

July 30, 1929.

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1,722,950

INTERNAL COMBUSTION ENGINE

Filed Dec. 3, 1924

Fig. 1.

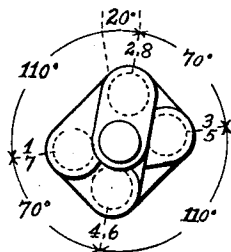


Fig. 6.

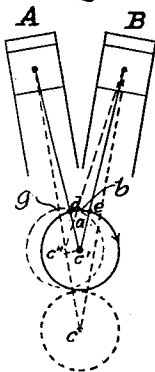


Fig. 4.

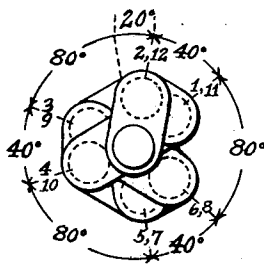


Fig. 2.

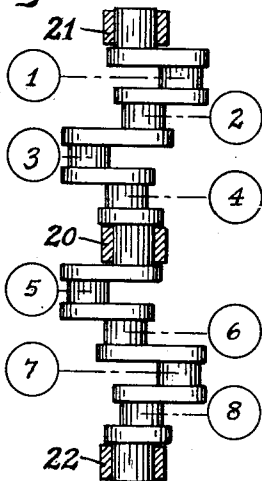


Fig. 3.

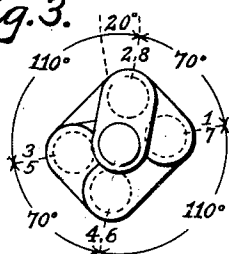
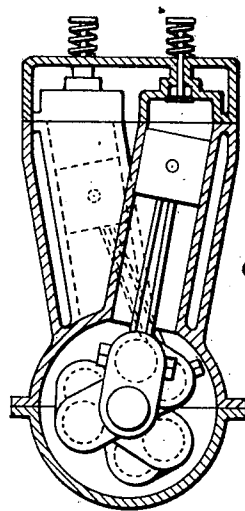


Fig. 5.

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INTERNAL-COMBUSTION ENGINE.

Application filed December 3, 1924. Serial No. 753,608.

My invention relates to crank shafts for multiple cylinder internal combustion engines of the V-type.

One object of my invention is to provide a crank shaft adapted for a relatively short and light weight engine of the V-type having its cylinder groups staggered so that each piston is connected to a separate crank pin and having a small angle between the cylinder groups so that a single casting is possible. Another object is to stagger and dovetail the cylinders of each group with those of the other group, as will be shown in the drawings. This arrangement has the advantage of bringing the cylinders even closer together and allowing even a sharper angle between the cylinder groups without excessive long connecting rods. A drawing on natural scale will show, that, of the crankshaft-ends of all the cylinders are located entirely on either side of a symmetrical transverse plane between the cylinder groups, the length of the connecting rods because of excessive length if the angle is decreased to about 20° . If the cylinders are dovetailed, as shown in Fig. 5, shorter connecting rods and consequently lighter reciprocating parts are possible. The height of the motor and its weight can be considerably decreased. The bottom ends of the cylinders will be partially on either side of said plane and the top ends will be entirely on either side of this plane. A modification (shown in Fig. 6) preserving equal firing, is applicable to both arrangements of the cylinders, the staggered and the staggered plus dovetailed arrangement of the cylinders. This modification allows even shorter connecting rods and lighter reciprocating parts than either one of the two arrangements.

Another object is to place the cylinders so close together that their circumferences in parallel planes perpendicular to the crankshaft axis overlap those of the cylinders in at least two parallel planes. If more than two rows of radial cylinders are applied this construction is not absolutely necessary, but may be applied equally, as in the engines with only two cylinder rows at an angle smaller than 360° (or smaller than 720°) divided by the number of crankpins of the crankshaft. The angle of the cylinders may be even 360° (or 720°) divided by the number of crankpins.

Another object is to provide a crank shaft

for an engine of the character described, having its crank pins so arranged as to eliminate the production of torque or couples in a horizontal plane through the axis of the crank shaft.

Another object is to stagger the cylinders and to offset the crankshaft with respect to one cylinder group, which results in more space at the top of the cylinders for valves, inlet and exhaust passages, valve gear etc. This arrangement applied to parallel cylinders results in a better cooling of the individual cylinders and diminishes the periodic and torsional vibrations due to the reciprocating parts.

Additional objects of my invention are the production of even firing in the cylinders and balance of the reciprocating parts of the engine.

Other objects and advantages will appear hereinafter and while I show herewith and will describe a preferred form of construction, I desire it to be understood that I do not confine my invention to such preferred form but that various changes and adaptations may be made therein without departing from the spirit of my invention as hereinafter claimed.

Referring to the drawings which accompany this specification and form a part thereof:

Fig. 1 is an end view of a crank shaft of my improved form for an eight cylinder engine having an angle of 20° between its cylinder groups.

Fig. 2 is a plan view of a similar crank shaft having a different arrangement of crank pins.

Fig. 3 is an end view of the crank shaft shown in Fig. 2.

Fig. 4 is an end view of a similar crank shaft adapted for a twelve cylinder engine having an angle of 20° between its cylinder groups.

Fig. 5 is a vertical sectional view, showing a staggered and dovetailed arrangement of the cylinders of a V type engine with an angle of 20° between the cylinder groups and having a crankshaft as shown in Figs. 1, 2, 3, 4, or the crankshafts shown in the copending application No. 753,609 (of the same date and claiming more or less the same subject matter) or any other crankshaft having as many separate crankpins as cylinders and having angles between said separate crankpins, which correspond with

the angle of the cylinder group, as shown in Patent No. 1,322,579 and the French patent to M. Philippon No. 371,242.

Fig. 6 is a diagrammatic view of a small angled V-type engine, illustrating the relation between cylinder angle and crank pin angles.

The number of crank pins being equal to the number of cylinders, the angle between the cylinder groups may be made usually small so that an engine construction is possible which is not only short but relatively narrow and consequently exceptionally light. Furthermore in eight and twelve cylinder engines the number of bearings may be limited to three, making possible increased thickness of crank arms and length of crank pins and facilitating the use of ball bearings.

With the forms of crank shaft here shown, the reciprocating parts associated with each group of cylinders are balanced with respect to transverse planes midway between the innermost cylinders thereof. They are arranged for one middle bearing 20 and two end bearings 21 and 22, shown in Fig. 2.

In Figs. 1, 2 and 3, crank pins 1 and 7 are diametrically opposite to crank pins 3 and 5; likewise crank pins 2 and 8 are diametrically opposite 4 and 6, the odd numbered crank pins being connected to pistons in one group, and the even numbered crank pins being connected to those in the other group of cylinders. The only difference between Figs. 1 and 3 is that crank pins 1 and 7 and also crank pins 3 and 5 in the former figure are in opposite positions to the similarly numbered ones in the latter figure.

This arrangement is equivalent to two separate four-cylinder engines placed side by side and acting on the same crank shaft, the angle between the cylinder groups not affecting the balance of the engine in any way.

In Fig. 4 the odd numbered crank pins are arranged in three pairs with angles of 120° between them and the even numbered crank pins are similarly arranged in pairs, the angle between the two groups being 20° or equal to that between the cylinder groups. The pistons connected to the odd numbered crank pins here operate in one group of cylinders and those connected to the even numbered crank pins in the other group similar to those in the 8-cylinder type described above and a similar balance of reciprocating parts obtain here.

Fig. 5 illustrates a V engine with staggered and dovetailed arrangement of the cylinders adapted for the crankshaft shown in Figs. 1, 2, 3, 4 or the crankshaft shown in the copending application No. 753,609, or any other crankshaft as for instance shown in Patent No. 1,322,579 U. S. Patent or the French Patent No. 371,242, the cylinder groups being

arranged on an angle etc., of 20° so that a single casting is easily possible. The construction of Fig. 5, shows the cylinders dovetailed in order to obtain an even more compact arrangement for a single casting as shown in Fig. 12 of the copending application of the same date No. 753,609. This arrangement is adaptable to the arrangement of crank pins as shown in Fig. 4 but

equally to that of Figs. 1, 2 showing an arrangement of crank pins for an 8 cylinder fundamentally equal to that of Fig. 4 for a twelve cylinder, and in fact adaptable to any arrangement whereby the crankshaft has as many crank pins as there are cylinders and whereby the angle between the crank pins correspond to that of the cylinder groups in order to obtain equal firing. The arrangement of Fig. 5 is thus equally adaptable to all the crank pin arrangements shown in the copending application and to an almost infinite number of other crank pin arrangement based on the same principle. The dovetailed arrangement allows closer approximation of the cylinders, allows shorter connecting rods, allows an engine of smaller height and weight. The reciprocating parts are lighter and easier to balance, since about half of the length of the connecting rod is considered to be a pure reciprocative part; this supposition approaches the actual condition pretty close. A drawing on natural scale will show however this advantage much clearer and better than the drawing of Fig. 5 on patent scale. Fig. 6 shows an arrangement, which is equally adaptable to the dovetailed arrangement shown in Fig. 5 and the ordinary arrangement shown in Fig. 12 of the copending application No. 753,609. The dovetail arrangement could hardly be applied to a crankshaft having only a number of crank pins equal to half the number of the cylinders, the advantages disappear here partially on account of the wide angle necessary for equal firing and consequent short connecting rods.

From the diagram in Fig. 6, showing a small angled V-type engine, it is evident that a crank shaft placed at c , the point representing the line of intersection of the two axial planes of the cylinder groups, would require connecting rods so long that an engine of excessive height would be necessary. This may be avoided by placing the crank shaft at a higher point c' in the same vertical plane with c , but this position would result in unequal firing unless the angle α between crank pins d and e is made greater than the angle between the cylinder groups as is shown in Fig. 6. The angle of a pair of crank pins and their respective crank arms should always be such, that said crank arms and respective connecting rods from a straight line at a cer-

tain moment. Both respective pistons will reach now their highest position simultaneously as the straight line is the shortest connection between two points. In any other position of the crank arm will the distance $e'g$ be greater since the hypotenuse of a triangle, which is represented by the crank arm $c'e'$ plus the connecting rod $e'g$, is always shorter than the sum of the two other sides. These two other sides consist of a crank arm and connecting rod of the same length, consequently if g could be at a higher or lower point, the connecting rod had to be longer in both cases.

Assuming that the crank shaft rotates clockwise, the latter position would produce an offset in the wrong direction for advantageous action of pistons in cylinder group A. By placing the crank shaft at point c'' , in the axial plane of cylinder group A, so that it is offset with reference to cylinder group B only, this difficulty is overcome. The angle between crankpins d' and e' should be in accordance with this position, so that crankarms and respective connecting rods form a straight line at the same moment.

It is evident that point c'' might be placed at any point on the axis of the cylinder group A. The more c'' approaches c the less will be the crankshaft displaced with respect to cylinder group B.

It is known that offsetting of cylinders increases the travel of a piston to a length greater than twice the crankthrow. The pistons in the right group indicated by B in Fig. 18 will travel a greater distance than those belonging to the left group and consequently the explosion chambers belonging to this right group should have greater capacity than those belonging to the left group. It would however be possible to shorten the crankthrows belonging to the right group of cylinders in Fig. 18 in order to compensate for this difference of travel of the piston, but this will increase appreciably the cost of manufacturing. It would be advisable to make the connecting rods belonging to the pistons B a little shorter than those belonging to the pistons A, in order to construct the explosion chamber at the same level, but the fact that the axis of the crankshaft is at c'' compensates more than the increased travel of the piston, and for this reason the connecting rods belonging to cylinder group B have to be longer than those of A in order to bring the explosion chambers on the same level.

As far as balance is concerned, it has been shown that in the case of a single cylinder with a connecting rod crank ratio of 5 inch and an offset equal to half the crank radius (this would be 25% of the crank diameter = $1\frac{1}{4}$ inch, which is just about sufficient for the arrangement shown in Fig. 6) that

the increase in the fundamental unbalanced force is only 0.002 of its normal value, and that the unbalanced force is about 1.5% greater than that in a normal type. Speaking generally, with the degree of offset necessary for the proposed arrangement of Fig. 6, the influence of the offset upon engine balance is negligible. If the stroke of the right group of pistons B is greater as the stroke of that of the group A, then the increased, greater, explosive charge, and resulting greater side thrust will compensate for the decreased side thrust on account of the offset position of the cylinders of Group B and reversely.

The alternate firing in both cylinder groups will compensate for the unequal charge in those groups on account of the unequal stroke and the evenness of torque will not be affected appreciably.

It is understood that the number of intermediate bearings can be increased but the length of the engine will be increased proportionally.

It will be readily seen that the angle between the cylinder groups A and B may be reduced to zero and that the suggested construction, with the axis of the crank shaft placed at c' and c'' will still be practicable.

Supposing that the ignition of the gas in the cylinders is instantaneous, when the piston reaches its top position, one sees that the firing orders shown in Figs. 1 and 2 are equal to those of a straight engine, in which the crankpins are so arranged that crankpins 1 and 7, and 3 and 5 opposite, lie in one plane perpendicular to a plane in which crankpins 2 and 8 lie opposite 4 and 6. The same firing orders are obtained for the arrangement of Fig. 3, if the direction of rotation is considered. The firing orders for the twelve cylinders in Fig. 4 are equal to a straight twelve cylinder in which the crankpins are so arranged that crankpins 2 and 12, 4 and 10, 6 and 8 are arranged in three radial planes, 120° apart, and in which crankpins 2 and 11, 3 and 9, 5 and 7 lie in three other radial planes 120° apart and 60° apart from those of the first group. If in Fig. 6 the position of the shaft is removed from the point of intersection of the cylinder groups and the angle of the relative pairs of crankpins are not changed accordingly, as explained, to establish a regular firing interval, the firing intervals will be irregular. If this irregularity, however, does not exceed a number of degrees equal to 720° divided by twice the number of the cylinders, it is seen that the firing orders will be still the same, as explained.

It is understood that all the crankshafts shown, can be built as shown in my Patent No. 1,595,372 (application No. 631,022, April 9, 1923), in which all crankarms are discs and form intermediate bearings. The length

of the crankshaft and motor are thereby greatly decreased and consequently their weight.

Resuming the main characteristics of the invention,

1. The cylinders and respective crankpins are numbered in longitudinal direction, the even numbered cylinders being in one group, the uneven numbered in another group, said groups located in two planes.

2. The cylinders, at least 4, grouped in two planes, are at an angle or in two planes parallel to each other.

3. The crankpins are always aligned in pairs, at 360° divided by half the number of crankpins or at a reduced angle conforming to the angle of the cylinders in the two planes (see Figs. 1 and 4). In a six cylinder the crankpins are arranged in pairs with respect to a plane of symmetry at right angles to the crankshaft, approximately through the middle intermediate bearing. In an eight cylinder with respect to one plane of symmetry through the middle intermediate bearing perpendicular to the shaft axis or two perpendicular planes of symmetry through each block of cylinders, perpendicular to the shaft axis. In a twelve cylinder again with respect to one plane of symmetry through the center of the engine or with respect to two planes of symmetry through each block of cylinders and their respective crankpins.

In a six cylinder these pairs are at an angle of 120° , crankpins 1 and 6, 2 and 5, 3 and 4 aligned, forming a standard six cylinder shaft, and forming the limiting case of the six crankpins as shown in Figs. 1-4, and Figs. 13-14 of the copending case 753,609.

In the eight cylinder crankpins 1 and 8, 2 and 7, 3 and 6, 4 and 5, are aligned as a limiting case of the crankpin arrangement of Figs. 5-11 and Figs. 15-16 of said copending application.

In Fig. 1 of this application crankpins 2 and 8, 1 and 7, 4 and 6, 3 and 5 are arranged with respect to two planes of symmetry, respectively for crankpins 1, 3, 5, 7 for a plane through the left block of cylinders and for crankpins 2, 4, 6, 8 for a plane through the right block of cylinders perpendicular to the shaft axis. As the horizontal and vertical couples for these two kinds of arrangements differ very little, the latter only is shown as being at the same time somewhat different from the limiting case of said copending application.

In Fig. 4 the crankpins 1, 3, 5, 7, 9, 11 are symmetrically arranged with respect to a plane through the middle of the left group of cylinders and the crankpins 2, 4, 6, 8, 10, 12 for the right group of cylinders through the middle of the right group of cylinders perpendicular to the shaft axis.

In all positions of the shaft this symmetrical arrangement is a fixed relation.

For the six cylinder engine the pistons would not reach their top position in pairs with equal intervals, if the crankpins 1 and 6, 2 and 5, 3 and 4 were aligned and have to be spread apart so that they are adjacent angularly to each other in the same pairs, as shown in said copending application (supposing the angle of cylinders is 60°).

Equally for the eight cylinder the respective pistons would not reach their top position in pairs with equal intervals if the crankpins are arranged at right angles to each other in the order cited. Only if the crankpins are arranged in the order as shown in Fig. 1, and these pairs are at an angle corresponding to the angle of the cylinder groups, the pistons will reach their top position simultaneously in pairs with respect to their respective cylinders (supposing the angle of the cylinders 45° as a limit).

The same condition obtains for the twelve cylinder. They have to be spread apart in twelve radial planes to effect two pistons to reach their top position simultaneously, supposing the cylinder angle to be 30° . In Fig. 4 however the arrangement of the crankpins may be in six radial planes to effect this result, but the crankpins have to be rearranged in slightly different order crankpins 2 and 12, 1 and 11, 3 and 9, etc., aligned in pairs to effect this result, without sacrificing the elimination of couples in a horizontal and vertical plane, which would be the result of any other arrangement of said crankpins, differing from those proposed in this and the copending application. (As here explained; crankpins 1 and 12, 2 and 11, 3 and 10, etc., are in said application angularly adjacent to each other at a maximum angle of 30° , or aligned in said pairs, and as shown in said copending application.)

It is further understood that to each crankpin, being in a separate parallel plane perpendicular to the crankshaft axis, more than one piston may be attached without disturbing the balance of the first twelve pistons, singularly attached to said crankpins. Equally as the proposed constructions could have been prolonged longitudinally for a fourteen and sixteen cylinder or shortened for four or a six cylinder, equally can the proposed arrangement of crankpins and cylinders be enlarged in radial direction without disturbing the fundamental principles already explained in extenso.

It is further understood that the form of the crankshaft as proposed in my Patent 1,595,372 (application No. 631,022 of April 1923) may be applied on the present arrangement, thereby increasing the number of intermediate bearings without increasing the length of shaft or engine.

It is further understood that said engine may operate on the four or two stroke cycle.

Having thus illustrated and described my invention, I claim:

1. A multicylinder internal combustion engine of at least four cylinders, having its cylinders arranged in two groups in two radial longitudinal planes, in staggered relation to each other, so that the even numbered cylinders are in one plane, the uneven numbered in the other plane, a crankshaft having as many crankpins as cylinders, said crankpins numbered successively in longitudinal direction corresponding to the numbering of the cylinders, said crankpins arranged in $n/4$ radial planes, n being the number of crankpins or cylinders, said crankpins angularly aligned in pairs, said cylinders arranged at an angle less than 720° divided by the number of crankpins.

2. The combination of claim 1 in which the outermost crankpins of each group of crankpins, belonging to one group of cylinders in one plane are angularly aligned in pairs.

3. The combination of an internal combustion engine with at least eight cylinders, said cylinders arranged in staggered relation, in two planes, said cylinders numbered successively in longitudinal direction, the even numbered in one group in one plane, the uneven numbered in the other plane, a crankshaft having as many crankpins as cylinders, said crankpins arranged in pairs in $n/4$ radial planes, n being the number of crankpins, said crankpins so arranged in pairs that the pistons connected to the outermost crankpins of each group, reach their top position simultaneously and equally those of the innermost crankpins of each group of cylinders in one plane, said cylinders arranged at an angle less than 720° divided by the number of crankpins.

4. The combination of claim 3 in which said crankshaft is located in the plane of only one cylinder group, said $n/4$ radial planes located at an angle of 720° divided by the number of crankpins, minus the angle of the cylinder groups.

5. An internal combustion engine having cylinders arranged in at least two radial planes, or a multiple thereof, in at least four parallel planes, being a multiple of two, at right angles to the axis of its crankshaft, said crankshaft having its crankpins, in number equal to said parallel planes, symmetrically arranged in pairs with respect to one or two planes perpendicular to said shaft; the angle between said two cylinder groups being less than 720° divided by the number of said crankpins.

6. An internal combustion engine, having cylinders arranged in at least two radial planes or a multiple thereof, in at least six parallel planes perpendicular to the axis of its crankshaft, said crankshaft having

as many crankpins as parallel cylinder planes, said crankpins arranged in angularly aligned pairs and further symmetrically arranged with respect to at least one plane of symmetry perpendicular to said shaft, but not to more than two planes of symmetry, said cylinder groups arranged at an angle equal or smaller than 720° divided by the number of crankpins.

7. An internal combustion engine having cylinders arranged in at least two radial planes, said planes at an angle less than 720° divided by the number of crankpins of its crankshaft, said shaft having at least six crankpins rotating in six parallel planes perpendicular to the shaft axis, said crankpins arranged symmetrically with respect to one plane of symmetry perpendicular to the shaft axis, said cylinders in staggered relation.

8. An internal combustion engine having cylinders arranged in two radial planes, said planes at an angle less than 720° divided by the number of crankpins of a crankshaft in said engine, said shaft having at least four crankpins rotating in four parallel planes perpendicular to the shaft axis, said crankpins arranged symmetrically with respect to one plane of symmetry perpendicular to the crankshaft axis, said cylinders in staggered relation, the even numbered cylinders in one plane, the uneven numbered in another plane, said cylinders numbered successively in longitudinal direction.

9. An internal combustion engine, having cylinders arranged in two radial planes, or a multiple thereof, said planes at an angle of less than 720° divided by the number of crankpins of a crankshaft in said engine, said shaft having at least four crankpins, rotating in four parallel planes perpendicular to said shaft axis, said crankpins symmetrically arranged with respect to not more than two planes of symmetry perpendicular to said shaft axis, said cylinders arranged in staggered relation, the even numbered cylinders in one plane, the uneven numbered in the other plane, said cylinders numbered successively in longitudinal direction.

10. In an internal combustion engine having at least four cylinders arranged in two planes, said cylinders numbered successively in longitudinal direction, said cylinders so arranged that the even numbered cylinders are in one plane, the uneven numbered in another plane, a crankshaft having as many crankpins as cylinders, said crankpins so arranged that they reach their top position simultaneously in pairs; said crankpins angularly aligned in pairs with respect to not more than two planes of symmetry perpendicular to the crankshaft axis, said cylinders arranged at an angle less than 720° divided by the number of crankpins.

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