AXIAL PISTON MACHINE HAVING A PILOT CONTROL DEVICE FOR DAMPING FLOW PULSATIONS AND MANUFACTURING METHOD

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Abstract

The invention relates to an axial piston machine having expellers arranged in a rotating cylinder block, and a valve plate which connects the expellers via valve openings to a port, and having a pilot control device for reducing volume flow pulsations. The pilot control device comprises at least one inertia duct which has a cross-sectional area of less than 3 mm² and extends along the valve plate in its circumferential direction over at least 45°. The valve opening is effectively connected to the expeller which opens into it by this inertia duct during a specific time period before, in the course of the rotation of the cylinder block, the expeller is connected to the port. In the process, the pressures prevailing in the expeller space and in the port are equalized under the control of the inertia of the oil column which is located in the inertia duct.
The measure of providing pilot control pistons can extend over only a few angular degrees because the cross section has to be widened drastically after this if it is desired to avoid significant throttling of the kinematic volume flow. In fact, in this way it is also only possible to achieve an optimum for a narrow combination of the delivery volume, rotational speed and pressure operating parameters. If the hydrostatic piston machine is also to be operated with other parameters, which is usual, it is necessary to find a compromise with the notches which satisfies all the relevant operating states to the same extent and is far from the possible optimum.

It has also already been proposed that the compression process should be brought about by the expeller piston itself, i.e. the expeller space is only connected to the high pressure after a delay where a non-delivery angle has been passed through. This concept can also be implemented satisfactorily only for one operating point. The necessary non-delivery angle can vary in a range from 1° to 25° depending on the operating parameters. For this reason, the application of this principle in the majority of operating points either entails incomplete compression or external pressure peaks in the expeller space. Such pressure peaks can be eliminated by installing a non-return valve, which connects the expeller to the high pressure in the region of the non-delivery angle and clears the expeller space as soon as the pressure there is higher than at the port. Owing to the extreme loading of the non-return valve and in view of extreme pressure peaks when the delivery volumes are large, this solution has hardly ever been applied in practice. A further disadvantage of this principle is that it cannot be applied to units which also operate at least temporarily in the motor mode because the non-return valve would then not open, with the result that the expeller space could only be filled after a delay, and could not be filled completely.

DE 197 06 114 Al proposes a precompression volume. In this context, an accumulator is provided which opens into the valve plate via a connecting duct in the region between the control kidneys, and equalizes the pressure prevailing in the expeller to the pressure prevailing on the outlet side. The accumulator element is filled here in the time period in which the expeller space is connected to the high-pressure kidney via the block kidney and the connecting duct.

Such a precompression volume is also proposed in DE 42 29 544 Al. In the precompression phase, an additional compression volume is quickly released from a chamber into the respective expeller, and said volume is subsequently allowed to pass back into the chamber from the high-pressure side more slowly over a relatively long period of time. This can considerably reduce the pulsation and is basically suitable for achieving the objective of briefly reducing pressure in the expeller space. However, in this way, the expeller space can not entirely be brought to the same pressure as that in the high-pressure kidney. It is also disadvantageous that the pilot control notch can no longer be optimized to the objective of a gentle increase in pressure. Instead, it must be made larger in order to return the precompression volume to the pressurized state before the next expeller space is connected to it. As a result, the excitation of the swashplate support by force becomes
stronger. This results in a conflict of objectives such that improvement in the volume flow pulsation entail worsening of the excitation by force.

[0011] The object of the invention is therefore to make available an axial piston machine with improved pilot control.

SUMMARY OF THE INVENTION

[0012] For this purpose, the invention provides at least one inertia duct which has a cross-sectional area of less than 3 mm and a length of at least one eighth of the circumference of the reference circle, i.e. the inertia duct extends over at least 45° if it is guided along the valve plate in its circumferential direction. In the process, the inertia duct connects the valve opening to the expeller which opens into it during a specific time period before, in the course of the rotation of the cylinder block, the expeller is connected to the port so that the pressures prevailing in the expeller space and in the port are equalized under the control of the inertia of the oil column which is located in the duct.

[0013] A limitation of the maximum compression volume flow by including the inertia of an oil column which is located in a correspondingly dimensioned duct is therefore proposed. When pilot control notches are used, the maximum compression volume flow occurs at the moment at which the expeller space is connected to the high-pressure port. At this moment, the pressure difference is at its maximum value. In the pilot control notch, there may instantaneously be a very large compression volume flow because, for various reasons, for example reasons of fabrication, the pilot control notch cannot be made as fine as would be necessary for a gentle increase in pressure. This results not only in the dip in the pressure line which was mentioned at the beginning but also in an extreme acceleration of the oil particles in the zone in question. This gives rise to premature wear as a result of cavitation and erosion as well as to increased emission of noise.

[0014] If, on the other hand, the connection of the expeller space to the high-pressure kidney is firstly implemented via a long thin line, the maximum compression volume flow cannot flow immediately, despite a maximum pressure difference, because at first the oil column which is present in the line has to be accelerated. However, this process takes a certain amount of time so that the compression volume flow does not reach its maximum value until after this. However, owing to the oil which has already flowed in the acceleration phase, a counter-pressure has built up so that the first critical moment has been overcome. The rate of change in pressure therefore evens out significantly and is also no longer so highly dependent on the pressure in the high-pressure kidney. The actual connection to the high-pressure kidney does not occur until after this pilot control phase, in the course of the rotation of the cylinder block.

[0015] Since the expeller space is not sealed hermetically, it would also be possible, under certain operating parameters, for a certain excess increase in pressure to be tolerated in the expeller space. This would accelerate the oil column in the opposite direction, and thus counteract the excess increase in pressure.

[0016] Further advantageous refinements of the axial piston machine according to the invention are given in the subclaims. As a result, the time period in which the oil column present in the inertia duct is active for pressure equalization purposes can be determined by means of a further expeller which opens into or closes the valve opening and which is occluded in the connection path from the expeller to the valve opening via the inertia duct. In this way, the angle over which the inertia duct is effective can be shortened. In addition, in this way the pressure in the expeller space can be reduced at the transition to the low-pressure side before the actual connection is brought about.

[0017] It is also advantageous if a plurality of inertia ducts, which are optimized for respectively different rotational speed ranges, are provided for the pilot control process.

[0018] According to the invention, one or more inertia ducts are provided respectively both for the high-pressure side and for the low-pressure side, said inertia ducts being configured in the same way if the units are to be used in a closed circuit in which the high-pressure side can change. If, for example in the case of pumps for the open circuit, the high-pressure side does not change, the inertia ducts can be used to optimize the pressure change process both on the high-pressure side and on the low-pressure side, in each case independently; this usually means an asymmetrical arrangement with ducts which are configured differently on the two sides.

[0019] Inertia ducts can be particularly advantageously combined with pilot control notches. Their disadvantage that the maximum volume flow occurs with the starting of the pilot control, is largely eliminated. However, the function and the possibilities for influencing the properties of the drive unit are completely retained as a result of the shaping of the pilot control notches.

[0020] The invention also relates to a method for manufacturing inertia ducts in an axial piston machine of the type described.

[0021] Inertia ducts can preferably be implemented by virtue of the fact that they are formed as grooves, by a cutting or casting process, in the rear face of the valve plate or in the support face of the valve plate in the end casing, the valve plate and the support face subsequently being connected to one another in order to form pressure-proof ducts.

[0022] The ducts can advantageously also be formed as grooves in the radial outer face of the valve plate, the outer face being subsequently sealed by applying, in particular by shrink-fitting, a tubular or annular component, in order to form pressure-proof ducts.

[0023] Finally, the inertia ducts can also be implemented as high-strength wires in a cast part, the wires being pulled out from the cast part after hardening.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Further features and advantages of the invention will now be described by means of the drawings, in which:

[0025] FIG. 1: shows a valve plate in a plan view of the surface facing the cylinder block;

[0026] FIG. 2: shows the valve plate with contiguous bores of the cylinder block (block kidneys) in two positions which limit the effective angle of the inertia duct;
FIG. 3: shows the valve plate with contiguous bores of the cylinder block with limiting of the effective angle by inclusion of a further, closing expeller; and

FIG. 4 shows a valve plate with a plurality of inertia ducts for reducing the dependence on the rotational speed.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows the basic configuration of the valve plate 1 of an axial piston machine according to the invention in a plan view of the contact surface facing the cylinder block. From a point in the region of the dead centre points of the valve plate 1, inertia ducts 2 are positioned with respect to the kidney 3 which respectively follows in the direction of rotation of the cylinder block. The length of the lines and their diameter determine the inertia of the oil column which is occluded therein. In the symmetrical arrangement shown, the valve plate 1 can be used for units in the closed circle in which the high-pressure side can change. If, as for example in the case of pumps for the open circuit, the high-pressure side does not change, it is possibly sufficient to provide only the inertia duct 2a from the inner dead centre to the following high-pressure kidney 3a. On the low-pressure side, the inertia ducts 2b can then be omitted entirely with respect to the corresponding kidney 3b or can also be used to optimize the pressure-changing process from high pressure to low pressure. In this case, the geometric dimensions of the ducts will then be different on the two sides.

The method of the inertia ducts can advantageously be combined with the pilot control notches which are shown per se and which are illustrated schematically in FIG. 1 at the ends of the valve openings 3a, 3b.

FIG. 2 illustrates the interaction between the valve plate and the openings of the expellers in the cylinder block. The time period of the pressure change, i.e. the time over which the inertia duct is effective, is determined by the angular range in which the expeller space is connected to the inertia duct. The angular range results from the size of the block kidney which connects the expeller space to the valve opening. In the position of the block kidney 4 shown in FIG. 2a, this actual connection starts to become effective via the inertia duct when the expeller space is 15.7° before the internal dead centre. In the position illustrated in FIG. 2b, i.e. 16.2° after the internal dead centre, the connection via the inertia duct ends. Up to then, the pilot control notch and the valve opening have themselves also already become effective.

If, in order to optimize the pressure-change process, it is necessary to limit the effect of the inertia duct to a relatively small angle, this can be done by means of an arrangement according to FIG. 3. Here, although the connection between the inertia duct and block kidney 4 of the changing-over expeller space remains essentially unchanged, the inertia duct is, as it were, connected to the high pressure only after a delay, specifically by the block kidney 5 of an expeller space which is leaving the high-pressure kidney. In the example illustrated in FIG. 3a, this takes place when the expeller space which is associated with the block kidney 4 has arrived at 9.6° before the internal dead centre. In the situation shown in FIG. 3b, the connection between the block kidney 4 and the inertia duct ends 8.1° after the internal dead centre. The angular range which is effective overall is, at 17.7°, only still about half as large as in the arrangement according to FIG. 2.

A further advantage of this arrangement is shown in FIG. 3c, which shows the block kidneys several degrees in angle later. The block kidney 5 is still always connected to the inertia duct, but now via the block kidney 6 to the low-pressure side. As a result, the pressure in the expeller space which is associated with the block kidney 5 is reduced before it is connected to the low pressure in the usual way.

The volume of oil which is necessary for precompression of the expeller space increases linearly with the pressure difference. A change-over method should follow this linear relationship as far as possible, but on the other hand a satisfactory result can be obtained only for a narrow variation range of the pressure. When pilot control notches are used, the volume flow increases only with the square root of the pressure. In contrast, in the case of the precompression which is controlled by inertia, the quantity which is transmitted per time unit is primarily directly proportional to the pressure difference. Friction losses which increase over-proportionally have a significant effect only at very high flow rates. Therefore, the inertia-controlled precompression which is proposed here has a considerably smaller pressure-dependence than the known pilot control notches.

With the development of the proposed principle which is illustrated in FIG. 4 it is also possible to reduce greatly the dependence of the precompression effect on the rotational speed. For this purpose, a plurality of inertia ducts 7, 8, 9 with different hydraulic inductance, i.e. different inertia of the occluded oil column, are provided. The duct 7 with the highest inductance is firstly connected to the opening expeller in the direction of rotation, 100 before the dead centre in the example shown. Its inductance is set such that the increase in pressure does not take place until approximately 10° later at a rotational speed of 1000 min⁻¹. At higher rotational speeds, a correspondingly larger angle is passed through at the same time so that this duct 7 then remains largely ineffective.

The next duct 8 is not connected to the expeller space until 5° before the dead centre. Its inertia is set such that the increase in pressure already takes place after approximately 5° at medium rotational speeds. At even higher rotational speeds, this duct 8 is also virtually ineffective, and at low rotational speeds it contributes to the increase in pressure, but remains comparatively small because this duct begins to have an effect too late. This can be continued with a third duct 9, and possibly with further ducts which have an effect only at correspondingly higher rotational speeds owing to the further reduced inertia and because of the even later connection to the expeller space.

The effect of the inertia duct results from the inertia of the occluded oil column and the angular range or the time period in which the duct forms the effective connection between the high-pressure kidney and the opening expeller space. The characteristic variable which characterizes the inertia is the hydraulic inductance. It is proportional to the quotient formed between the length and cross-sectional face of the duct. For a plurality of reasons, the cross-sectional face can be varied only in a very small range here.

Firstly, even when careful maintenance is carried out and great care is taken, it is never possible to completely
prevent small particles being flushed out by the hydraulic system. In order to prevent functional impairments as a result of blocked orifices and pores, the diameter in the smallest flow cross section must therefore be at least approximately 0.5 mm to 0.7 mm. For long ducts, it is better to make this value higher in order to reliably avoid particles which have entered being flushed out.

[0039] Secondly, the oil column which is occluded in the duct is capable of oscillating. For this reason, for satisfactory functioning it is necessary to provide appropriate damping. This can be done by means of a shut-off orifice, which however signifies additional fabrication work. It is simpler to bring about damping by means of side wall friction within the inertia duct. This means that the cross section of the duct cannot be made as large as desired.

[0040] Thirdly, it is necessary to bear in mind the fact that the hydraulic resistance of a pipeline, and thus the aforementioned damping effect, are proportional to the length, but to the fourth power of the reciprocal value of the diameter. In order to keep the influence of fabrication tolerances small here, the diameter within the permitted range must be selected as large as possible.

[0041] In order to achieve a predefined inductance, only a very small room for play for the variation of the length and diameter of the inertia duct are available owing to these peripheral conditions. Calculations on a 75 ccm drive unit have shown that an appreciable effect can be achieved starting from a length of the inertia duct of approximately 30 mm. Given the respective diameter of the reference circle of 80 mm for this drive unit, this means that the duct has to extend at least 45° in the circumferential direction of the valve plate. With other overall sizes, the diameter of the reference circle changes, but at the same time the typical rotational speed range also changes so that the 45° criterion continues to apply approximately. The desired damping effect can be achieved only if the diameter of the duct is less than 2 mm or the cross-sectional area is less than 3 mm².

What is claimed is:

1. Axial piston machine having expellers arranged in a rotating cylinder block, and a valve plate which alternately connects the expellers via valve openings to, in each case, one of two ports, and having a pilot control device for reducing volume flow pulsations, characterized in that the pilot control device comprises at least one inertia duct which has a cross-sectional area of less than 3 mm² and a length of at least one eighth of the circumference of the reference circle, the valve opening being effectively connected to the expeller which opens into it by the inertia duct during a specific time period before, in the course of the rotation of the cyylinder block, the expeller is connected to the port, and the pressures prevailing in the expeller space and in the port being equalized under the control of the inertia of the oil column which is located in the inertia duct.

2. Axial piston machine according to claim 1, characterized in that the specific time period in which the inertia duct contributes to the increase or decrease in pressure in the opening expeller is determined by the fact that a further opening or closing expeller is occluded in the connection path from the inertia duct to the valve opening.

3. Axial piston machine according to claim 1, characterized in that a plurality of inertia ducts are provided which are optimized for respectively different rotational speed ranges.

4. Axial piston machine according to one of claims 1 to 3, characterized in that one or more inertia ducts are provided both for the high-pressure side and for the low-pressure side.

5. Axial piston machine according to claim 4, characterized in that the inertia ducts for the high-pressure side and for the low-pressure side are configured in the same way.

6. Axial piston machine according to claim 4, characterized in that the inertia ducts for the high-pressure side and for the low-pressure side are configured in different ways.

7. Axial piston machine according to claim 1, characterized in that one or more inertia ducts are provided in combination with pilot control notches.

8. Method for manufacturing inertia ducts in an axial piston machine according to claim 1, characterized in that the inertia ducts are formed as grooves, by a cutting or casting process, in the rear face of the valve plate or in the support face of the valve plate in the end casing, the valve plate and the support face subsequently being connected to one another in order to form pressure-proof ducts.

9. Method for manufacturing inertia ducts in an axial piston machine according to claim 1, characterized in that the inertia ducts are formed as grooves in the radial outer face of the valve plate, and the outer face is subsequently sealed by applying, in particular by shrink-fitting, a tubular or annular component in order to form pressure-tight ducts.

10. Method for manufacturing inertia ducts in an axial piston machine according to claim 1, characterized in that the inertia ducts are implemented as high-strength wires in a cast part, and the wires are pulled out from the cast part after hardening.