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Hydraulic impactor with impact energy and frequency adjusted independently and steplessly①

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[Abstract] Based on analysis of the present hydraulic impactor, a new hydraulic impactor with pressure feedback control was developed, whose structure and operation principle were introduced. The results show that the pressure of the impact system can be adjusted steplessly to change the impact energy of the impactor steplessly. By adjusting the oil flow of supply pump steplessly, the impact frequency will also be changed steplessly. So the impact energy and frequency of the new impactor can be adjusted independently and steplessly. In order to decrease the energy loss, a new kind of sleeve valve has been designed, which has features of little leakage, little pressure loss and low energy cost. The new type hydraulic impactor can be operated under various conditions with decreased energy consumption and improved operation efficiency.

[Key words] hydraulic impactor; adjusted independently and steplessly; impact energy; impact frequency
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1 INTRODUCTION

Although there are many types of hydraulic impactor structure, all the impactors have the same character, i.e., the return stroke of piston is caused by high-pressure oil which enters front chamber to drive piston return; at the same time, the accumulator stores of energy, then the energy releases out to work in the next forward stroke. The main difference in structure lies in the methods to implement forward stroke and the ways to distribute oil.

With the recent development of hydraulic technology, the hydraulic impactors of many factories in the world were designed with the capability to adjust the impact energy. So they can adapt to the requests of breaking different kinds of rocks with different block degrees and hardness. This ensures the output impact energy to be close or equal to the optimum impact energy of rock fragmentation. Consequently it can not only reduce production cost but also extend the application range of hydraulic impactor. Different from the commonly hydraulic machines, the load of hydraulic impactor is the inertia force of piston movement. So if the supply flow of the hydraulic impactor is changed, the operation pressure and impact energy will also be changed. However, because the impact power is in direct ratio to the cube of oil flow and is in inverse ratio to the stroke of piston, to change the impact energy and frequency of the hydraulic impactor needs the piston stroke to be changed in the mean time when the impact flow is changed. The scheme of changing the piston stroke of hydraulic impactor is called shift scheme[1,2].

Making a comprehensive review of hydraulic impactors in the world, all their adjusting methods of stroke are stepped, commonly with two or three shifts. Some of them are not very convenient in actual work. So generally the hydraulic impactor need not be adjusted the impact energy when it is working, unless it meets a great deal of hunk rock. It needs to be put out that because of the limit of structure dimension, the stroke of impactor will not be designed very long and the impact frequency of hydraulic impactor will not be designed very low. Therefore the impact energy can not be very great, and its adjusting range can not be very wide[3,4].

According to the theory of rock fragmentation, there exists the lowest fragmentation energy of rock. When the impact energy is lower than the lowest fragmentation energy, the impactor cannot break rock. In order to break rock with different block degrees and hardness, if the stroke of piston is invariable, the impact energy can be changed by adjusting the operation pressure. In order to enlarge the impact energy, the impact pressure must be increased. In this way the impact frequency is increased and the impact power is enlarged very much. Because the impact energy and frequency of the common hydraulic impactor which applies stroke feedback control principle are changed concatenately and synchronously in the adjusting process, when the impact energy is enlarged, the impact power is also enlarged. This requires improving the loading capacity. Because the impact frequency can not be designed very low, one unreasonable situation that the large loading capacity is matched with the small impactor will bring such

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disadvantages as selection of its chassis with more unnecessary ability, increase of machine production cost and limitation of hydraulic impactor application[5,6].

2 KEY TECHNIQUE OF NEW TYPE HYDRAULIC IMPACTOR

The impact system pressure is in direct ratio to square of flow. When the supply flow is enlarged, the system impact pressure is also enlarged. At the same time the impact energy, impact frequency and power are enlarged synchronously. The way to solve this problem is to break the direct proportion relation between pressure and square of oil flow, so that the impact pressure and supply flow can be adjusted independently and steplessly as well as the impact energy and frequency. In this way the impact energy can be adjusted to a very great amount and the impact frequency can be adjusted to a very low amount, without increasing the impact power much higher. According to different kinds of rocks, selecting suitable type of hydraulic impactor chassis can increase the working efficiency and reduce the cost. All these are helpful to extend the application of hydraulic impactor. Therefore, it is beneficial to seek a new operation principle of hydraulic impactor[7,8].

3 PRINCIPLE AND SCHEME

With the pressure feedback control principle and without the relation that the pressure is in direct ratio to square of oil supply flow, the new type hydraulic impactor can be adjusted the impact energy and oil supply flow independently and steplessly. This means the performance parameters of hydraulic impactor can be controlled independently and steplessly. The structure and operation principle of the new impactor has many types; in this paper a primary type of structure and operation principle is discussed and analyzed.

3.1 Structure

As shown in Fig.1, the hydraulic impactor is made up of impact piston 1, cylinder body 2, nitrogen chamber 3, pickaxe 4, high pressure accumulator 5, return oil accumulator 6, pressure control cone valve 7, distribution valve core 8 and valve body 9. The impactor also adopts the back chamber control type in which the front chamber holds constant high oil pressure and the back chamber holds high and low oil pressures alternately. Piston 1 and cylinder body 2 form four chambers, i.e., constant high oil pressure front chamber ① with opening oil hole Ⅰ, constant low oil pressure chamber ② which can link stroke feedback signal hole Ⅱ and oil hole Ⅲ, back chamber ③ which can adjust oil pressure with oil hole Ⅳ and nitrogen chamber 3. The constant high pressure oil chamber at the front of cylinder body is connected with constant high pressure oil chamber ⑤of oil distribution valve and the high pressure oil source *P* of supply pump by oil hole Ⅰ and oil line. The oil source channel sets up a high pressure accumulator 5. The oil hole Ⅱ is connected with thrusting valve chamber ④ of distribution valve by oil line. The oil hole Ⅲ is connected with the constant low pressure chamber ⑦ of distribution valve and return oil *T* by oil line. Moreover return oil accumulator 6 is set

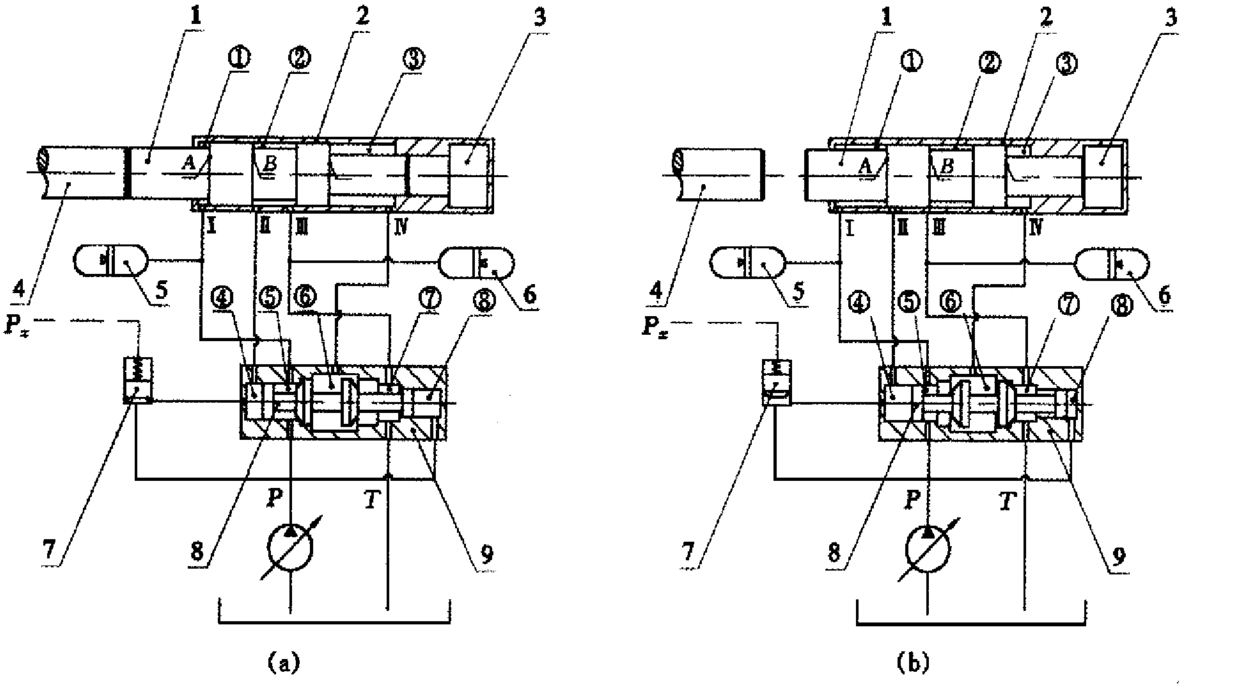

Fig.1 Structure and operation principle of new type hydraulic impactor
(a) —Return stroke; (b) —Stroke

up on the return oil line. When the stroke is proceeded to the end, the extremity side B of piston gets across oil hole Ⅱ, the oil chamber ② connects with stroke feedback signal hole Ⅱ and oil hole Ⅲ. The back chamber ③ of cylinder connects with the shift pressure chamber ② by oil hole Ⅳ and oil line.

The distribution valve takes the techniques of cone valve and optimum unequal opening of valve. Because the velocity is low in return stroke, less oil is needed, so the opening of valve is small. Because the velocity is high in stroke, more oil is needed, so the opening of valve is large. The valve consisting of core 8 and body 9 has many chambers. The thrusting valve chamber ④ is connected with the pressure controlled cone valve 7 by oil line, its turn on or block with high pressure oil resource are controlled by cone valve 7. The turn on pressure of control cone valve is controlled by control oil pressure P_x, which can be adjusted steplessly by pressure release valve. The left and right cones and cylinder stage shoulders alternatively control the opening and blocking of the constant high pressure chamber ⑤ of distribution valve with shift pressure chamber ⑥, and the constant low pressure chamber ⑦ of distribution valve with shift pressure chamber ⑥. When chamber ⑤ connects with chamber ⑥, chamber ⑦ blocks with chamber ⑥. When chamber ⑤ blocks with chamber ⑥, chamber ⑦ connects with chamber ⑥. The available action area of chamber ④ of valve core is larger than that of chamber ⑧, the thrusting valve chamber ⑧ is connected with high pressure oil source P by oil line.

3.2 Operation principle

1) Return stroke

Fig.1(a) shows that the piston has completed a forward stroke, and the valve has already exchanged direction. The whole system is at the beginning state of a return stroke. At the same time, chamber ④ of distribution valve is connected with return oil T by oil hole Ⅱ and Ⅲ, and the thrusting valve chamber all the time is connected with high pressure oil source P by the oil line and central hole path of valve core. The valve core 8 locates at left position under the action of high pressure oil of chamber ⑧. The high pressure oil source P is connected with the front chamber ① of piston by the way of high pressure chamber ⑤ of valve body and oil hole Ⅰ. And that the back chamber ③ connects with return oil by the way of oil hole Ⅳ and shift pressure chamber ⑥ and low pressure chamber ⑦. So piston 1 begins to return rightward under the action of front chamber high pressure oil, at the same time it compresses nitrogen chamber 3. The high pressure accumulator 5 stores of oil, along with the increase of return stroke the compressed space of nitrogen chamber 3 decreases. Its pressure rises, the system pressure also rises. When the pressure rises to the turn on pressure of pressure control cone valve 7, cone valve 7 opens up, the high pressure oil enters into thrusting valve chamber ④. Because the working area of chamber ④ is larger than that of chamber ⑧, the valve core rapidly changes movement direction to right under the action of pressure difference. The shift pressure chamber ⑥ of valve body connects with high pressure chamber ⑤. In this way, both the front and back chambers of piston connect with high pressure oil, forming differential connection. Then the accelerated return stroke of piston is ended. Although the working area of back chamber of piston is larger than that of front chamber and nitrogen air pressure action, the piston will continuously move to right due to the inertia action. It moves with a negative acceleration, till the velocity becomes zero, completing the entire return stroke movement.

From above analysis we can conclude that the return stroke of piston practically consists of two stages of return stroke acceleration and return stroke deceleration.

2) Forward stroke

When the return stroke of piston is over, it prepares for forward stroke. The forward stroke begins like the stage of return stroke deceleration, and the state of entire oil line is shown in Fig.1(b). Valve core 8 is still located at right under the action of difference of oil pressure. The front and back chambers of piston still connect with high pressure oil, keeping differential connection. Piston 1 is accelerated to left under the action of oil pressure difference and nitrogen expanding force, so the forward stroke begins. In the late period of the stroke acceleration, the velocity is very high. So the system needs more oil flow and its pressure decreases. The high pressure accumulator discharges a great deal of oil supplying to back chamber. When the side face B gets across the feedback signal hole Ⅱ of stroke direction exchange, thrusting valve chamber ④ is connected with return oil by oil hole Ⅱ and Ⅲ and it losses high pressure. At the same time, pressure control cone valve 7 closes up, the valve core rapidly changes direction of stroke and moves left under the action of high pressure. Then piston 1 impacts pickaxe 4, so the forward stroke is ended. The impactor again comes back to the beginning of return stroke, preparing for its next cycle of return stroke movement.

Through the operation principle we can conclude that the pressure control valve can control the impact pressure P. When other parameters of hydraulic impactor are determined, we can steplessly adjust the control pressure P_x. The control pressure of cone valve can be changed steplessly, thus making the impact energy of hydraulic impactor change steplessly. The high the pressure is high, the high the impact energy is. By adjusting the oil flow of supply pump steplessly, the impact frequency will also be changed steplessly, i.e., the more the flow is, the higher the impact frequency is. Its key advantage is that the adjustment can be carried out synchronously and separately. In this way, the impact frequency can be adjusted to a very low value, while the impact energy can be adjusted to a very high value. So it can take full advantage of loading capacity to adapt the requests of various work conditions.

Otherwise, if P_x is adjusted too high and the system impact pressure rises at return stroke but can not turn on pressure control cone valve 7, the piston is still at return stroke. When it continually returns to side face A of the piston and gets across signal hole Ⅱ, the high pressure oil will enter into thrusting valve chamber ④ by front chamber ①, oil holes Ⅰ and Ⅱ, thus making valve core change the movement direction and return right. The back chamber connects with high pressure oil, the piston decelerates in return, and then begins forward stroke movement. In this way it can confine the pressure of impact system not too high, the stroke not too long, the impact energy not too high to damage the machine.

3.3 New type of distribution valve

The impactor adopts a new type of distribution valve which using cone valve core. Its sealing method adopts both cone face and cylinder pressure. When the valve core moves to its rest location, the leakage of valve is sealed by the combination of both cone face and cylinder; when the valve core changes movement direction, it is sealed by cylinder. The rest time of valve core is long enough so that the leakage of cone face sealing almost equals zero, and the movement time of valve core is very short so that the leakage of valve leakage is very little in the entire work course. When the coefficient of leakage of cone valve is big, the pressure loss of oil passing through valve is little and the energy cost is also low. The new type of distribution valve takes a new technique of optimum unequal opening of valve. When the hydraulic impactor in stroke needs more oil flow, it makes the opening of valve large while the valve core locates at right. When the hydraulic impactor in return stroke needs less oil flow, it makes the opening of valve small while the valve core locates at left. In this way it can reduce the movement distance of valve core and the energy consumption of changing movement direction as well as the energy loss of distribution valve. As soon as the valve on return stroke changes direction, the area of core to thrusting valve rapidly increases, the valve core rapidly moves to location. Also it has hydraulic pressure oil to from cushion, so can avoid the valve core damaged in the impact movement[9,10].

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