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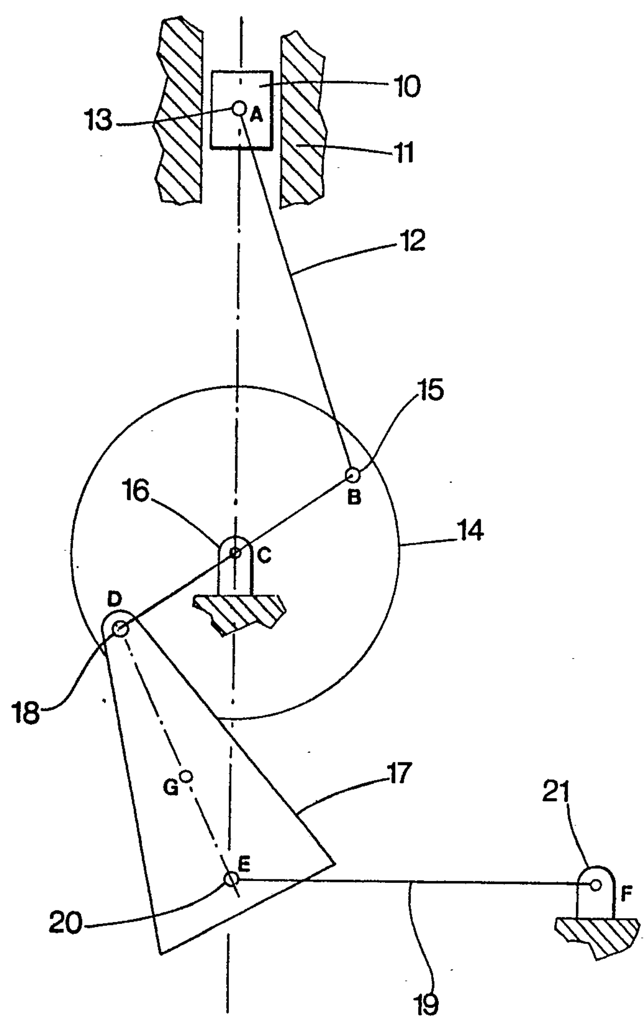
(54) **Means for reducing vibration in reciprocating engines**

(57) In an engine having a piston 10, connecting rod 12 and crankshaft 16, vibrational forces are balanced by a link 17 which constitutes a balancing weight and is pivotally mounted at one end 18 on the crankshaft assembly. The other end 20 of the link is constrained by guide means 19 to follow a generally rectilinear path normal to the crankshaft axis in opposition to the piston to balance the inertia forces of the piston and connecting rod. Guide link 19 is pivotally connected to a fixed part 21 of the engine crankcase.

FIG.1



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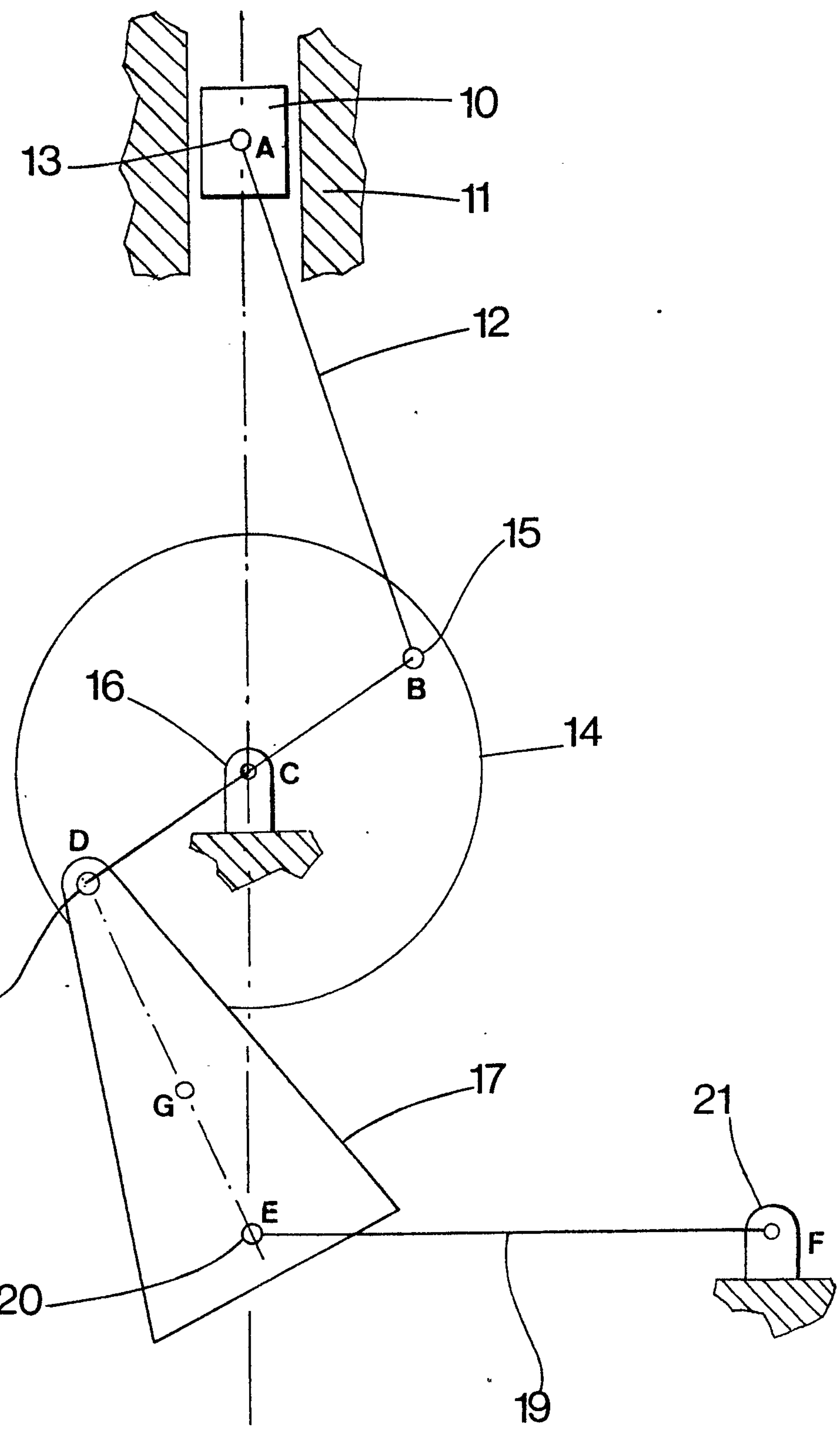

FIG.1

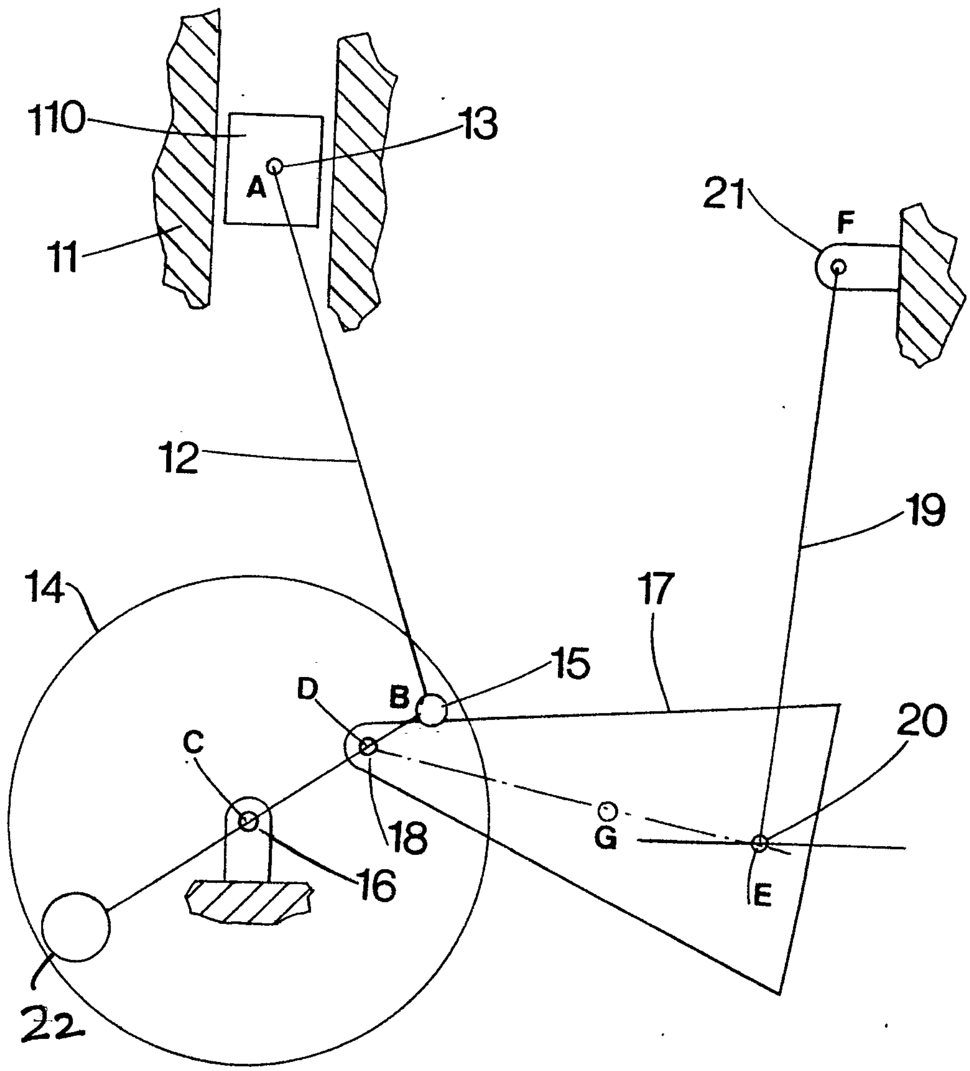

FIG. 2

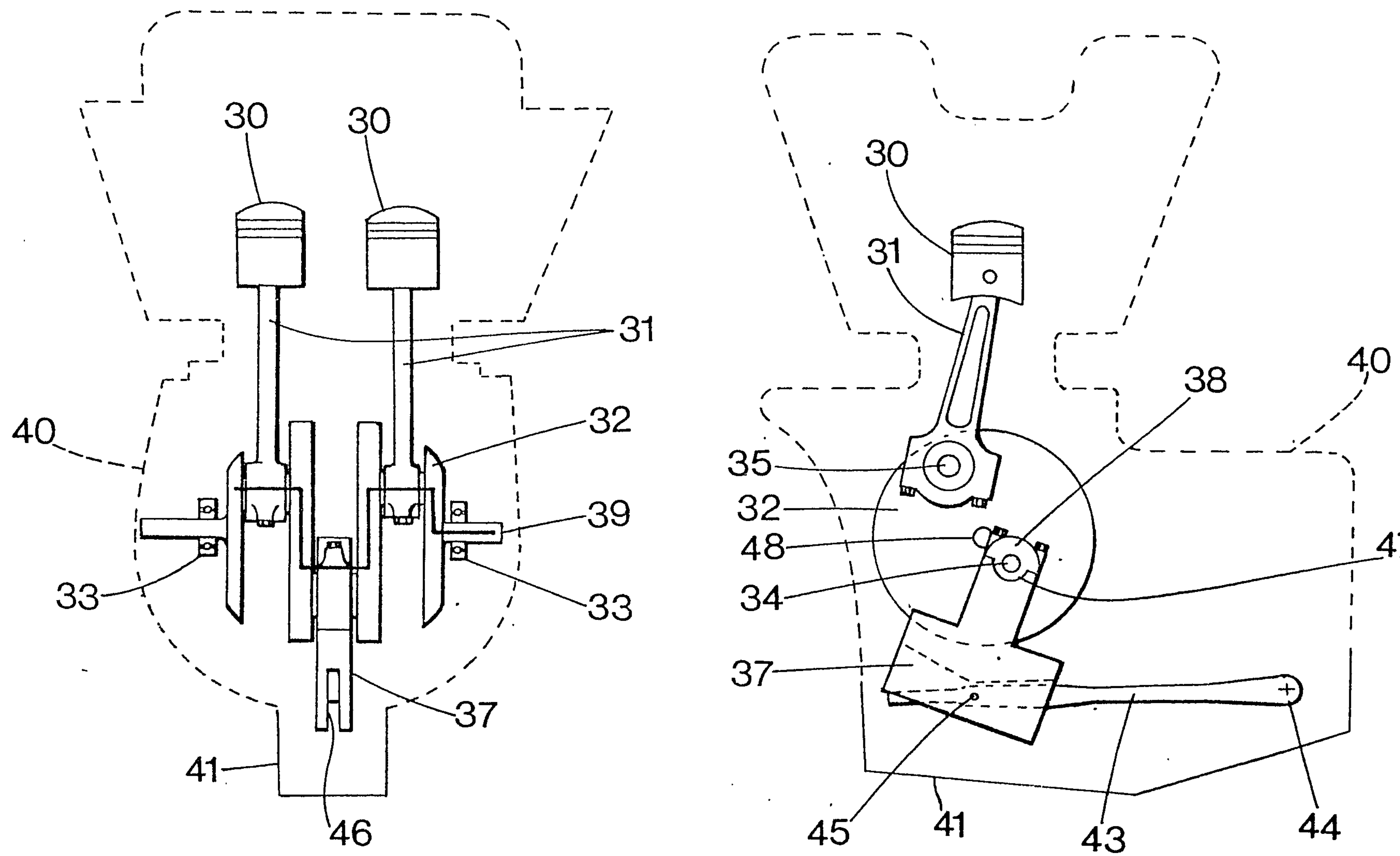

FIG. 3

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SPECIFICATION

Means for reducing vibration in reciprocating engines

This invention relates to means for reducing vibration in reciprocating engines, in particular, but not exclusively, high-speed internal combustion engines.

Internal combustion engines are prone to two kinds of vibration one due to rocking about the crankshaft axis and the other termed translational vibration. The present invention is concerned with reducing translational vibration which arises due to the inertia forces emanating from the reciprocating parts, primarily the piston and connecting rod. In most six cylinder engines these vibrational forces are self-balancing due to the arrangement of the pistons. In the case of four cylinder in line engines rotational frequency forcing is self balancing and only the harmonic vibrations are unbalanced. With large single cylinder and parallel twin engines considerable problems arise in reducing the rotational frequency and twice rotational frequency vibration forcing.

Various methods have been proposed such as the use of unbalanced shafts rotating counter to the crankshaft. However such arrangements only cancel out the vibration at engine rotational frequency, they require a special drive arrangement, they can be noisy and they are relatively expensive to be incorporated into an engine.

An object of the invention is to provide a relatively simple engine balancing means producing low noise levels.

According to the invention a reciprocating engine comprises at least one piston, a connecting rod associated with the piston, a crankshaft to which the connecting rod is attached, and at least one balancing link constituting a balancing weight and pivotally mounted at one end on the crankshaft, the other end of the balancing link being constrained by guide means to follow a generally rectilinear path normal to the axis of the crankshaft in opposition to the piston so that, during operation of the engine, the balancing link balances substantially all the inertia forces of the piston and connecting rod.

Preferably the guide means is a guide link pivotally attached at one end to a fixed point and at the other end to the balancing link.

Conveniently a notional line joining the crankshaft axis and the attachment of the balancing link to the guide link is substantially colinear with a notional line joining the crankshaft axis and the attachment of the piston to the connecting rod.

Further features of the invention will appear from the following description of various embodiments of the invention given by way of example only and with reference to the drawings, in which:—

Fig. 1 is a schematic side elevation of one form of engine embodying the invention,

Fig. 2 is a schematic side elevation of another embodiment of the invention, and

Fig. 3 is a side elevation of a practical embodiment of the invention applied to a parallel twin internal combustion engine.

Referring to the drawings and firstly to Fig. 1 an engine includes a piston 10 movable to reciprocate in a cylinder 11 and pivotally connected to a connecting rod 12 through a bearing 13. The other end of the connecting rod 12 is connected to a crankshaft 14 through a bearing 15, all in known manner.

A balancing link 17 is attached pivotally to the crankshaft 14 through a bearing onto a crankpin 18. The crankpin is disposed at 180° around the pivot axis 16 of the crankshaft 14 from the bearing 15. In the illustrated arrangement point 20 of the balancing link should move in a direction lying on a notional line joining the crankshaft axis 15 and the bearing 13 and for this purpose point 20 may be constituted by a guide means or slider moving rectilinearly between guides. However in the illustrated arrangement a guide link 19 is pivotally attached at 20 and the guide link 19 extends generally normal to said notional line when point 20 is at its central position of movement. The other end of the guide link 19 is pivotally attached to a fixed point 21 which may be on the engine crankcase.

In Fig. 1 the centres of pivots 13, 15, 16, 18, 20 and 21 are designated A, B, C, D, E and F respectively and G denotes the centre of gravity of the balancing link 17. If the mass of the balancing link is m, the moment of inertia of the guide link 19 is I and the reciprocating mass of the engine is M, then the ideal form of the balance link configuration is governed by the following equations:—

$$1.\ \frac{m \times DG \times DC}{DE} + \frac{I \times DC}{FE^2} = M \times BC$$

$$2.\ \frac{AB}{BC} = \frac{DE}{DC}$$

3. The square of the polar radius of gyration of the balance link = DG × GE.

This condition 3 determines the position E at which the pivotal connection 20 is located, so it is important that this condition is met to ensure that 20 is correctly placed. The position E is denoted the 'centre of percussion' of the balancing link.

If these conditions are met the reciprocating forces are balanced and no spurious vibrations perpendicular to the plane through A, C and E are introduced.

4. In addition to these conditions the crankshaft should be balanced taking into account a mass equal to the rotating portion of the original connecting rods positioned at C as well as a mass

equal to

$$m \times \frac{GE}{DE}$$

located at D.

Using the guide link 19 the locus of the pivot 20 is not rectilinear but an arc having a relatively large radius EF. Accordingly vibration forces of twice running frequency are introduced with an amplitude of approximately

$$\frac{DC}{EF}$$

times the original unbalanced force amplitude. With a relatively large radius EF the movement of pivot approximates to a rectilinear movement and the vibration forces introduced are at an acceptable level.

Referring now to Fig. 2 a different arrangement is illustrated in which a balance link 17′ is arranged transversely to the balance link 17 of the Fig. 1 arrangement. The Fig. 2 arrangement reduces the overall height of the engine and associated balancing arrangement. In Fig. 2 similar parts are given the same reference numbers as in the Fig. 1 embodiment.

In Fig. 2 the engine includes piston 10, cylinder 11 and bearing 13. A connecting rod 12 is connected to a crankshaft 14 having an axis 16. The balancing link 17′ is positioned so that a line joining the bearing 13 and the crankshaft axis 16 is at approximately a right angle to a line from bearing 20 to the crankshaft axis 16.

The balancing link 17′ is pivoted to the crankshaft 14 at 18 at one end of the link 17′ and the other end of the link is pivotally attached at 20 to a guide link 19, the other end of which is pivotally attached to a fixed point at 21, above pivot 20.

In the arrangement of Fig. 2 the conditions (1), (2) and (3) given above in relation to the Fig. 1 arrangement still apply. However with regard to condition (4) it is necessary to assume that the whole of the piston and connecting rod mass is placed at B and should be balanced in the rotational sense as by a balance weight at 22.

Referring now to Fig. 3 an application of the invention to a parallel twin motorcycle engine is illustrated based on the schematic arrangement of Fig. 1.

Conventional pistons 30 and connecting rods 31 are connected to a common crankshaft 32 mounted in bearings 33. The crankshaft 32 carries a crankpin 34 in addition to and between crankpins 35 for the connecting rods 31.

A balancing link 37 is carried on the crankpin 34 and is retained by a cap 38 to run on a white metal bearing. Lubrication of the bearing is by means of drillings fed from the engine oil pump (not shown) and shown diagrammatically by a line 39. Thrust bearings 47 are provided on both sides of the balancing link 37.

The engine crankcase 40, shown dotted, is extended as shown by full lines 41 to accommodate the balancing link 37 and a guide link 43 mounted on a pivot pin 44. The guide link 43 is connected to the balancing link 37 by a pivot pin 45 and a slot 46 is formed in the balancing link 37 to receive the guide link 43.

The throw of the crankpin 34 which is the distance between the axis of the pin 34 and the axis of rotation 48 of the crankshaft is displaced through 180° from the throw of the connecting rod crankpins 35 and is chosen to minimise the depth of the extension 41 of the crankcase 40. The distance between the pivot pin 45 and the guide link pivot 44 is of the order of eight times the throw of the crankpin 34. The dimensions of the balancing link 37 follow the principles outlined above and the size of the crankpin 34 is chosen to give the desired strength and lubrication characteristics. Thrust bearings 48 are provided on both sides of the balancing link 37.

Tests have shown that the invention is effective in suppressing vertical translational vibrations.

In the case of the parallel twin engine of Fig. 3 it will be seen that only one balancing link 37 and associated guide link 43 is provided to balance the two pistons. Moreover the balancing link moves in a plane parallel to the planes of movement of the pistons and in the same direction i.e. vertically as shown.

A different arrangement of balancing link may be provided for other kinds of engine. For example a single cylinder engine may have two balancing links, one located to each side of the connecting rod for the piston.

It will be seen that in the embodiment of Figs. 1 and 3 a line joining the piston to connecting rod connection and the crankshaft axis and a line joining the balancing link to guide link connection and the crankshaft axis are substantially colinear and this arrangement gives a superior balancing action to the Fig. 2 arrangement in which the corresponding lines are substantially normal to one another.

CLAIMS

1. A reciprocating engine comprising at least one piston, a connecting rod associated with the piston, a crankshaft to which the connecting rod is attached, and at least one balancing link constituting a balancing weight and pivotally mounted at one end on the crankshaft, the other end of the balancing link being constrained by guide means to follow a generally rectilinear path normal to the axis of the crankshaft in opposition to the piston so that, during operation of the engine, the balancing link balances substantially all the inertia forces of the piston and connecting rod.

2. An engine according to claim 1 wherein the guide means is a guide link pivotally attached at one end to a fixed point and at the other end to the balancing link.

3. An engine according to claim 1 or 2 wherein

a notional line joining the crankshaft axis and the attachment of the balancing link to the guide link is substantially colinear with a notional line joining the crankshaft axis and the attachment of the piston to the connecting rod.

4. An engine according to claim 1, 2 or 3 wherein the attachment of the balancing link to the crankshaft is displaced through substantially 180° about the axis of the crankshaft from the attachment of the connecting rod to the crankshaft.

5. An engine according to any one of the preceding claims comprising a parallel twin internal combustion engine having two pistons each with an associated connecting rod connected to a common crankshaft, and a balancing link connected to said crankshaft between said connecting rods.

6. An engine according to any one of Claims 1—4 comprising a single piston and associated connecting rod and camshaft, and two of said balancing links, one to each side of said connecting rod.

7. An engine according to Claim 2 wherein the balancing link is formed with a slot in which the guide link is movable.

8. An engine according to Claim 2 or 7 wherein the balancing link moves in a plane substantially parallel to the plane of movement of the piston and in the same direction as the piston.

9. An engine according to Claim 2 wherein the point of attachment of the guide link to the balancing link is at the centre of percussion of the balancing link.

10. A reciprocating engine having a balancing arrangement substantially as described with reference to Fig. 1, Fig. 2 or Fig. 3 of the drawings.

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