March 10, 1959 C. P. KOLTHOFF, JR 2,876,751

SYNCHRONIZING DEVICE FOR FREE PISTON ENGINES

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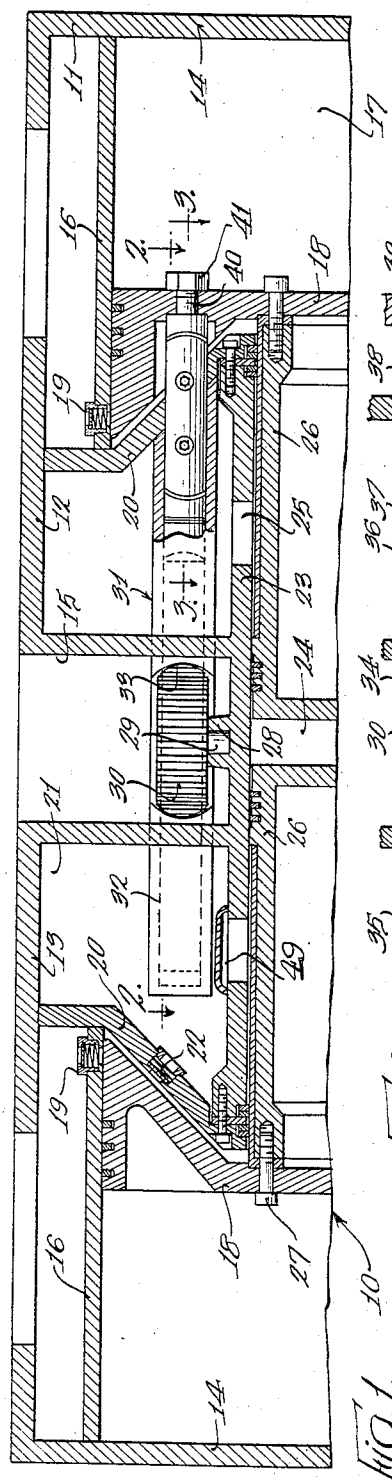

Fig. 1.

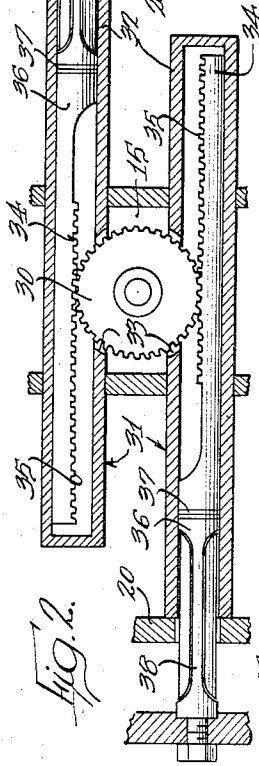

Fig. 2.

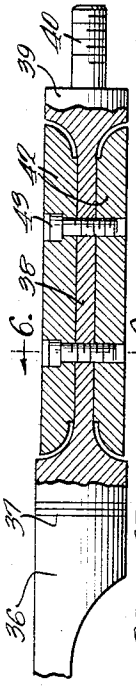

Fig. 3.

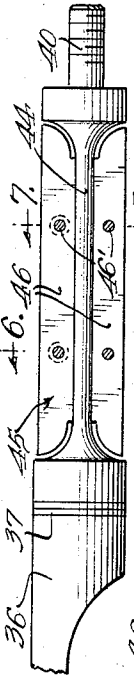

Fig. 4.

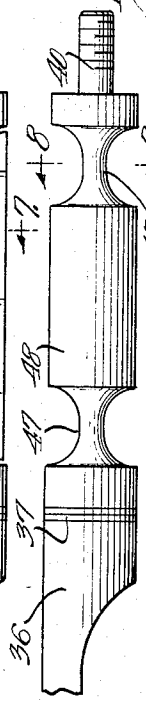

Fig. 5.

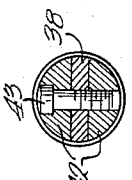

Fig. 6.

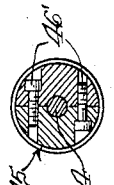

Fig. 7.

Fig. 8.

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SYNCHRONIZING DEVICE FOR FREE PISTON ENGINES

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5 Claims. (Cl. 123—46)

This invention relates to a synchronizing device for free piston engines. More particularly the invention relates to a free piston synchronizing device with flexible synchronizing rack elements.

In a conventional free piston engine, power pistons are freely mounted for reciprocation within a cylinder. The cylinder includes a combustion chamber and during the power stroke the pistons are moved in an outward direction. The power pistons are connected to compressor pistons which operate in compression chambers to bring the pistons back to their original starting position. Thus, the pistons are freely mounted in the cylinder and generally in devices of this type power is derived from the exhaust gases rather than from the direct mechanical connection to the freely moving pistons. It is, of course, necessary to properly synchronize the movement of the free pistons and that is generally accomplished by a rack and pinion arrangement which positively synchronizes the movement of the free pistons so that they are constantly in phase. Under certain conditions, power also may be derived from the racks where such power delivery is desired. The conventional free piston engine has the racks connected to the compressor piston and the pinion which engages the racks is arranged so that a movement of one piston causes a corresponding movement of the other piston relative to the center line of the engine. It is, of course, readily apparent that during the operation of the engine the racks are constantly in motion. Generally fine tolerances must be held in the manufacture of the engine to assure that the synchronizing racks are in precision sliding contact with the guides on which they are supported, so that whipping or blending of the racks is eliminated during the constant reciprocation which takes place. Due to tolerance build-ups, it is extremely difficult to hold the close tolerances normally necessary with the usual rigid type of rack element. As a result, malfunction can readily occur in the synchronizing mechanism of a free piston engine. It is a prime object of this invention therefore to eliminate the service problems usually occurring with conventional synchronizing mechanisms by the utilization of flexible racks which can readily accommodate slight misalignments between the racks, guide elements, and moving pistons so that the deleterious effects of such misalignments are avoided.

Still another object is to provide a pair of flexible rack elements for the synchronizer of a free piston engine, the rack elements having flexible portions adjacent the compressor pistons arranged to accommodate misalignment which may occur during construction or the normal operation of the engine.

A more specific object is the provision of improved rack elements for free piston engine synchronizers, the rack elements including reduced diameter portions permitting flexible movement of the rack elements with respect to the rack guides and the compressor pistons to which the rack elements are attached.

These and further objects will become more readily

apparent from a reading of the specification when examined in connection with the accompanying sheet of drawings.

In the drawings:

Figure 1 is a cross-sectional view showing the upper half of a free piston engine embodying the invention;

Figure 2 is a cross-sectional view taken particularly along the line 2—2 of Figure 1;

Figure 3 is a cross-sectional view through an improved rack element of a synchronizer mechanism, the said view being taken substantially along the line 3—3 of Figure 1;

Figure 4 is a cross-sectional view of a portion of a flexible rack element for free piston engine synchronizers showing a modified form of the invention;

Figure 5 is a view similar to Figure 4 showing another modification of a flexible construction for free piston synchronizer rack elements;

Figure 6 is a detailed sectional view taken along the line 6—6 of Figure 3;

Figure 7 is a cross-sectional view taken substantially along the line 7—7 of Figure 4; and

Figure 8 is a cross-sectional view taken along the line 8—8 of Figure 5.

Referring now particularly to Figures 1, 2 and 3, a free piston engine is generally designated by the reference character 10. The free piston engine 10 is generally of conventional construction and only portions thereof have been schematically shown. The engine 10 comprises a cylindrical housing 11 having an outer cylindrical wall 12. The cylindrical wall 12 includes air inlet openings 13 in communication with the atmosphere. The housing also includes oppositely disposed end walls 14 and a centrally disposed recess 15. Laterally spaced and oppositely disposed intermediate walls 16 are provided on the housing 11. The cylindrical walls 16 form compression chambers as designated at 17. Oppositely disposed compressor pistons 18 are suitably mounted for reciprocation within the compressor chambers 17. Each cylindrical wall 16 also includes one or more air inlet valves 19 positioned immediately adjacent to an inwardly extending inclined wall 20. The inclined walls 20 define the opposite ends of a compressed air chamber 21 and air to said chamber may be delivered through one or more valves 22 positioned on each of the walls 20.

An inner cylindrical wall is designated at 23 and this wall includes a combustion chamber 24 centrally positioned. The cylindrical wall 23 also includes a scavenging opening 25, adapted during a certain stage of operation of the engine, to scavenge the combustion chamber 24. A pair of oppositely disposed freely sliding power pistons are positioned within the combustion chamber 24. The power pistons 26 are suitably connected by means of screws 27 to the compressor pistons 18 so that they reciprocate with the power pistons 26.

The cylindrical wall 23 is provided with a boss 28 projecting upwardly into the recess 15. The boss 28 has connected thereto a shaft 29 on which a gear or pinion 30 is freely rotatable. The gear 30 forms part of a synchronizing mechanism generally designated at 31. The synchronizing mechanism 31 comprises a pair of cylindrical guide members 32 which are laterally spaced on opposite sides of the gear 30 and which may be formed as an integral part of the housing 11. Each guide member 31 includes a centrally disposed opening or access 33 so disposed that the gear 30 may project through said openings. A pair of laterally spaced substantially parallel rack elements 34 are reciprocally positioned within the guide members 32. Each rack element comprises a plurality of rack teeth 35 in meshing engagement with the gear 30. Each rack element 34 also includes a first cylindrical portion 36 having suitable seals 37 mounted there-

on, the said seals 37 being in sliding engagement with the inner surface of each cylindrical guide member 32.

The first cylindrical portion 36 is integrally connected to a flexible strap or reduced portion 38 which, in turn, is integral with a second cylindrical portion 39 which is provided at its end with a threaded projection 40. The threaded projection 40 of each rack element 34 is suitably connected to each of the compressor pistons 18 as indicated by means of nuts 41.

Referring now particularly to Figure 3 and 6, it should be pointed out that the flexible reduced portion 38 is positioned immediately adjacent the connecting end of the rack element 34. The reduced portion 38 permits a limited amount of flexing immediately adjacent the first and second cylindrical portions 36 and 39, respectively, and to prevent buckling of the strap 38 a pair of metal strip stiffeners 42 are connected. The stiffeners may be of light metal material and are of semi-cylindrical construction, the same being disposed on opposite sides of the reduced portion 38 and being suitably connected thereto by means of screws 43. Thus, a major portion of the reduced portion 38 is supported against possible buckling through sufficient flexibility of the rack is obtained by virtue of the flexibility achieved at opposite ends of the said flexible portion 38. This design provides flexibility in a plane perpendicular to the reduced section 38, but is stiff in the plane of the section 38.

Figures 4, 5, 7 and 8 show modified forms of the invention, the rack elements being substantially identical with the exception that different flexible portions are provided. These variations provide flexibility in all directions.

Referring now particularly to Figures 4 and 7, the reduced portion is designated at 44, the said portion being of cylindrical shape. A cylindrical stiffener 45 of a light metal encloses the reduced portion 44 by means of half portions 46 which are suitably connected together by screws 46'. Here again, flexibility of the portion 44 is apparent at its opposite ends, the main portion of the reduced portion being, of course, supported against buckling by means of the cylindrical stiffener 45.

In the modification shown in Figures 5 and 8, the flexible portion of the rack element shown here comprises essentially a pair of longitudinally spaced spool-shaped necks 47. The necks 47 provide for flexibility and are suitably connected together by means of a cylindrical connector 48 also integrally formed.

During the operation of a free piston engine, the power pistons 26, during the power stroke, are forced outwardly whereupon simultaneously the compressor pistons 18 compress air in the chamber 17. The opening 25 is now exposed and compressed air in the chamber 21 scavenges the combustion chamber 24 and discharges the gas through an exhaust outlet 49. The air which is compressed in the chamber 17 now forces the pistons 18 to return to the original position whereupon the valves 22 open to permit the inlet of air into the compressed air chamber 21. Thus, the operation has been briefly described and, of course, in this respect the engine disclosed is conventional.

As the pistons 26 and 28 reciprocate, it is, of course, desired that they are synchronized during the operation. This is achieved by the synchronizing mechanism 31. Since the rack elements are rigidly connected to the pistons 18, they are reciprocated with the said pistons. The rack teeth 35 engage the gear 30 and it is thus obvious that movement of one rack element is identical to the movement of the other rack element whereby synchronization is obtained. As indicated above, the rack elements, guides, and compressor pistons normally are required to maintain very close tolerances so that the racks will not bind, permanently bend or vibrate and will have a sufficiently satisfactory service life. In view of tolerance build-ups, during the engine assembly, and deflections occuring during operation, it is extremely difficult to hold close tolerances or to obtain satisfactory service. However, in the present invention, provisions are made for flexing of portions of the rack elements by means of the flexible reduced portions 38, 44 and 47. Thus, the rack elements will reciprocate in the guides without binding and the seals 37 are effective to seal lubricating oil, which may be contained within the guides, from the compressor chambers 17. In the embodiment shown in Figures 1, 2 and 3, the flexible element 38 is effective at its opposite ends to flex or bend during operation to accommodate any misalignment which might occur between the connecting portions 40 and the piston 18 with respect to the guide members 32. Yet by the inclusion of the stiffeners 42, buckling of the flexible element 38 is prevented. The stiffeners, being of light metal, reduce the reciprocating mass of the system, and also reduce the compressor clearance volume. It is apparent that flexibility to accommodate misalignment has been achieved with no moving joints which could result in axial clearance and wear.

Likewise, in the modified embodiment shown in Figures 4 and 5, the flexible reduced portions 44 and 47 permit flexing of the portion of the rack adjacent the compressor pistons to properly compensate for any slight misalignment which might occur. In the modified form shown in Figure 4, again the reduced portion 44 is reinforced against buckling by means of the casing or stiffener 45. The modification shown in Figures 5 and 8, of course, provide for flexing in the reduced portions 47 which are of spool shape and the intermediate portion 48 prevents buckling during operation.

It is now apparent that improved rack designs for free piston engines has been provided, the same fully achieving the stated objects. It must be understood, of course, that changes and modifications may be made which do not depart from the spirit of the invention as disclosed or the scope thereof as defined in the appended claims.

What is claimed is:

1. In a free piston engine comprising a housing having a combustion chamber, opposed power pistons reciprocally positioned within said combustion chamber, a compressor chamber associated with each power piston, and compressor pistons within said compressor chambers, said compressor pistons being connected to said power pistons for movement therewith; a piston synchronizing mechanism comprising a pair of laterally spaced guides associated with said housing, a gear mounted for rotation on said housing between said guides, a rack element reciprocally positioned on each guide, each of said rack elements having a rack portion in meshing engagement with said gear, means connecting one end of each rack element to one of said compressor pistons for reciprocation therewith, each rack element including an elongated flexible portion of reduced cross sectional dimension permitting flexing of said rack elements relative to said guides during reciprocation, and stiffening means connected to said reduced flexible portion on opposite sides thereof, said stiffening means including stiffeners having a length shorter than said flexible portion to permit flexing at longitudinally spaced points along said flexible portion.

2. In a free piston engine comprising a housing having a combustion chamber, opposed power pistons reciprocally positioned within said combustion chamber, a compressor chamber associated with each power piston, and compressor pistons within said compressor chambers, said compressor pistons being connected to said power pistons for movement therewith; a piston synchronizing mechanism comprising a pair of laterally spaced guides associated with said housing, a gear mounted for rotation on said housing between said guides, a rack element reciprocally positioned on each guide, each of said rack elements having a rack portion in meshing engagement with said gear, and means connecting one end of each rack element to one of said compressor pistons for reciprocation therewith, each rack element including an

elongated flat flexible strip portion of reduced cross sectional dimension permitting flexing of said rack elements relative to said guides during reciprocation.

3. In a free piston engine comprising a housing having a combustion chamber, opposed power pistons reciprocally positioned within said combustion chamber, a compressor chamber associated with each power piston, and compressor pistons within said compressor chambers, said compressor pistons being connected to said power pistons for movement therewith; a piston syncronizing mechanism comprising a pair of laterally spaced guides associated with said housing, a gear mounted for rotation on said housing between said guides, a rack element reciprocally positioned on each guide, each of said rack elements having a rack portion in meshing engagement with said gear, means connecting one end of each rack element to one of said compressor pistons for reciprocation therewith, each rack element including an elongated flat flexible strip permitting flexing of said rack elements relative to said guides during reciprocation, and metal stiffeners connected to said flat strip on opposite sides thereof, said stiffeners being shorter than said strip to permit flexing of longitudinally spaced portions of said strips.

4. In a free piston engine comprising a housing having a combustion chamber, opposed power pistons reciprocally positioned within said combustion chamber, a compressor chamber associated with each power piston, and compressor pistons within said compressor chambers, said compressor pistons being connected to said power pitons for movement therewith; a piston synchronism mechanism comprising a pair of laterally spaced guides associated with said housing, a gear mounted for rotation on said housing between said guides, a rack element reciprocally positioned on each guide, each of said rack elements having a rack portion in meshing engagement with said gear, means connecting one end of each rack element to one of said compressor pistons for reciprocation therewith, said means comprising a cylindrical flexible portion of less cross sectional dimension disposed between said rack portion and said connecting means to provide for flexing of said rack elements relative to said guides during reciprocation, and a stiffener member of lesser length than said flexible portion and connected to said flexible portion with its opposite ends disposed inwardly from the ends of the flexible member to localize the flexibility of said flexible portion.

5. In a free piston engine comprising a housing having a combustion chamber, opposed power pistons reciprocally positioned within said combustion chamber, a compressor chamber associated with each power piston, and compressor pistons within said compressor chambers, said compressor pistons being connected to said power pistons for movement therewith; a piston synchronism mechanism comprising a pair of laterally spaced guides associated with said housing, a gear mounted for rotation on said housing between said guides, a rack element reciprocally positioned on each guide, each of said rack elements having a rack portion in meshing engagement with said gear, means connecting one end of each rack element to one of said compressor pistons for reciprocation therewith, a cylindrical flexible portion of less cross sectional dimension disposed between said rack portion and said connecting means to provide for flexing of said rack elements relative to said guides during reciprocation, and a tubular stiffener member of lesser length than said flexible member and connected around said flexible portion with its opposite ends disposed inwardly from the opposite ends of the flexible member to localize the flexibility of said flexible portion.

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