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(54) PERCUSSION APPARATUS

(71) We, KABUSHIKI KAISHA YAMADA JUKI, a Japanese Company of No. 32, 4-ban, Kumano-cho, Nishinomiya City, Hyogo Prefecture, Japan, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a percussion apparatus. A percussion apparatus may be used in concrete breaking, rock drilling, earth ramming, removing casting fins or like impacting purposes.

Percussion apparatuses heretofore proposed are usually actuated either pneumatically or hydraulically, which requires a separate external pressure equipment such as an air compressor or a hydraulic power unit, that is expensive, not small in size, and demands skill in the operation. Further, this conventional type of percussion apparatus is complicated in construction, and expensive to manufacture, operate and maintain. Particularly in the art of pneumatic percussive type of apparatus, there is a hard problem that provision of more powerful apparatus is difficult to provide although an ever increasing demand therefor exists, because increase beyond a particular value of the fluid pressure does not provide a proportional increase in effective impact force, but inevitably causes an undesirable reactive force which is of great hindrance in operation.

It is an object of this invention to provide a percussion apparatus in which at least one of the foregoing disadvantages is alleviated.

According to the present invention, there is provided a percussion apparatus comprising a stationary outer cylinder having an upper and a lower end, a power transmission mechanism carried by said outer cylinder, said power transmission mechanism being of a type that can convert the rotary motion into the reciprocatory motion, an inner cylinder slidable within said outer cylinder, said inner cylinder being connected to said power transmission mechanism which is intended to be connected to a prime mover external to the cylinders; a free piston slidable within said inner cylinder, an upper sealing lid provided at the top of said inner cylinder, and a lower sealing lid provided at the bottom of said inner cylinder, a centre hole formed in said lower sealing lid, an upper pressure chamber in which air is trapped and compressed by the free piston being defined by part of the internal circumferential wall surface of said inner cylinder, the internal wall surface of said upper sealing lid and the upper end surface of said free piston, a lower pressure chamber in which air is trapped and compressed by the free piston being defined by part of the internal circumferential wall surface of said inner cylinder, the internal wall surface of said lower sealing lid, the lower end surface of said free piston, and part of a hammer which is integral with or joined to said free piston, said upper pressure chamber being considerably greater in volume than said lower pressure chamber, said hammer extending outwardly through said centre hole of said lower sealing lid in airtight relation therewith, and an impact tool joined to said hammer, or positioned with respect to said hammer so that it can be struck by said hammer.

The prime mover may be of known type available in the commercial market such as a petrol engine, a blended gasoline engine or an electric motor. Neither an air compressor nor a hydraulic power unit is required.

The impact tool, may be, for example, a chisel or a ramming stamp.

An embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:—

Figure 1 is a partly sectional front elevation of the apparatus embodying the present invention;

Figure 2 is a partly schematic and partly sectional fragmentary side elevation of the apparatus shown in Figure 1; and

Figure 3 is a diagrammatic representation illustrating a whole one working cycle of the reciprocating inner cylinder and free piston assembly designed in accordance with the present invention.

Referring now more particularly to the construction illustrated in Figures 1 and 2, the apparatus generally designated by reference numeral 10 has an elongated casing 11, within which is fixedly supported an outer cylinder 12 having in place near the opposite ends thereof at least a pair of bores 13*a* and 13*b* which communicate with atmosphere for admitting the outside air into the outer cylinder. At the upper end of the outer cylinder 12 there is mounted a transmission case 14 which houses a known power transmission mechanism of a type that can convert the axle rotating motion of a drive shaft into the reciprocating motion of a connecting rod. In the illustrated embodiment, the simplest form of crank mechanism is employed by way of example of such power transmission means, which includes a connecting rod 15, a crank shaft 16, a large gear wheel 17 and a small gear wheel 18. However, other known type of crank mechanism, cam mechanism or the like eccentric arrangement may be employed instead. Said small gear wheel 18 is connected through a flexible drive shaft 19 (shown in phantom lines in Figure 2) to an external prime mover 20 of known type (shown in phantom lines in Figure 2 which is available in the market as a petrol engine, a blended gasoline engine or an electric motor.

Within the outer cylinder 12 is disposed an inner cylinder 21 which has at its opposite ends an upper and a lower flanged lids or covers 22*a* and 22*b* respectively for sealing purposes, and a thin annular space 24 is interposed lengthwise between said lids 22*a* and 22*b* in order to provide an air passageway between the internal periphery of the outer cylinder and the external periphery of the inner cylinder 21. This annular space 24 is communicable with atmosphere via said bores 13*a* and 13*b*. On the upper lid 22*a* a joint means 23 of known type is provided for pivotally connecting the inner cylinder 21 with the lower end of the connecting rod 15, so that the inner cylinder 21 can be reciprocatingly driven up and down within the outer cylinder 12. Said lower lid 22*b* has a centre hole 22*c* formed therethrough in the manner to be described hereinafter. In the outer periphery of the inner cylinder 21, there are provided plurality of pairs of air ports 25 and 26, which communicate with said thin annular space 24 for admitting and discharging air for the purpose to be hereinafter described, with a radially spaced relation respective to each pair. Within the inner cylinder 21 there is provided a free piston 27 slidably reciprocable up and down along the internal wall surface of the inner cylinder. At the upper end of the free piston 27 there is formed an upper pressure chamber 28 which is defined by the internal wall surface of the inner cylinder, the internal wall surface of said upper flanged lid 22*a* and the upper end surface of the free piston 27, while, at the lower end of the free piston 27 is formed a lower pressure chamber 29 defined by the internal wall surface of said lower flanged lid 22*b*, the internal wall surface of the inner cylinder and the lower end surface of the piston 27. The volumes of these pressure chambers are predetermined in view of the stroke of the inner cylinder 21 as well as the length of the piston travel, in a manner such that the depth of the upper pressure chamber 28 is considerably greater than that of the lower pressure chamber 29 so that, when the inner cylinder 21 reaches its upper dead point P (shown in Figure 3), the free piston 27 can still continue to travel upwardly. Though being designed to be smaller in depth than the upper pressure chamber 28, the lower pressure chamber 29 should be at least of such depth that the free piston 27 can be still in its downward motion when the inner cylinder 21 reaches its lower dead point Q (shown in Figure 3) in order that the compressed air can not only facilitate buffer effect but also develop an effective expansion against the free piston 27. Thus, the repulsive nature of compressed air within both pressure chambers can be advantageous applied to the acceleration and buffer action for the free piston.

Said free piston 27 has at its lower end an integral extension 30 serving as a hammering means which extends through said hole 22*c* of the lower flanged lid 22*b* as well as a hole 12*a* formed at the bottom of the outer cylinder 12. The diameter of said hole 22*c* must be predetermined so that, when the hammer 30 passes therethrough, airtight relation can be kept between the hole 22*c* and the circumferential wall of the free piston 27. At the bottom end of the apparatus 10 an impact tool 31, such as a chisel or a ramming stamp, projects outwardly through a hole 32*a* formed at the bottom of a lower casing 32 and is arranged to be axially movable within limits in opposed relation with respect to the lower end of the hammer 30 so that it can be struck by the hammer for performing its intended function. If the apparatus is utilised in earth ramming, a desired ramming stamp (not shown) must be employed in place of the illustrated chisel 31 and it is preferable to attach the ramming stamp so as to be integral with said hammer 30.

Referring now again to the aforementioned air ports 25 and 26, the location of the lower air port 26 must be predetermined in a

manner such that, as soon as the lower edge of said free piston 27 in its downward travel passes over the lower air port 26 then the hammer 30 strikes the impact tool 31. This is because immediately the lower edge of the free piston has passed over said air port 26 (see Figure 3-V), the air trapped within the lower pressure chamber 29 starts to be compressed and as a result the downward velocity of the hammer will be steeply decreased, and consequently a stroke power is rapidly weakened. On the other hand, the upper air port 25 should be located so that a required amount of air can be trapped within the upper pressure chamber 29 and in the manner such that when the free piston 27 has compressed the air of the lower pressure chamber 29 to the maximum (see Figure 3-I) and immediately begins to move in the upward direction, the upper edge of the free piston is positioned below the upper air port 25 in order that fresh air is supplied via said port 25 into the upper pressure chamber 29. In other words, the upper air port 25 defines the lowermost end of the upper pressure chamber 28, while the lower air port 26 defines the uppermost end of the lower pressure chamber 29. Incidentally, it will be obvious that it is not always necessary to provide plurality of pairs of air ports as above described, but merely a single pair will be sufficient. Further, instead of said pair of ports 25 and 26, a single port of large diameter may be provided at the substantially intermediate location between the air ports 25 and 26 illustrated. It will be obvious that a single lengthwise oval bore, a single lengthwise slot or other air passageway of similar configuration can perform the same function as desired instead of said each pair of air ports 25 and 26.

Between the bottom end of the outer cylinder 12 and an annular flange 34 which is supported in place on the impact tool 31, a coil spring is mounted for resiliently suspending said flange 34 by means of which the impact tool 31 is movably supported. Reference numeral 35 denotes a buffer spring provided in place adjacent to the outer casing 11 for absorbing the reactive force which is delivered to the operator. On the casing 11 a suitable support 36 is mounted in place to which handles 37 are secured in the conventional manner.

In operation, when the crank mechanism is driven by the external prime mover 20, the crank shaft 16 is rotated, whereby the connecting rod 15 is reciprocated, and simultaneously therewith the inner cylinder 21 reciprocates up and down within the stationary outer cylinder 12. With specific reference to Figure 3 in which a series of Phases are represented to show a whole working cycle of the apparatus 10, both the inner cylinder 21 and the free piston 27 are in their course of upward travel in Phase I. In successive Phase II the connecting rod 15 is at its upper dead point P and the inner cylinder has just reached its end of the upward stroke, while at this stage the free piston 27 is still continuing its upward travel compressing the air trapped within the upper pressure chamber 28. However, in Phase III, the connecting rod 15 is descending from said upper dead point P urging the inner cylinder downwardly. At this stage the air confined between the descending cylinder end and the ascending free piston is forcibly compressed to the maximum and momentarily expands to develop an intense repulsive force upon the free piston. The next moment the free piston 27 is compelled to turn to rush downwardly preceding the inner cylinder, as is shown in Phase IV, at a combined velocity that is substantially composed of the downward speed of the inner cylinder plus a speed due to said accelerating repulsive force of the compressed air and due to gravity of the free piston itself.

Phase V shows the very moment when the free piston 27 is on the point of passing over the lower air port 26. At this moment the hammer 30 reaches the top end of the impact tool 31 and delivers a hard blow to it. At the next moment the air within the lower pressure chamber 29 starts to be compressed. However, at this moment, the inner cylinder and the free piston are both still in their downward motion. In Phase VI the connecting rod 16 has reached its bottom dead point Q and the inner cylinder is at its end of the downward stroke. At this Phase the intended impacting function has been finished and next the inner cylinder begins to move upwardly; the free piston is still moving downwardly compressing the air of the lower pressure chamber 29. Consequently, the air is compressed to the maximum in Phase I successive to said Phase VI. At this state, the free piston 27 is forced to turn upwardly and is accelerated upwardly due to the expansion of said maximumly compressed air. As soon as the upper edge of the free piston passes over the upper air port 25, the air of the upper pressure chamber is confined and starts to be compressed. As a result, the free piston starts to lose in speed gradually. It will be appreciated that in Phases I and III, the respective compressed air facilitates the buffer effect and prevents the free piston from dashing against the cylinder end.

In Phases II to VI, since the air in the lower pressure chamber is allowed to escape via the air ports 25 and 26, no upward repulsive force is developed against the descending free piston. On the other hand, in Phase I fresh air is supplied via the upper air port 25 and replaces a certain amount

of air which has been lost in the preceding cycle. In the manner thus described, the working cycle is performed repeatedly.

WHAT WE CLAIM IS:—

1. A percussion apparatus comprising a stationary outer cylinder having an upper end and a lower end, a power transmission mechanism carried by said outer cylinder, said power transmission mechanism being of a type that can convert the rotary motion into the reciprocatory motion, an inner cylinder slidable within said outer cylinder, said inner cylinder being connected to said power transmission mechanism which is intended to be connected to a prime mover external to the cylinders; a free piston slidable within said inner cylinder, an upper sealing lid provided at the top of said inner cylinder, and a lower sealing lid provided at the bottom of said inner cylinder, a centre hole formed in said lower sealing lid, an upper pressure chamber in which air is trapped and compressed by the free piston being defined by part of the internal circumferential wall surface of said inner cylinder, the internal wall surface of said upper sealing lid and the upper end surface of said free piston, a lower pressure chamber in which air is trapped and compressed by the free piston being defined by part of the internal circumferential wall surface of said inner cylinder, the internal wall surface of said lower sealing lid, the lower end surface of said free piston, and part of a hammer which is integral with or joined to said free piston, said upper pressure chamber being considerably greater in volume than said lower pressure chamber, said hammer extending outwardly through said centre hole of said lower sealing lid in air-tight relation therewith, and an impact tool joined to said hammer, or positioned with respect to said hammer so that it can be struck by said hammer.

2. A percussion apparatus, as claimed in claim 1, wherein said upper pressure chamber has such depth that when said inner cylinder reaches the end of its upward stroke said free piston can still continue its upward travel.

3. A percussion apparatus, as claimed in claim 1 or claim 2, wherein said lower pressure chamber has such depth that when said inner cylinder reaches the end of its downward stroke said free piston can still continue its downward travel.

4. A percussion apparatus, as claimed in any preceding claim, which includes at least one pair of axially spaced air ports formed in said inner cylinder, the upper air port of said or each pair being at the lowermost end of said upper pressure chamber when at its maximum length, and the lower air port of said or each pair being at the uppermost end of said lower pressure chamber when at its maximum length.

5. A percussion apparatus, as claimed in any preceding claim, wherein said power transmission mechanism includes a crank shaft and a connecting rod, said power transmission mechanism being connected to said external prime mover by means of a flexible drive shaft, and the lower end of said connecting rod being pivotally connected at its lower end to a joint provided on said upper sealing lid.

6. A percussion apparatus as claimed in claim 4 or in claim 5 as appendant to claim 4 wherein a thin annular space is formed between the internal surface of said outer cylinder and the external surface of said inner cylinder, said annular space being in communication with said upper and the lower air ports, respectively.

7. A percussion apparatus, as claimed in any preceding claim, wherein said impact tool is in the form of a chisel.

8. A percussion apparatus, as claimed in any of claims 1 to 6, wherein said impact tool is in the form of a ramming stamp.

9. A percussion apparatus substantially as hereinbefore described with reference to the accompanying drawings.

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