A Positive Displacement Rotary Compressor/Motor With Absolutely Smooth Flow in the Inlet and Outlet Ports.

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ABSTRACT

This paper is devoted to a new positive displacement rotary compressor, a two-stage device based on this compressor, a device combined with a piston machine and to some applications of these mentioned devices. The prominent feature of all proposed solutions is perfectly smooth flow in the outlet port.

INTRODUCTION

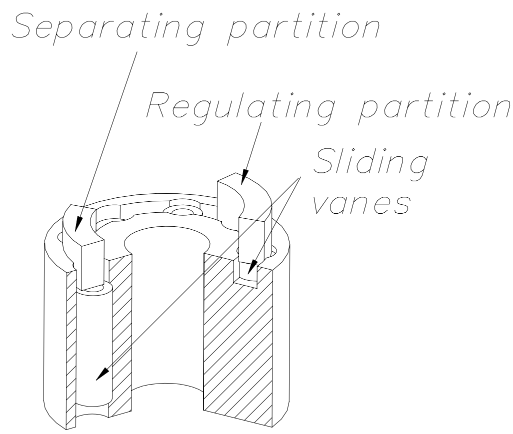
In the paper titled “A New Type of Reversible, Invertible, Variable Hydraulic Pump/Motor” the detailed description of a new positive displacement machine is given. It is known that some types of positive displacement machines are suitable for operation with both fluid and gas. For example there are screw compressors as well as screw hydraulic pumps. Also the radial piston type of piston pump corresponds with the piston compressor.

Every working fluid is compressible, both gases and liquids. Gases, obviously, are more compressible, liquids are less compressible, but every fluid changes its volume under a load of increasing pressure. This process introduces many problems in spheres both the hydraulic and pneumatic one.

The current paper is devoted to a technical solution which can be used in hydraulic pumps as well as in pneumatic compressors or even as an additional device for internal combustion engines. We will describe shortly the architecture of a core device in the first part of the current paper, in the main part we will describe the technical solution itself and we will outline some interesting applications in the conclusion.

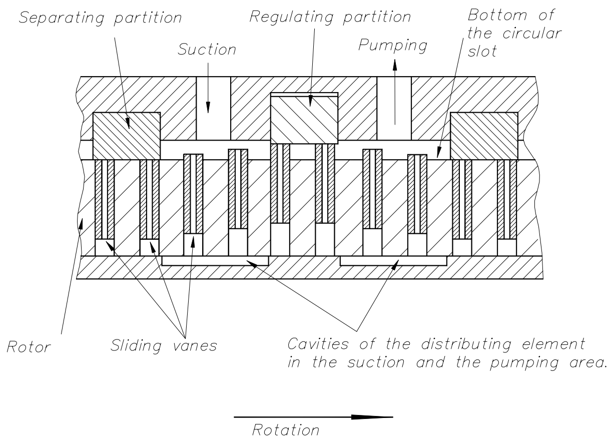
ROTARY MACHINE DESCRIPTION.

The machine presented is of a rotary type. The main part is a rotor in the shape of a barrel similar to barrel of a revolver. There are some openings along the axis, into which the sliding vanes are inserted. One end of the rotor includes a circular slot. Two partitions are installed in a housing end they operate by sliding around the circular slot. One partition, called the separating partition, slides along the bottom of the circular slot, another one called the regulating partition slides along the top ends of the sliding vanes. These partitions are shown in Picture 1.



Picture 1. The regulating and the separating partitions in the rotor.

The sliding vanes are able to move axially and they have channels to connect the opposite ends of the vanes. By means of these channels the two opposite ends of the rotor are connected as well. The sliding vanes operate by being driven towards the circular slot and back again. In the current paper we will not emphasize the technical details of the device but we will consider carefully its operation in regard to the task of smooth overall displacement. To analyze the operation of the device, refer to a radial section view of the rotor in Picture 2.



Picture 2. A radial section view of the rotor and the circular slot.

While the rotor is rotating, the sliding vanes perform an axial movement and slides out of the rotor and into the circular slot. The volume of a vane itself does not influence the volume of the fluid in the suction area. While the vane is sliding out of the rotor and into the circular slot the displaced fluid flows through the channel in the vane to the area below the vane. These areas are connected to each other by means of special cavities made in the housing. The areas under equal pressure are connected with each other. Thus, movements of the sliding vanes toward the circular slot do not produce a distortion of the volume of fluid under suction. After at least two vanes have touched the regulating partition a closed volume of fluid is transferred to the pumping area. The same situation is observed in the pumping area. While the sliding vanes are moving towards the rotor, the channels in the vanes help to compensate for the vanes' movement. As the volume of the sliding vanes does not influence the displaced volume, the volumetric displacement is perfectly smooth.

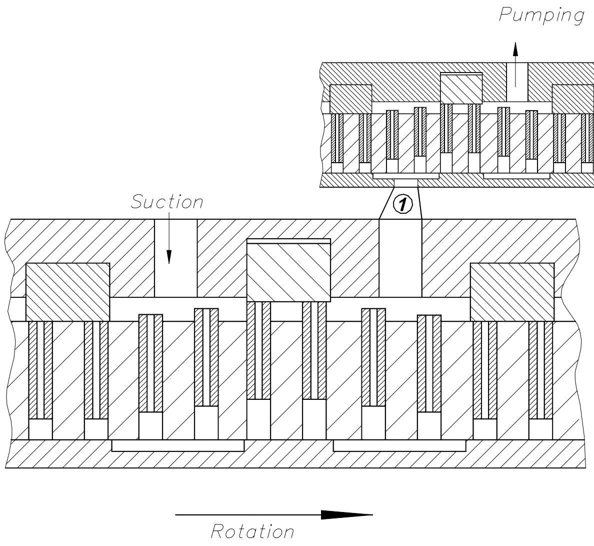
It is very important to note that the smooth volumetric displacement will be maintained the compressibility of the fluid becomes noticeable. Gases are highly compressible so this effect will be observed immediately at any pressure, liquids are not so compressible so its compressibility will be noticed under greater pressures. Anyway both fluids gases and liquids are compressible and this property worsens the operation of any fluid power pumps or compressors.

TWO STAGE DEVICE.

The causes of noise in hydraulic systems are described in [1]. We will consider the main causes shortly. The fluid portion in the transition volume, which transfers fluid from inlet to outlet port, is not pressurized. Because of compressibility factors, fluid in the outlet area is compressed and its volume is smaller than it would be at normal pressure. The fluid in the transition volume is not compressed yet. When the transition volume connects with the outlet area the compressed volume in the outlet port mixes with the uncompressed volume in the transition area. A rapid change of pressure occurs, so noise is generated. A device with absolutely smooth volumetric displacement is not able to solve this problem because of fluid compressibility, but the entire system can be built using two proposed devices. This kind of solution prevents pressure ripples in the outlet port. To consider its operation in detail, refer to the gas system shown in Picture 3. There are radial section views of a two-stage device. The first stage of the system draws a gas from the atmosphere, so the pressure in the suction portis atmospheric. The displacement of the first stage is adjusted according to the load. In the output port of the second stage the working pressure of the load can be observed. The first stage draws the gas from the suction area and transfers it to the pumping area where the pressure is equal to the working pressure. The second stage operates by transporting the gas from Area 1 to the output port. The second stage does not compress the gas, it transports the pressurized gas from Area 1 to the outlet port and does not additionally compress it. This transporting stage is necessary in order to separate pressure pulsations which occurred in Area 1 from the output pressure. As the second stage is variable, it is easy to adjust its working volume so it will not pump the gas but just transport it. An increase in the working volume of the second stage will make this device work as a usual two-stage compressor, but the main idea of smooth displacement will be eliminated.

In order to achieve a perfectly smooth displacement it is necessary to synchronize these stages. At the moment when a closed transition volume in the first stage opens to Area 1 there is a drop in pressure. It occurs because the transition volume is not compressed. The second stage has to be synchronized so that its transition volume closes when the transition volume in the first stage opens. This moment is shown in Picture 3. The second stage takes as much gas from the area 1 as is pumped there by the first stage.

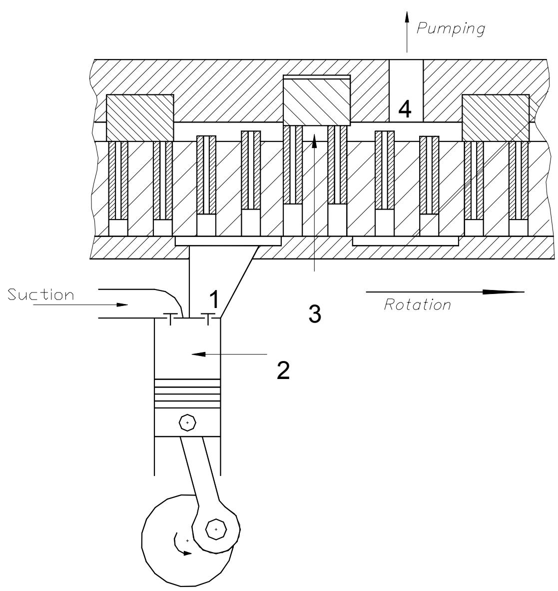
The possibility to adjust both stages allows any necessary displacement and any working pressure in the outlet port. In the overall range of the output pressure the displacement will be kept absolutely smooth. It is very important to notice that because of variability of these machines the entire system can work successfully at variable pressure.



Picture 3. A radial section view of the two-stage device.

COMBINED OPERATION WITH PISTON COMPRESSORS.

Piston compressors are widely used in modern industry. They are use in many diverse applications. Piston compressors have some advantages and disadvantages, for example they are able to achieve high pressure but they are noisier than screw compressors and they have pulsations of displacement due to their reciprocating operation.



Picture 4. A radial section view of the rotary machine and a section view of the piston machine.

A combination of a piston compressor with the proposed rotary device can eliminate any pulsation in the output. Refer to Picture 4. A piston machine will boost a rotary one. A redial section view of the rotary machine and a section view of the piston machine are shown. The delivery to Area 1 is not smooth because of reciprocal movements of the piston. Anyway, if volume 2, delivered by a boost stroke, were equal to the transition volume 3, the displacement in outlet port 4 would be absolutely smooth. While the piston machine is implementing the boost stroke a displaced gas fills volume 3. As soon as the piston machine finishes the displacement the transition volume 3 closes. Each piston's displacement is placed in a corresponding volume between two neighboring vanes. Because of smooth volumetric displacement the overall displacement of the entire system will be smooth as well. The working volume of the rotary machine must be adjusted so that the pressure in Area1 and in outlet port 4 is equal. The rotary machine is variable so it is very easy to adjust its displacement appropriately. In order to achieve the better performance, synchronization can be made so that many transition volumes from the first machine will correspond with one transition volume in the second machine.

CONCLUSION. APPLICATIONS.

COMPOUND FOR INTERNAL COMBUSTION ENGINE

The turbo compound for diesel engines have been exploited for years but have been rejected. Today, some manufacturers are working with these devices again. For example a new Scania 470 model diesel engine is equipped with a Holset HP 72 slow-speed turbocharger, which operates by extracting energy from the exhaust. It allows the recovery of approximately 10 per cent of the overall power. The use of the proposed device as a positive displacement compound may become a new development in the idea of compounding in general. One advantage is having a slower speed of thepositive displacement compound than a turbine, so it is much easier to transfer torque energy to the crankshaft. The working volume of this kind of positive displacement compound has to be adjustable in order to provide a dependence on a quantity of combusted fuel. The exhaust silencer is not necessary if this positive displacement compound is used. The total quantity of diesel engines with more than 250 hp produced for the automotive and nonautomotive sectors in 1998 in the USA with power more than 250 hp numbered approximately 284 thousand pieces. Almost all of them can be equipped with some kind of compound, either turbo or positive displacement kind.

COMPRESSOR

Another application is also widely used. Compressors operate in many fields and they are used as a source of pneumatic power as well as a source of compressed air in general. With the purpose of providing an adequate reaction to short-term changes in air consumption they use compressed air tanks. This kind of tank is not necessary if the proposed two-stage compressor is used. The proposed compressor is able to deliver air smoothly and to react as quickly as required to a change in air consumption. The proposed device is able to react to both pressure or air consumption in order to stabilize either pressure or delivery.

In 1999 there 740.430 stationary air compressors were produced in the United States to the value of about 791 million dollars. An essential part of them is referred to powerful stationary compressor stations where an application of the proposed system is very attractive.

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ADDITIONAL SOURCES

1. Russell W. Henke, "The dB(A)s of hydraulic system noise.", Diesel Progress International Edition, Vol.19, No.5, Sep-Oct 2000, pp 18-21.