IMPROVEMENTS IN HYDRAULIC IMPACT MECHANISMS CONTROLLED BY ROTATABLE DISTRIBUTORS

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Abstract: *Descriptions of two known hydraulic impact mechanism are realized. One of the impact structures is to be patented. Improvements in the constructive structure and in the operating hydraulic scheme of these impact mechanisms are analyzed. The aim is to simplify the hydraulic scheme and the command and control structure, to minimize the hydraulic parasitic capacities and to attain an adjustable impact frequency. In brief, the goals are to improve the constructive structure of a hydraulic impact device or a hydraulic rotary percussive mechanism controlled by a rotary distributor and the operating principle of the mechanism.*

Keywords*: impact mechanism, percussive device, rock drill, hydraulic hammer, control system, control valve, rotary valve, rotatable distributor*

1. Constructive structures for hydraulic impact mechanisms using rotary distributors

An older patented impact mechanism, Fig.1, comprises, according to [1], an impact piston, a rotating distributor and a hydraulic turbine. The impact piston delimitates in the impact mechanism housing two working chambers, C1 and C2. The hydraulic rotating distributor is a 3/2-ways control valve and is used to feed with high-pressure fluid flow the working chamber C2 and alternately to discharge it. The mobile element of the used hydraulic distributor is a rotating spool with longitudinal grooves. For the rotation of the rotating spool it is chose a hydraulic turbine. The working or drive chamber C2 is connected alternately through the longitudinal grooves of the

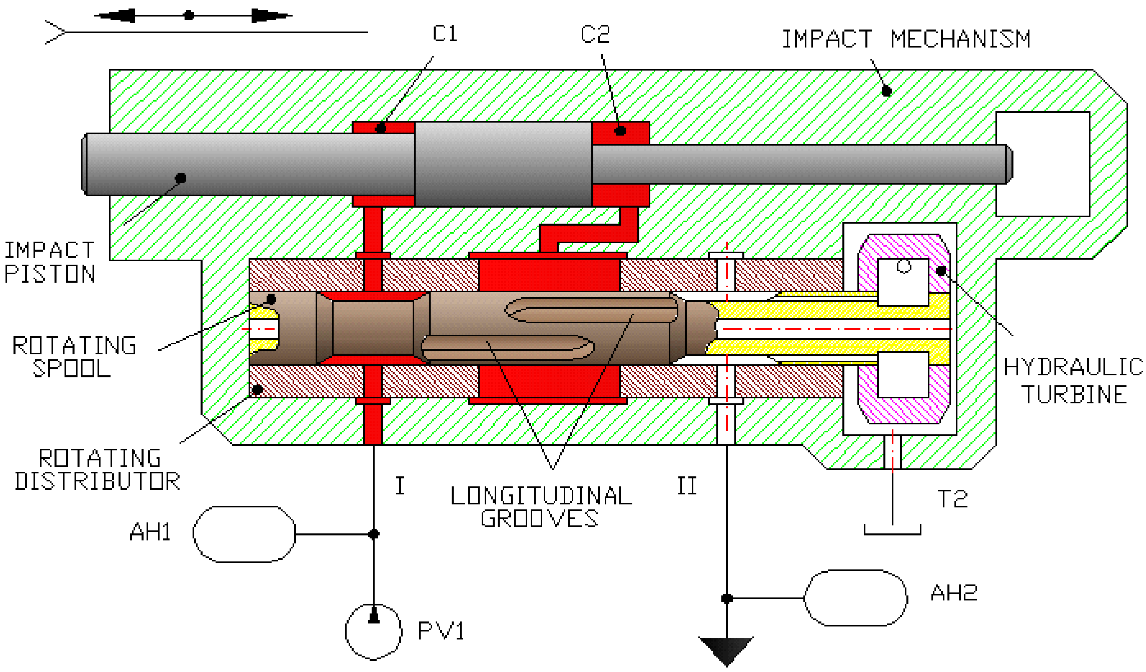


Fig.1. A constructive structure of a hydraulic drilling mechanism using a hydraulic rotary distributor, according to [1], where:
PV1 – hydraulic pressure source (volumetric pump); AH1, AH2 – hydraulic accumulators; T2 –tank; C1, C2 – work chambers; I – pressure line; II – discharge line.

rotating spool with the line I and line II. The working chamber C1 communicates permanently with the hydraulic pressure source PV1.
The line I is for supplying with hydraulic fluid under pressure by means of a hydraulic pressure source PV1. A hydraulic accumulator AH1 is also mounted on the line I.
The line II is connected to the hydraulic rotary mechanism taken picked for the rotation of the dislocation tool or of the drill steel. The rotary mechanism and the percussive mechanism use two separate hydraulic pressure sources, necessary to realize the rotation of the dislocation tool and the collision of the tool with the target material (rock, concrete, asphalt).
A recent impact mechanism [2] presented in [3] and [4] comprises, Fig.2, essentially, an impact piston and a rotary distributor with a rotatable spool. The impact mechanism housing is formed by two bodies, B1 and B2. The impact piston delimitates likewise two working chamber in the impact mechanism housing, C1 and C2. The working chamber C1 is in permanent connection with the hydraulic pressure source PV. The working chamber C2 communicates alternatively by means of the rotatable spool with the hydraulic pressure source PV and with the tank T. The rotatable spool forms with the piston body a 3/2-ways hydraulic rotary distributor. The rotary displacement of the spool is provided by a hydraulic gear motor MRD2-212D.

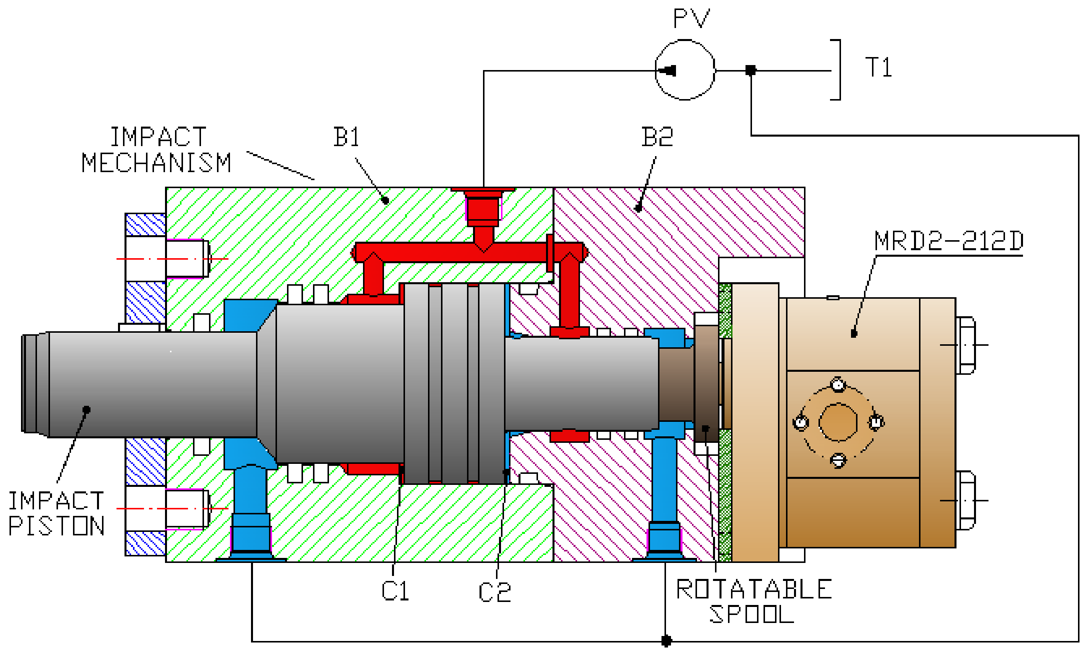


Fig.2. A constructive structure of a hydraulic drilling mechanism using a hydraulic rotary distributor, according to [2], where:
PV – hydraulic pressure source (volumetric pump); B1, B2 – bodies or housings of the impact mechanism; T1 – tank; C1, C2 – work chambers; MRD2 – hydraulic gear motor.

The impact mechanism and the rotary mechanism can be mounted in series using the same hydraulic pressure source or can function independently with separate hydraulic pressure sources. Both cases are exemplified in the prior art. The mounting in series of the percussion mechanism and the rotary mechanism appears earlier than the 80's. It is affirmed in [5] that the said mounting in series implies the need of a single hydraulic pressure source thus simplifying the pumping station and the hydraulic scheme. Contrary, as the rotary hydraulic mechanism is supplied with fluid flow from a separate pump and through a separate circuit, as in [6], the working of the rotary mechanism is realized independently from the percussive mechanism but the resulted hydraulic scheme is more complex with the other corresponding consequences.
The operation cycle of the impact mechanisms from Fig.1 and Fig.2 is controlled by feeding with working liquid along the line I, respectively from the pump PV to the hydraulic linear motors. It is to be underlined that for the second impact mechanism, Fig.2, it is needed additionally an external separate element to rotate the rotatable spool in contrast with the first impact mechanism. The hydraulic turbine, Fig.1, which rotates the rotatable spool, is incorporated in the impact mechanism housing and is operated hydraulically by the fluid spent in the working chamber C2. The rotatable

spool, Fig.2, is rotated by means of a rotary mechanism actuated in this case hydraulically, MRD2-212D, and supplied with hydraulic fluid from a separate hydraulic pressure source (not illustrated).

2. Operating principles for hydraulic impact mechanisms using rotary distributors

The operation principle of the impact mechanism with the construction scheme in Fig.1 is illustrated in Fig.3.

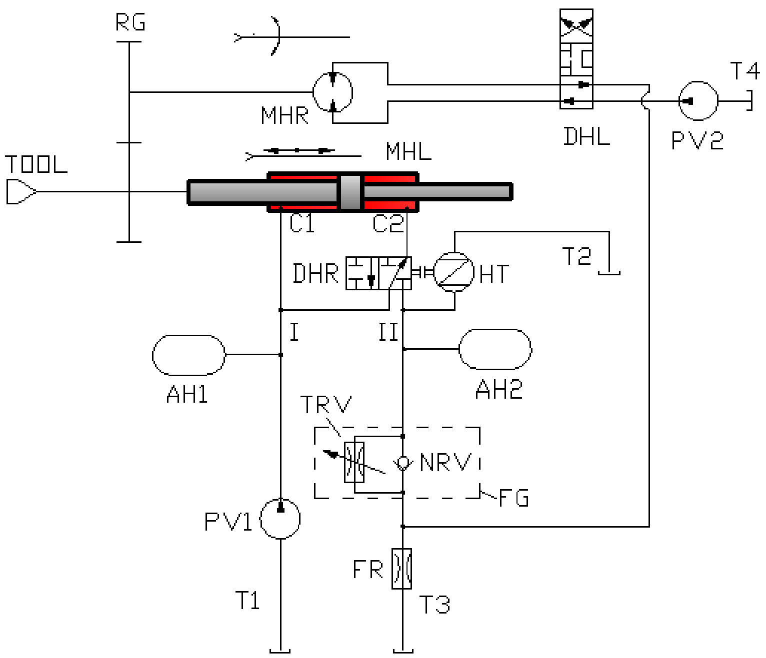


Fig.3. The operating principle of the hydraulic impact mechanism presented in [1], where:
T1, T2, T3, T4 – tanks; PV1, PV2 – hydraulic pressure sources; AH1, AH2 – hydraulic accumulators; C1, C2 – work chambers; DHR – hydraulic rotary distributor; DHL – hydraulic linear distributor; MHL – hydraulic linear motor; MHR – hydraulic rotary motor; HT – hydraulic turbine; RG – reduction gear; FG – flow governor; NRV – non-return valve; TRV – throttling valve; FR – flow restrictor.

The liquid flow sent from the hydraulic pressure source PV1 to the hydraulic linear motor MHL is divided into two flows. One liquid flow is conveyed to the working chamber C1 through an existing permanent communication. The rest of the liquid flow is sent through the rotary distributor DHR to the working chamber C2. The working liquid spent to obtain a certain piston stroke is farther sent to the return line the destination being the tank T3. Not all the working fluid arrives in the tank T3 due to the non-return valve NRV and the throttling valve. The remained working fluid is reflected. At this time the working position of the rotary distributor is switched and the connection with the working chamber C2 through the rotary distributor is blocked. In consequence, the flow will charge the hydraulic accumulator AH2 and will start the hydraulic turbine. The hydraulic turbine communicates according to [1] through two tangential holes with a discharge line connected to the tank T2.

As long as the hydraulic pressure source PV1 is supplying with working fluid the impact mechanism, the hydraulic turbine HT operates on the base of the liquid sent to the working chamber C2. Moreover, the hydraulic accumulator AH2 tends to discharge and feed the hydraulic turbine. In consequence the hydraulic turbine continues to rotate the fluid distributor at substantially the same speed. The rotatable spool of the distributor DHR is rotated at the maximum rate achieving the highest frequency of impacts delivered by the impact piston to the tool.

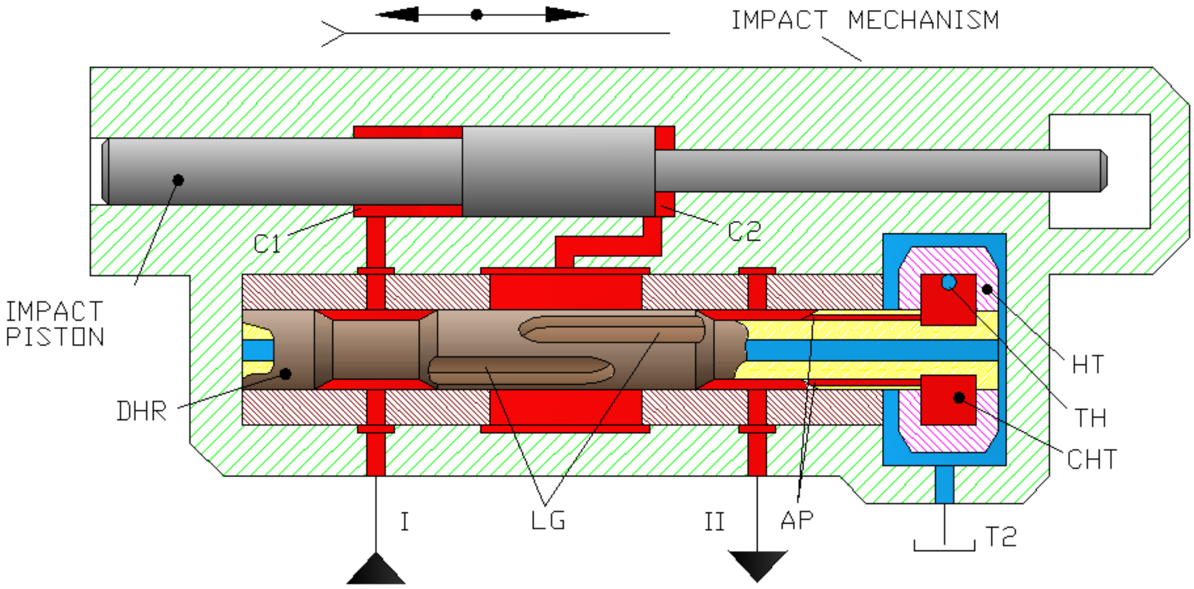
The main part of the fluid withdrawn by the rotary mechanism MHR through the 4/3-ways linear hydraulic distributor DHL is used to rotate the fluid distributor when the supply with high-pressure fluid flow from the hydraulic pressure source PV1 to the hydraulic percussive mechanism is cut off. The said main part of the liquid is conveyed by mean of the flow governor through line II and to the hydraulic turbine. The rest of liquid passes through the flow restrictor FR to the tank T3. The achieved frequency is lower in this case and increases back when feeding with liquid to the hydraulic percussive mechanism is resumed.

Another way to redistribute the liquid spent by the hydraulic rotary mechanism MHR to rotate the drill tool is revealed through [7]. In [7], the flow governor misses and the fluid flow discharged from the rotary mechanism is directed to the impact piston serving in increasing the impact piston velocity.

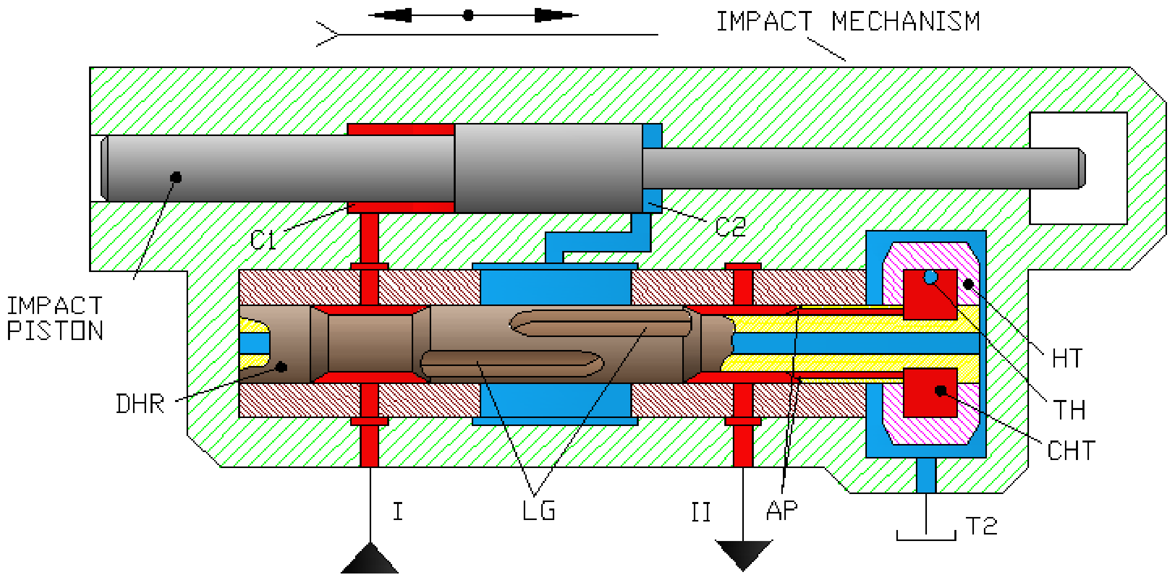
Thereafter, as the rotation of the hydraulic turbine HT is started, the hydraulic turbine receives an extra fluid flow only when the hydraulic percussive mechanism is supplied with high pressure fluid flow from PV1. The increase in fluid flow in the line II leads in closing of the non-return valve NRV and in increasing of the rotational speed of the rotary distributor.

The flow restrictor FR can provide a pressure difference sufficient for opening the non return valve NRV and the main part of the liquid from the hydraulic rotary motor MHR will flow through it to the hydraulic turbine HT. The liquid that enters the hydraulic turbine actuates the turbine causing the rotation of the rotatable spool of the rotary distributor DHR. The rest of liquid passes through the flow restrictor FR to the discharge line.

When the feed of fluid in the impact mechanism is resumed, the entire fluid flow sent to the working chamber C2 to advance the impact piston charges the hydraulic accumulator and rushes to the hydraulic turbine at the retreating piston stroke. The rotational speed of the fluid distributor is substantially increased now. The operating of the impact piston maintains the rotation of the rotary distributor at maximum speed.



a)



b)

Fig.4. The hydraulic impact mechanism presented in [1], when:
a) both work chambers C1 and C2 are supplied with high pressure fluid flow;
b) the work chamber C2 is discharged and the high pressure fluid flow is directed to the line II.

The Fig.4 b is uncertain and improper taking into account that the fluid flow discharged from the work chamber C2 is adjustable according to [1] and in the line II a certain required pressure is provided to cause the rotation of the hydraulic turbine.

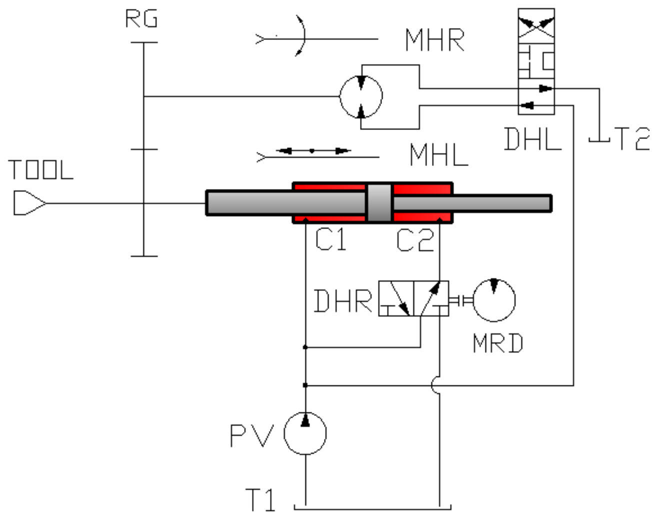


Fig.5. The operating principle of the hydraulic impact mechanism presented in [2], where:
T1, T2 – tanks; PV – hydraulic pressure source; C1, C2 – work chambers; DHR – hydraulic rotary distributor; DHL – hydraulic linear distributor; MHL – hydraulic linear motor; MHR – hydraulic rotary motor; MRD – hydraulic gear motor; RG – reduction gear.

Omitting the hydraulic rotary mechanism MHR from the Fig.5, it can be said that the liquid flow sent from the hydraulic pressure source PV to the hydraulic linear motor MHL is likewise divided into two flows. One liquid flow is conveyed permanently to the working chamber C1 through certain communication channels. According to one of the working positions of the rotary distributor DHR, the rest of the liquid flow is conveyed through it to the working chamber C2. As the hydraulic rotary distributor allows the communication of the working chamber C2 with the hydraulic pressure source PV through the pressure line, the impact piston executes a work stroke and delivers an impact on the drill tool (drill steel or drill bit). The working liquid spent to obtain a certain piston stroke – work stroke – is farther sent to the return line through the rotary distributor DHR back to the tank T1, according to the other working position of the distributor.

In addition it can be used also a rotary hydraulic motor operated by a 4/3-ways control valve. The control valve serves to stop and reverse the rotation of the drill tool. By mounting the hydraulic rotary mechanism in series with the hydraulic percussive mechanism, the liquid flow sent from the hydraulic pressure source PV to the hydraulic linear motor MHL is divided into three flows, Fig.5. The hydraulic fluid used by the rotary hydraulic motor MHR to rotate the drill tool is discharged to the tank T2. To be capable of executing percussive action independently from the hydraulic rotary motor MHR there can be chose two hydraulic pressure sources feeding the mechanism separately. Examples of hydraulic rotary percussive mechanism with two hydraulic pressure sources are [6], [7] and with one hydraulic pressure source are [2], [3].

According to the design structures of both impact mechanism, as the impact piston advances to apply a strike the fluid flow from the working chamber C1 joins to the fluid flow sent to the working chamber C2 resulting in increasing the velocity of the impact piston. By directing the fluid flow from the working chamber C2 to the tank T1 through the rotary distributor DHR the impact piston is forced to do a reverse stroke, as the working chamber C1 continuously communicates with the hydraulic pressure source PV.

A representation of the high pressure liquid zones and low pressure liquid zones in the mechanism's structure for each working position of the hydraulic rotary distributor is presented in Fig.6.

3. Similarities and dissimilarities

- Similarities in the described impact mechanisms

Both structures, Fig.1 and Fig.2, incorporate a rotary spool and a differential impact piston delimitating two working chambers, C1 and C2. The drive chamber controlled by the hydraulic rotary distributor is the largest one, C2. The rotary spool presents on the external cylindrical face longitudinal grooves. The longitudinal grooves are disposed as opening through which the drive chamber C2 communicates with the hydraulic pressure source of the impact mechanism and as openings through which the drive chamber C2 communicates with the tank. Both hydraulic rotary distributors operate as 3/2-ways control valve.

- Dissimilarities in the described impact mechanisms

The rotary distributor from Fig.1 is mounted separately from the hydraulic linear motor. Conversely, the rotary distributor from Fig.2 is mounted in the hydraulic linear motor. Moreover, the element comprising the rotary spool of the rotary distributor is chose to be the impact piston itself. To be mentioned, the impact piston does not act itself as a valve unlike the valveless impact devices.
The rotary spool from the Figl.1 is rotated by means of a hydraulic turbine. The rotary spool from the Figl.2 is rotated by means of a hydraulic gear motor.
The hydraulic turbine uses the fluid directed to it from the spent fluid to advance the impact piston.

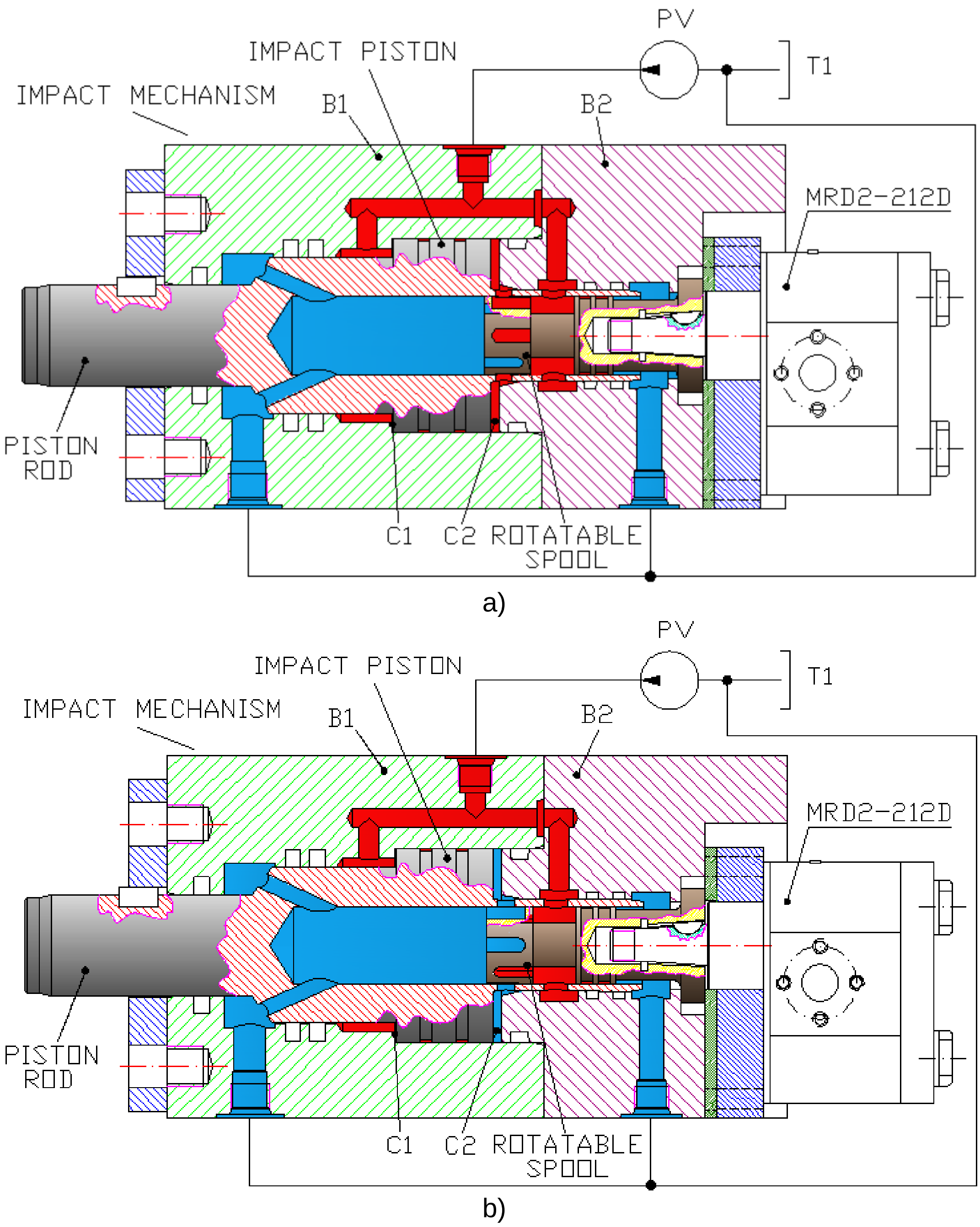


Fig.6. The hydraulic impact mechanism presented in [2], when:
a) both work chambers C1 and C2 are supplied with high pressure fluid flow;
b) the work chamber C2 is discharged and the high pressure fluid flow is directed to the tank.

With other words, the element rotating the rotatable spool is driven internally. The hydraulic gear motor can use high pressure fluid flow from a separate hydraulic pressure source or item from the hydraulic pressure source of the impact mechanism. In Fig.2 the method of feeding or acting the hydraulic gear motor is undecided.
The longitudinal grooves are set for the structure from Fig.2 to eight equidistantly, alternatively and reversely disposed. According to the description of the rotary spool from [2], as the spool is rotated the longitudinal grooves communicate four by four with the work chamber C2 through radial orifices drilled in the piston body. The arrangement for the longitudinal grooves of the rotary spool from Fig.1 is not revealed.

4. Discussions

To opt for the method of rotating the spool with a hydraulic turbine (a reaction turbine) it is needed to take into account the effect of the mounting a hydraulic accumulator at the relief of the fluid flow from the impact mechanism. In Fig. it is illustrated the structure with the rotatable spool mounted in the piston body and actuated by a hydraulic turbine without including in the impact mechanism housing hydraulic accumulators.

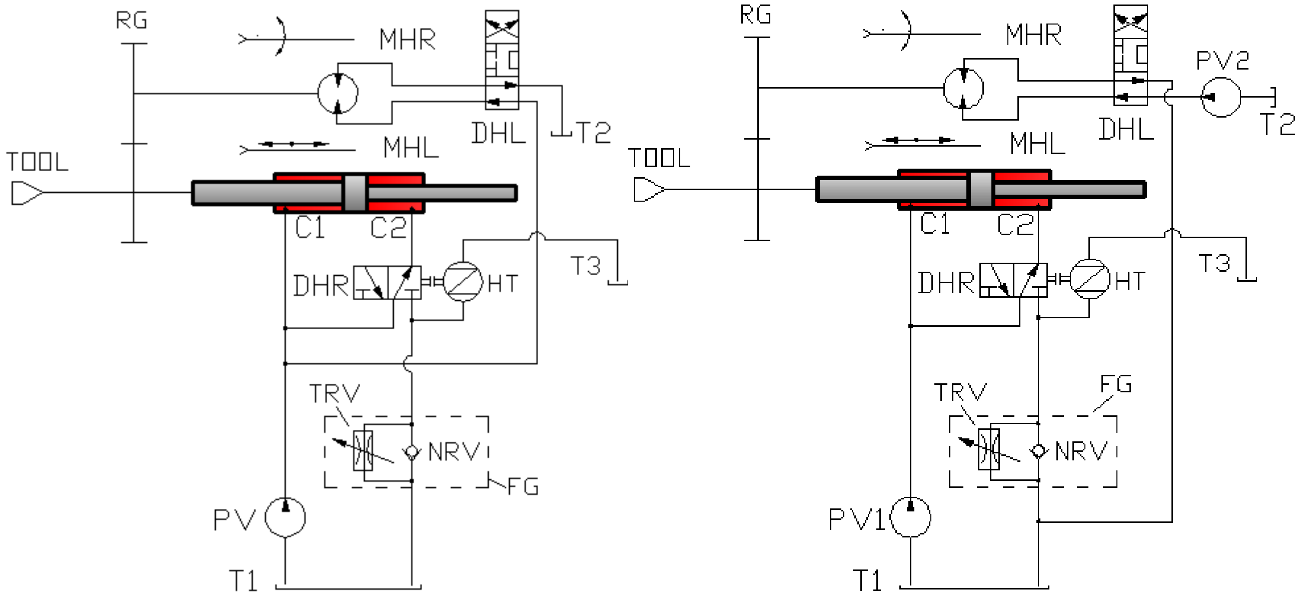


Fig.7. The operating principle of the hydraulic impact mechanism presented in [2], modifying the actuating method of the rotary distributor:
T1, T2, T3 – tanks; PV, PV1, PV2 – hydraulic pressure source; C1, C2 – work chambers; DHR – hydraulic rotary distributor; DHL – hydraulic linear distributor; MHL – hydraulic linear motor; MHR – hydraulic rotary motor; HT – hydraulic turbine; RG – reduction gear; FG – flow governor; NRV – non-return valve; TRV – throttling valve.
a) with the hydraulic motor MHR connected to the pressure line;
b) with the hydraulic motor MHR connected to the discharge line;

When the hydraulic motor MHR is connected to the pressure line of the hydraulic pressure source PV the hydraulic turbine does not rotate, Fig.7 a. Conversely, when the hydraulic motor MHR is connected to the discharge line as in Fig.7 b the hydraulic turbine HT rotates but at low speed with a stopped impact mechanism. Thus, the hydraulic turbine rotates continuously at low rotations per minute until the impact mechanism is started. As the feeding of the impact mechanism starts, the rotational speed of the hydraulic turbine increases.
A redistribution of the liquid sent to the tank T1 can be obtained by means of the flow governor. Accordingly, the working liquid spent by the rotary mechanism to rotate the tool can be sent to the hydraulic turbine through the non-return valve of the flow governor FG. Also, the working liquid

spent by the percussive mechanism to strike the tool can be blocked and reflected and further directed to the hydraulic turbine to rotate it.
The working liquid conveyed from the hydraulic percussive mechanism to the non-return valve NRV acts to close it in each case presented in Fig.7.
The throttling valve TRV controls the fluid flow directed to the tank T1.
To modify the rotational speed of the rotary distributor the throttling valve TRV has to be adjusted. In consequence, by controlling the throttling valve TRV of the flow governor FG it is attained an adjustable rotational speed of the rotatable spool. More important it is attained an adjustable impact frequency for the impact piston of the impact mechanism.
A fully open throttling valve reduces the fluid flow entering the hydraulic turbine and the rate of rotation of the rotatable spool leading to a minimum frequency of impacts delivered by the impact piston. A fully closed throttling valve increases the fluid flow entering the hydraulic turbine and the rate of rotation of the rotatable spool leading to a maximum frequency of impacts delivered by the impact piston.
The frequency of impacts delivered by the impact or strike piston is controlled by varying the rotational speed of the rotary distributor by means of the flow throttling valve TRV.
By mounting a hydraulic accumulator on the discharge line similarly as in Fig. 3 the liquid is forced from the working chamber C2 by the impact piston, the non return valve and the throttling valve to the flow governor FG, the hydraulic accumulator AH2 and the hydraulic turbine HT. The hydraulic accumulator AH2 discharges and feeds the hydraulic turbine to maintain a desired rotational speed of the rotatable spool.
One simplification of the described construction from Fig.1 is the use of the hydraulic reaction turbine fixed at the rotatable spool of the rotary distributor.
The arrangement of the flow governor in the manner of that illustrated in Fig.3 ensures that the rotational speed of the hydraulic turbine can be controlled independently of the hydraulic motor MHR. Moreover, the mentioned arrangement facilitates the conveying of the flow spent by the impact mechanism to the hydraulic turbine and permits the adjustment of the rotational speed of the hydraulic turbine and more of the impact frequency of the impact mechanism. The rotation speed of the hydraulic turbine can be maintained by means of a hydraulic accumulator mounted as illustrated in Fig.3 on the discharge line of the impact mechanism.
One simplification of the second described construction, Fig.2, is the mounting of the rotatable spool of the hydraulic distributor in a cylindrical bore made in the piston body, more precisely in the smaller piston rod. Channels are provided in the piston body and in the smaller piston rod to assure a first communication of the working chamber C2 with the internal piston cavity (the cylindrical bore) and a second communication of the internal piston cavity with the discharge line through which the fluid flow is sent to the tank.
The said simplifications allow reduction in weight and size and furthermore simplify the pumping station, reduce the rate of high pressure liquid consumed, increase the efficiency and improve the reliability of the impact mechanism.

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