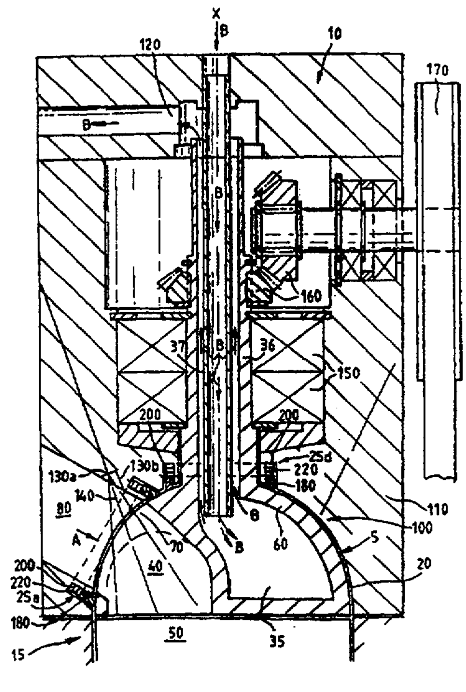
(54) Abstract Title
Improvements in or relating to rotary valves

(57) There is disclosed an improved rotary valve (5), and to an internal combustion engine including such a valve (5). In internal combustion engines use of poppet valves has predominated due to an inability of rotary valves to perform reliably without excessive oil consumption. However, the invention provides an improved valve (5) for use with an internal combustion engine (10) comprising at least one cylinder (15) having a reciprocable piston (50), the valve (5) comprising a valve seat (20) having at least one inlet (80) and/or at least one outlet (90), a rotatable valve member (60) mountable within the valve seat (20) at a compression end of one of the at least one cylinders (15) and having at least one orifice (70) extending therethrough between the valve seat (20) and an interior of the cylinder (15), wherein there is provided a seal member(s), (25a, 25b, 25c) between the valve member (60) and the at least one inlet (80) and/or the at least one outlet (90).



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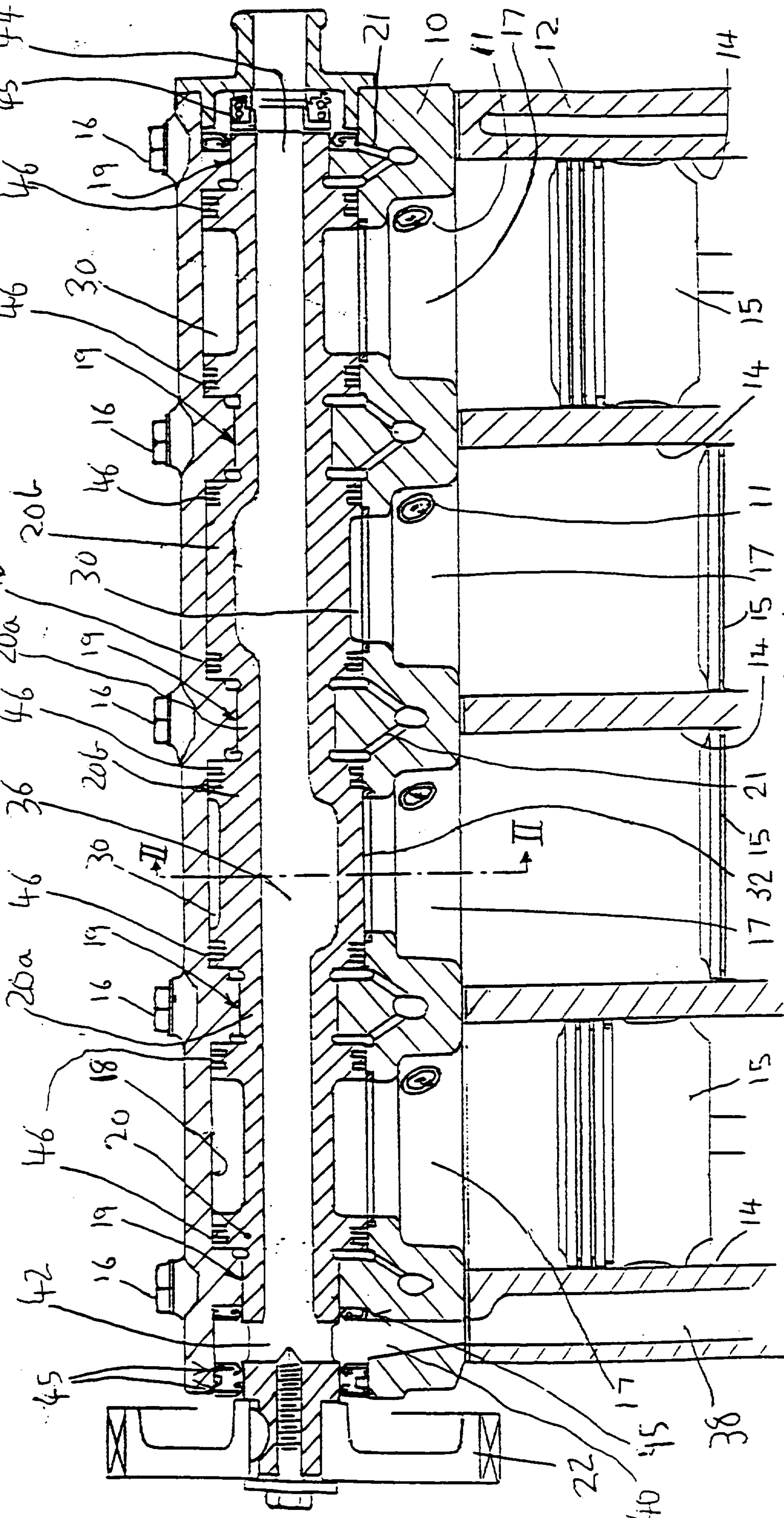
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Fig. 1.

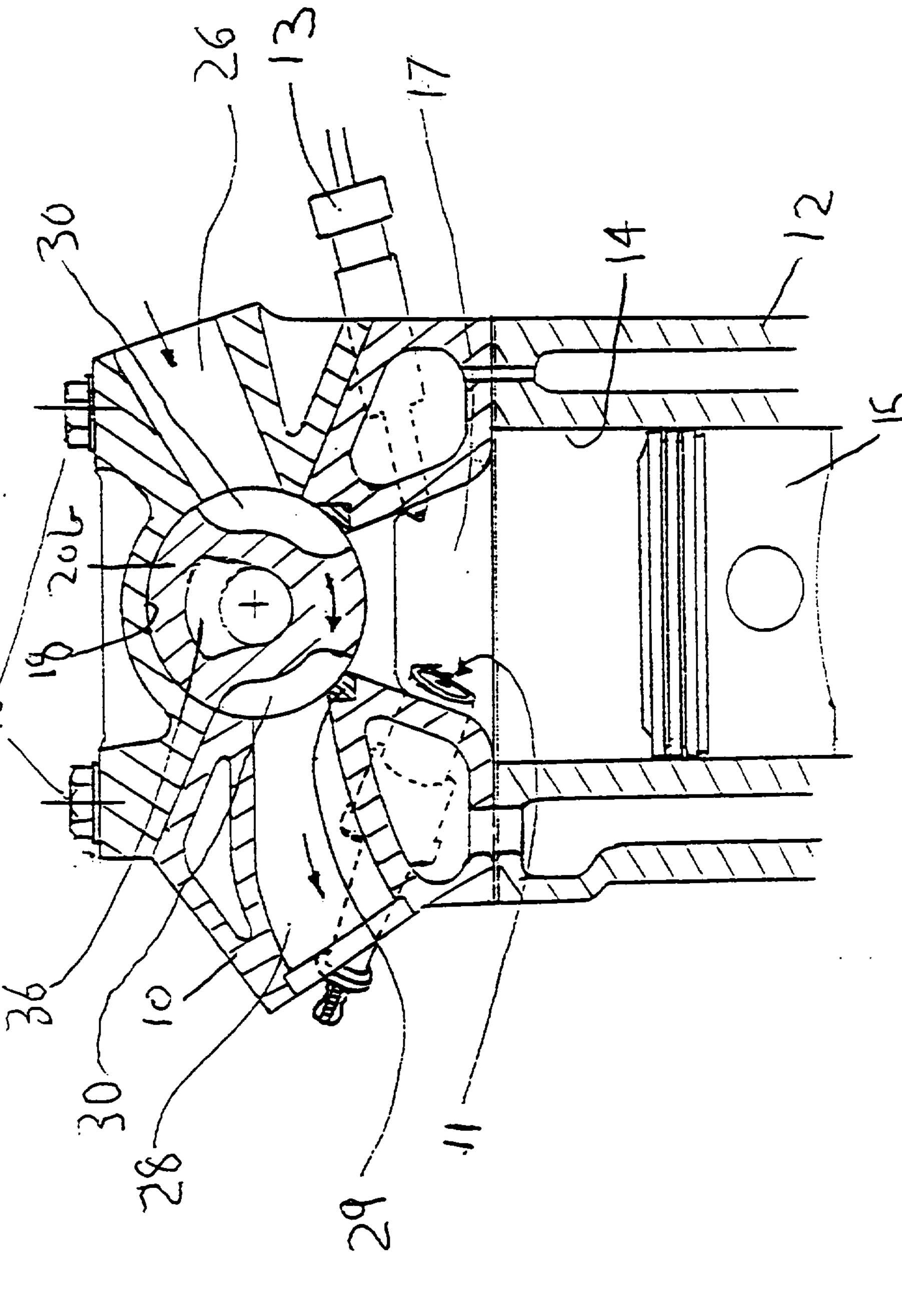

Fig. 2

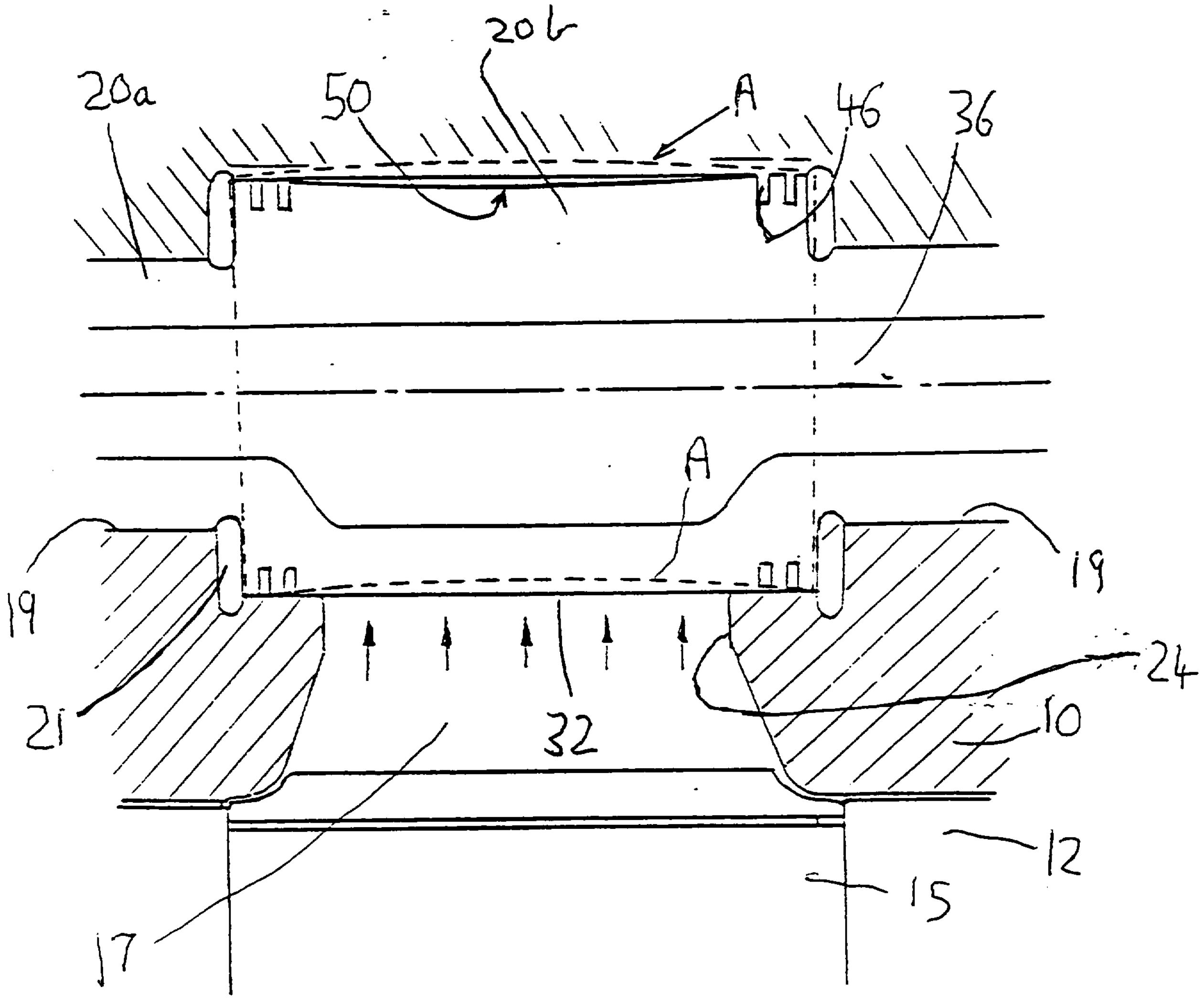

Fig.3.

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VALVE ARRANGEMENT FOR AN INTERNAL COMBUSTION ENGINE

This invention relates to a valve arrangement for controlling the induction and/or exhaust events of an internal combustion engine. The valve arrangement is, primarily, but not exclusively, suitable for engines of the four-stroke cycle type.

Four-stroke cycle internal combustion engines, whether operating on gasoline, diesel or gaseous fuels, customarily have their induction and exhaust processes controlled by camshaft actuated poppet valves. This type of valve arrangement has attained a high level of reliability following nearly a century of progressive development. It permits satisfactory operation at high engine revolution speed, and provides excellent sealing against gas pressure effects. On the deficit side, power consumption and noise levels can be excessive with multiple poppet valve layouts; the operating mechanism may be complex, highly stressed and subject to resonant vibration effects; moreover, the complete system may be quite costly.

The present invention describes an alternative valve arrangement that is particularly suited to circumstances where all the cylinders are in line, or each cylinder bank of a V-engine is in-line. It is conceptually simpler than a multiplicity of poppet valves, has lower power consumption but has mass flow characteristics comparable to poppet valves, and can have provision for direct axial cooling. Both liquid and gas sealing systems can be provided using known technology. A particular feature of the valve arrangement herein described is that it has a lower total installed cost than an equivalent array of poppet valves, whilst providing markedly lower Noise, Vibration and Harshness (NVH) levels with no reduction in power.

The invention provides a valve arrangement for controlling the induction and/or exhaust events of an internal combustion engine, the valve arrangement comprising a housing which defines a generally cylindrical recess which communicates with a combustion chamber of the engine, a spool mounted for rotation in said recess, and rotating means operable to rotate the spool in said recess in synchronisation with the operating cycle of the engine, the housing also defining at least one port which communicates with said recess, the spool having surface portions which, as the spool rotates, close said port at appropriate times in the operating cycle of the engine and connect the port to the combustion chamber at other appropriate times, wherein a relief space is formed in the spool and/or the housing, said relief space being positioned so that it accommodates flexing of the spool caused by combustion events in said combustion chamber.

In a valve arrangement according to the invention, the spool can rotate, eg in journal bearings, whilst maintaining a minimum clearance to allow lubricant free operation. The size of the relief space is determined according to the section modulus of the spool, the elastic modulus of the spool material, the variation of the gas pressure, and the unsupported span of the spool between bearing supports.

In a valve arrangement according to the invention, the relief space may vary in depth such that the spool, when flexed by a combustion event, is a close fit in the relief space.

Preferably, to enable said relief space to be easily formed, eg by machining, said relief space is formed in the spool in a region of the surface thereof which is diametrically-opposed to the portion of the surface of the spool which faces the combustion chamber during combustion events.

In order to cool the spool, said spool may have a cooling passage extending axially therethrough. The cooling passage may vary in cross-sectional area such that the cooling effect, achieved by passing coolant through said cooling passage, is concentrated in regions of the spool which are exposed to the most heat.

A valve arrangement according to the invention may comprise a plurality of lip or face seals acting between the spool and the housing.

A valve arrangement according to the invention may comprise split sealing rings formed from springy metal, the sealing rings being mounted in grooves in the spool and engaging the housing.

The illustrative example of a valve arrangement according to the invention will now be described in some detail, with reference to the accompanying drawings, using a notional in-line four cylinder engine as an example of application.

In the drawings:

Figure 1 is a longitudinal cross-sectional view taken through an engine which incorporates the illustrative valve arrangement;

Figure 2 is a cross-sectional view taken on the line II-II in Figure 1; and

Figure 3 is an enlargement of a portion of Figure 1.

The engine shown in Figure 1 comprises a head 10 formed from aluminium alloy, and a block 12 in which four cylinders 14 are formed. A piston 15 reciprocates in each cylinder 14 and a combustion chamber 17 is defined above each piston 15 by the head 10 and the block 12. The head 10 is bolted to the block 12, in conventional manner, by bolts 16. The combustion chamber 17 is provided with a spark plug 11 and a fuel injector 13 as depicted in Figure 2. The illustrative valve arrangement is for controlling the induction and exhaust events of the engine.

The illustrative valve arrangement comprises a housing provided by the head 10. The head 10 defines a row of four generally cylindrical axially-aligned recesses 18 which are positioned one above each of the cylinders 14 of the engine. The combustion chamber 17 of each cylinder 14 has a mouth defined by the head 10 which opens into the cylindrical surface of that recess 18 which is above that cylinder 14. In the three gaps between the recesses 18 and also at both ends of the row of recesses 18, the head 10 defines cylindrical concave bearing surfaces 19 which are co-axial with the recesses 18 but are of smaller diameter. The spaces defined by the bearing surfaces 19 connect the recesses 18.

The illustrative valve arrangement also comprises a spool 20 which extends through all four of the recesses 18 and is mounted for rotation in said recesses 18 on the bearing surfaces 19. The spool 20 has five cylindrical portions 20a which are fitted rotationally into the five bearing surfaces 19. Between the portions 20a, the spool 20 has four generally cylindrical portions 20b which fit closely in the recesses 18. Axial location of the spool 20 may be provided by a flange (not shown). The spool 20 may be made from alloy iron or nodular iron. A casting is particularly suitable since acceptable accuracy of form can be cheaply obtained, alternative materials such as steel are also acceptable for this duty.

The spool 20 rotates on the bearing surfaces 19 with a very small clearance. The bearing surfaces 19 are hydrodynamically lubricated through passages 21 in the head 10. As an alternative to the spool 20 rotating on plain bearings formed of the material of the head 10, bearings of the thin wall steel shell type can be inserted. The bearings must receive an element of pressure loading due to combustion which is borne by the spool 20 and must be transferred to the fixed structure of the engine.

The illustrative valve arrangement also comprises rotating means operable to rotate the spool 20 in said recesses 18 in synchronisation with the operating cycle of the engine. The rotating means comprises a sprocket 22 fixed to one end of the spool 20. The sprocket 22 and hence the spool 20 is driven at half engine speed by orthodox drive means (not shown), eg a chain, a cogged belt, gears, etc.

The housing provided by the head 10 also defines a plurality of gas admission and exit ports to provide the desired phasing and duration of the induction and exhaust events of the engine. Specifically, two ports are provided per cylinder 14 which communicate with the recess 18 associated with the cylinder. The ports open into the cylindrical surface of the recess 18. These ports are an induction port 26 (figure 2), and an exhaust port 28. Surface portions of the outer surface of the spool portions 20b form closure surfaces for the ports 26 and 28 and also form gas exchange passages 30. The passages 30 are arranged so that, at appropriate times in the operating cycle of the engine, the port 26 is connected to the combustion chamber 17 to allow induction of air, and, at other appropriate times, the port 28 is connected to the combustion chamber 17 to allow exhaustion of gases. At other appropriate times, when combustion events occur in the combustion chamber 17, the mouth of the combustion chamber 17 is closed by a surface portion 32 of the spool portion 20b. Any circumferential gas leakage from the exhaust port 28 to the induction port 26 is very small and decreases with rising engine speed as the time available for gas transfer for a given pressure differential decreases approximately linearly with speed; any gas which does pass from exhaust to induction at low rev/min provides a limited degree of Exhaust Gas Recirculation, (EGR); this is a feature used by many engines at low speeds to suppress the formation of nitrogen oxide emissions by lowering the peak combustion temperature.

The mouth of the combustion chamber 17 is formed by a gas erosion resistant local insert 29 (Figure 2) in the head 10 to minimise erosive wear effect of the outgoing hot exhaust gasses. The insert 29 may be formed by powder metallurgy processes, for example. A mean clearance not in excess of 0.025mm between this insert 29 and the spool 20 is preferred.

The spool 20 has a cooling passage 36 extending axially therethrough. Coolant passes through a passage 38 in the block 12 into a passage 40 in the head 10 and enters the passage 36 through radial ports 42 in the spool 20 which are located adjacent to the sprocket 22. The ports 42 may incorporate vanes to promote uptake of coolant into the valve coolant passage, but the vanes should be of small radial dimension to discourage centrifugal counterflow of coolant. The coolant exits through an axial port 44 at the opposite end of the spool 20. The cooling passage 36 varies in cross-sectional area, being larger in the portions 20b, such that the cooling effect, achieved by passing coolant through said cooling passage, is concentrated in regions of the spool 20 which are exposed to the most heat. Cooling of the spool 20 helps to maintain straightness of the spool in service, and minimises thermal expansion effects.

The illustrative valve arrangement has seals to separate lubricant and coolant from one another and from the gases. Fluid seals comprise a plurality of lip seals 45 acting between the spool 20 and the head 10. Gas seals comprise split sealing rings 46 formed from springy metal, the sealing rings being mounted in grooves at opposite ends of the portions 20b of the spool 20. The rings 46 engage the walls of the recesses 18 to contain axial gas leakage. Gas leak-off slots may be provided in the head 10 to short circuit any leakage from the rings 46, back to the induction port 26 for recirculation (EGR). Lubricant is positively scavenged from the bearing zones in a conventional manner.

Since the spool 20 is subject to flexure caused by combustion forces acting on the portions 20b, a relief space 50 (see Figure 3) is formed in the outer surface of each spool portion 20b. The relief space 50 positioned so that it accommodates flexing of the spool 20 caused by combustion events in said combustion chamber 17. The relief space 50 is formed in the spool portion 20b in a region of the surface thereof which is diametrically-opposed to the portion 32 of the surface of the spool portion 20b which closes the combustion chamber 17 during combustion events. The relief space 50 varies in depth, being deepest in the centre thereof such that the spool portion 20a, when flexed by a combustion event, is a close fit in the relief space 50.

The relief space 50 is depicted in Figure 3 in which the influence of combustion gas forces are represented by arrows. These forces create high local loading causing the spool 20 to deflect by several hundredths of a millimetre even with the stiffest construction and close fit of the bearing surfaces 19. This deflection is shown in exaggerated form by the broken line A. To counteract this effect and ensure a close running fit of the spool 20 in the recesses 18 and the bearing surfaces 19, the surface of the spool 20 is relieved as depicted. The exact profile is determined by a calculation of the deflection of the spool 20, depending upon its section modulus, material properties, unsupported span between bearing surfaces 19, bearing clearance and stiffness, and the gas pressure profile with respect to the angular position of the spool. This local exterior profile may be asymmetric in form to reflect the relative pressure deflections on the compression and firing (expansion) strokes of the engine. If necessary, the corners of the bearing surfaces 19 can be locally relieved by profiling.

Without the relief space 50, the valve arrangement would require either increased clearance, copious lubrication or some movable element to provide sealing without excessive loss of gas pressure or seizure. With the relief space, flexing of the spool 20 is possible without contact with the wall of the recess 18, alleviating the need for lubrication of the spool 20 in this area, and ensuring that exhaust emissions are not compromised due to excessive hydrocarbons arising from short circuited lubricating oil to the exhaust system. The depth and profile of the relief space 50 is determined by calculating the deflection due to gas forces under unthrottled conditions. The profile is applied by turning, milling or more preferably cam grinding between centres on an orthodox camshaft lobe grinding machine.

By the use of the illustrative valve arrangement, engine compartment noise level reductions of the order of 5~7dBA at 1 metre can be achieved at idle engine speed condition. The total cylinder head and valve train assembly can be reduced in cost by 7-10 percent depending upon the features of the design. The valve drive life, particularly if of the cogged belt type, can be extended to equal the life of the engine and a tensioner omitted in some cases. Moreover, the NVH reduction over comparable engines using poppet style valve gear can be up to 30 percent at low engine speed. Fuel economy at low engine speeds is improved by 2~4 percent due to frictional loss reduction but decreases at higher speeds to a level equal to that realised by poppet valve trains, however, there is no engine speed limit imposed by the valve train.

It will be apparent to those versed in the art that either one dual function rotary spool 20 may be used per cylinder bank, or if required, two such spools may be deployed, each handling induction or exhaust functions only, in a similar manner to the way in which current engines use single or dual overhead camshafts.

CLAIMS

1 A valve arrangement for controlling the induction and/or exhaust events of an internal combustion engine, the valve arrangement comprising a housing which defines a generally cylindrical recess which communicates with a combustion chamber of the engine, a spool mounted for rotation in said recess, and rotating means operable to rotate the spool in said recess in synchronisation with the operating cycle of the engine, the housing also defining at least one port which communicates with said recess, the spool having surface portions which, as the spool rotates, close said port at appropriate times in the operating cycle of the engine and connect the port to the combustion chamber at other appropriate times, wherein a relief space is formed in the spool and/or the housing, said relief space being positioned so that it accommodates flexing of the spool caused by combustion events in said combustion chamber.

2 A valve arrangement according to claim 1, wherein the relief space varies in depth such that the spool, when flexed by a combustion event, is a close fit in the relief space.

3 A valve arrangement according to either one of claims 1 and 2, wherein said relief space is formed in the spool in a region of the surface thereof which is diametrically-opposed to the portion of the surface of the spool which faces the combustion chamber during combustion events.

4 A valve arrangement according to any one of claims 1 to 3, wherein said spool has a cooling passage extending axially therethrough.

5 A valve arrangement according to claim 4, wherein the cooling passage varies in cross-sectional area such that the cooling effect, achieved by passing coolant through said cooling passage, is concentrated in regions of the spool which are exposed to the most heat.

6 A valve arrangement according to any one of claims 1 to 5, wherein the arrangement comprises a plurality of lip or face seals acting between the spool and the housing.

7 A valve arrangement according to any one of claims 1 to 6, wherein the arrangement comprises split sealing rings formed from springy metal, the sealing rings being mounted in grooves in the spool and engaging the housing.

8 A valve arrangement substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

Application No: GB 9725849.5
Claims searched: 1 to 8

Examiner: John Twin
Date of search: 4 September 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): F1B (B2Q5B)

Int Cl (Ed.6): F01L 7/00, 7/02, 7/16, 7/18

Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2267934 A	(Lotus Cars) - see eg page 12, lines 14-30, note radial clearance 46	
X	GB 1548825	(Alto) - see eg page 4, lines 62-66	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.