HYDROSTATIC FLOW-AMPLIFIER

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ABSTRACT
The amplifier has a poppet valve enclosing a high pressure area, an intermediate pressure area connected to a reference pressure by another valve, and a load pressure area, and with a throttling disc as the poppet. The disc cooperates with a control seat and a load seat. A servo loop is formed by the other valve, the high and intermediate pressure areas, the disc, and the gap between the control seat and the disc. In one embodiment, bellows seals so divide up the pressure areas that the position of the disc is independent of the load pressure.

13 Claims, 16 Drawing Figures
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HYDROSTATIC FLOW-AMPLIFIER

BACKGROUND OF THE INVENTION

The invention relates to a hydrostatic flow-amplifier that has a poppet valve as the throttling means. Servo-valves enable a virtually inertia-less control of power in analog hydraulic control systems. The amplification is undertaken by a spool valve in a known manner. The position of the spool valve is determined by a low pressure acting on the end piston of the valve. The low-pressure level is controlled by an electrically, mechanically, or hydraulically pneumatically actuated throttling of the high pressure. The throttling arrangement and the spool-valve amplifier, however, are both very delicate and difficult to manufacture. In operation, both require a very thoroughly filtered working medium.

SUMMARY OF THE INVENTION

An object of the invention is to replace the spool-valve amplifier and the arrangement for controlling the low-pressure level by simpler components. This object and others will be apparent from the following detailed description of several embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described, with reference to the Figures of the accompanying drawings, wherein:

FIGS. 1 and 2 are schematic sectional views through a plane hydrostatic flow-amplifier;

FIG. 3 is a view in cross section showing the parameters of the servo loop;

FIG. 4 is a functional diagram of the servo loop;

FIG. 5 shows the corresponding equivalent system using conventional components;

FIG. 6 is a schematic view in cross section of another embodiment of the invention;

FIG. 6a shows the corresponding equivalent system using conventional components;

FIG. 7 is a schematic view in cross section of a hydrostatic flow-amplifier with an adjustable control seat;

FIG. 7a shows the corresponding equivalent system using conventional components;

FIG. 8 is a schematic view in cross section of a hydrostatic flow-amplifier arranged as the balanced throttle of a sealed load loop;

FIG. 8a shows the corresponding equivalent system using conventional components;

FIG. 9 is a schematic view in cross section of a hydrostatic flow-amplifier arranged as the balanced throttle of three sealed load loops; and

FIG. 9a shows the corresponding equivalent system using conventional components;

FIG. 10 is a cross sectional view of an embodiment combining the amplifiers shown in FIGS. 6 and 8, and having a viscothermic throttle.

FIG. 11 is a vertical sectional view of a screw valve.

FIG. 12 is a vertical sectional view of an electromagnetically operated flapper valve.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to the Figures, FIG. 1 shows a supply pressure line 1, which opens through a seat member 2 into a high pressure area 3 of the amplifier. A throttling disc 4, acting as the poppet of a poppet valve and which is movable at right angles to the stationary, lower seat member 2, forms throttling gaps 5 and 6, the gap 5 separating the high pressure area 3 from an intermediate pressure area 7 and the gap 6 separating the high pressure area 3 from a load pressure area 8. The throttling disc 4 is enclosed by a housing 9. As required, suitable throttling devices can be screwed into this housing, such as a screw valve 10 or an electromagnetically operated flapper valve 11, as shown in FIGS. 11, 12, respectively, to connect the intermediate area with a reference pressure. FIG. 2 is a cross sectional view through the throttling gaps 5 and 6 at right angles to the direction of movement of the throttling disc 4. High pressure delivery branches 12, fed from the line 1, and the mouth 13 of a load pressure line are visible in FIG. 2. The branches 12 are also visible in FIG. 1, but are not referenced. Grooves in the stationary seat member 2 form the continuous high pressure area 3 and the load pressure area 8, these two areas being separated by a labyrinthine load seat 14. The entire space is enclosed by the housing 9, which has rail-like projections 15 that guide the throttling disc in its movements. As in a hydrostatic seal, the position of the throttling disc 4 — in other words, the width of the control throttling gap — is determined by a controllable device, such as the flapper valve 11. Since, in accordance with the invention, the load throttling gap width at 6 changes with the control throttling gap width 5, a change of the flapper valve 11 results in a gap-separating change in the load flow, caused by movement of the throttling disc 4. If the hydraulic resistance of the control throttling gap 5 is a multiple of that of the load throttling gap 6, the poppet valve (of which the throttling disc 4 is the poppet) acts like a hydrostatic flow-amplifier; and the high pressure area 3, the control throttling gap 5, the throttling disc 4, and the intermediate pressure area 7 form a servo loop, which will be explained with reference to FIGS. 3 and 4.

In FIG. 3 h denotes the gap width, which, if the underside of the throttling disc 4 is flat, is common to the load seat and the control seat, the latter being performed by that part of the seating 22 which forms the disc 4, the gap 5. The intermediate pressure p2 existing above the throttling disc exerts on the latter a force Fw, whereas the high pressure p and the load pressure p2 acting on the under surface of the throttling disc produce a force Fp opposing the force Fw; if these two forces are equal, the throttling disc is in a stable rest position. The servo loop corresponding to this system is shown in FIG. 4. Since the controlled member G1 is in the same way dependent on the setting of the valve (10 or 11) as is the control feedback G2, the output k is a function of d; which is the desired effect. The equivalent system, illustrated in FIG. 5, consists of conventional hydraulic elements that would act in a way similar to that of the flow-amplifier. The control throttling gap 5 is represented by an adjustable throttle 5' and the load throttling gap 6 by an adjustable throttle 6', these two throttles being operated by a differential jack 4' that corresponds to the throttling disc 4. The differential jack is analogously acted upon by all of the pressures that occur in the amplifier.

The supply pressure line, in agreement with FIG. 1, is again denoted by the reference numeral 1 and the load pressure line by the numeral 13, in agreement with
FIG. 2. The line leading from the load pressure line 13 to the differential jack 4" represents, in accordance with FIG. 3, the load pressure acting directly on the throttling disc.

The geometry shown in FIGS. 1 and 2 ensures between the control flow and the load flow a ratio of 100 that is virtually independent of the high pressure and the viscosity. Higher amplifications can be obtained by changing the geometry.

The purposes of the embodiments of the hydrostatic flow amplifier that will be described is to make the amplifier more adjustable to different demands, particularly to radically changed operating conditions in the servo loop and in the load loop. Each of the FIGS. 6a, 7a, 8a and 9a also contains the equivalent system, which reproduces with conventional components the function of the corresponding amplifier.

The arrangement shown in FIG. 6 is similar to the embodiment illustrated in FIG. 1, corresponding parts being denoted by the same reference numerals.

The supply pressure line 1 opens through the lower seat member 2 into the high pressure area 3. The throttling disc 4, which is movable at right angles to the stationary seat member 2, determines the control throttling gap 5 and the load throttling gap 6. The control, or intermediate, pressure area is denoted by the numeral 7 and the load pressure area by the numeral 8. The throttling disc 4 is enclosed in the housing 9. A threaded opening 17 enables a suitable valve to be screwed into the housing 9, as required. The mouth of the high pressure line is denoted by the numeral 12 and that of the load pressure line by numeral 13. In the embodiment shown in FIG. 6, however, a wall forming the control throttling seat 19 is located radially within a wall forming the load throttling seat 14, which makes it necessary to separate the load pressure area 8 from the control pressure area 7 by an elastic, deformable sealing means constructed as a bellows 16. The servo loop resistance, owing to the shortest possible sealing length, is automatically a multiple of the load loop resistance, which enables a substantially simpler construction of the labyrinthine wall that increases the length of the seal. Even an annular load throttling seat 14 gives good amplification.

The equivalent system for this embodiment is made up of conventional components that would act in a way similar to the amplifier. The control throttling gap 5 is represented by an adjustable throttle 5' and the load throttling gap 6 by an adjustable throttle 6', these two throttles being operated by a differential jack 4'.

The electronic equivalent of this system is the bipolar transistor, the opening 17 corresponding to the base, the load pressure line mouth 13 to the emitter, and the feed line 1 to the collector.

The embodiment shown in FIG. 7 is similar to that shown in FIG. 6, although the control throttling gap 5 can be varied by shifting the control throttling seat 19 with a screw 20. This enables a part of the control flow to be withdrawn from the throttling action of the throttling disc 4. This means that the load flow falls below a certain value. Consequently, by interposition of the amplifier, a control member that does not completely shut off, such as a flapper valve, can completely close off a load loop at the quiescent flow.

This supplementary control is represented in the equivalent system by a throttle 5" shunted across the controlled throttle 5'. The setting of the throttle 5" is controlled externally, such as by a screw 20.

The arrangement shown in FIG. 8 corresponds generally to the fundamental embodiment illustrated in FIG. 6, but additional elastic seals, in the form of bellows, so divide up the pressure areas that the position of the throttling disc is made independent of the load pressure. The upper face of the throttling disc 4 is subject to the control pressure, and the lower face of the disc is divided by bellows seals 23 and 24 into two areas: the previously described high pressure area 3 and an area 25 that is kept pressure-free by a vent 21. Consequently, the control pressure works only against the supply pressure, and the servo loop is completely sealed from the load loop. To prevent any force from acting on the throttling disc in the load loop, the load pressure in the space 26, which pressure must be throttled, is led by a passage 27 to a compensating space 28, which exists between the bellows 16 and 22. Some fluid other than that in the servo loop can be controlled in the load loop between the lines 1a and 13a. If the load loop is removed, the arrangement can be used as a very low output impedance pressure divider, since the feed pressure of line 1 is divided only as a function of the pressure acting on the throttling disc at the opening 17.

The servo loop divides the load pressure by a constant ratio independent of the control flow.

The equivalent system clearly shows how the throttling disc is made insensitive to the load pressure by eliminating feedback of the load pressure to the differential jack 4', and by completely separating the servo and load loops by means of separate lines 1 and 17, on the one hand, and 1a and 13a, on the other.

The arrangement illustrated in FIG. 9 is based upon that illustrated in FIG. 8, and shows a plurality of load loops controlled by a single servo loop. To this end, a plurality of bellows seals and a plurality of lines 1a, 1b, and 1c and 13a, 13b, and 13c are provided. In order to prevent the load loops from reacting on the throttling disc, all pressures acting on one face of the disc must be compensated for on the opposite face.

In the equivalent system, the three load loops are controlled by the valves 6a', 6b', and 6c'.

FIG. 10 illustrates the series connection of an amplifier of the kind shown in FIG. 6 with a load amplifier insensitive amplifier of the kind shown in FIG. 8. The series connection enables the use of a viscomerthermic throttle as an electrohydraulic interface, since the unusually small oil flow, which can be viscothermally influenced, is sufficiently increased by two series-connected flow amplifiers. The upper amplifier has an O-ring seal 16A, and the lower amplifier is provided with clamped seals 16B, 22B, 23B, and 24B.

Parts which in FIG. 10 and in FIGS. 1 to 9 play the same role are denoted by the same reference characters, except for the addition of an A or B. The upper amplifier, having the viscothermic throttle as its control element, is amplifier A, and the lower amplifier, having amplifier A as its control member, is amplifier B. The manner of opened of the two series-connected amplifiers is not different from that of the individual members. It should be observed that the supply pressure of amplifier A is the same as the intermediate pressure of amplifier B. The consequence of this is that the supply pressure line 1A of amplifier A and the opening 17B of amplifier B are one and the same, and that the lower seat member 2A of amplifier A is identical with the
housing 9B of amplifier B. The vent for the pressure-free area 25B, the control flow of the viscothermic throttle, and the load flow of amplifier A are returned to the tank (not shown) by a collecting line 34. The effective load connection is the load pressure line 13aB of amplifier B.

The throttling at the opening 17A is ensured by a viscothermic throttle consisting of an electrically heated resistance wire 29, which is held coaxially in a bore of a throttle body 30 by the housing 9A and a terminal holder 32. The whole is held in a recess of the housing 9A by a setscrew 33, which is electrically isolated from the terminal holder 32 by an insulating plate 31. The control flow, which is regulated by changing the hydraulic resistance of the bore in the body 30 by varying the viscosity of the flow, by electrical heating is extremely small. The flow is accordingly increased by the amplifiers A and B.

Although the preferred embodiments of the invention have been described, the scope of, and the breadth of protection afforded to, the invention are limited solely by the appended claims.

1. A hydrostatic flow-amplifier with a poppet valve as the throttling means comprising housing means defining a space; a throttling disc forming the poppet of said valve; said disc being received in said space and being recircular therein, said disc defining with said housing a first pressure area, a second pressure area, and a third pressure area, first intake means communicating with said first pressure area; outlet means communicating with said second pressure area, second intake means communicating with said third pressure area; a first seat for said disc formed in said housing, said seat separating said first and third pressure areas; a second seat for said disc formed in said housing, said second seat including an annular surface concentric with said first seat and separating said first and second pressure areas, said first and second seats confronting the same side of said disc, control means for establishing effective positions of displacement of said disc simultaneously with respect to said first and second seats, said control means including a source of fluid at adjustable reference pressure, passage means connecting said source and said second intake means of said third pressure area, adjustable valve means disposed intermediate said source and said third pressure area, first pressure area is a high pressure area, said second pressure area is a load pressure area said third pressure area is an intermediate pressure area, and wherein said first seat is a control seat, said second seat is a load seat, said control seat defining with said disc a control throttling gap and said load seat defining with said disc a load throttling gap.

2. The hydrostatic flow-amplifier as defined in claim 1, wherein the hydraulic resistance of the control throttling gap is greater than that of the load throttling gap.

3. The hydrostatic flow-amplifier as defined in claim 1, wherein said load seat is labyrinthine.

4. The hydrostatic flow-amplifier as defined in claim 1, wherein said high pressure area, the control throttling gap, said throttling disc, said intermediate pressure area, and said valve means form a servo loop, and further including at least one load loop comprising the load throttling gap, and one or more elastic seals on at least one side of said throttling disc for dividing up the pressure in said poppet valve to obtain suitable input and output impedances, and wherein said load and control seats are staggered.

5. The hydrostatic flow-amplifier as defined in claim 4, wherein said load seat defines a radius and said control seat is radially positioned within said load seat, and at least one said elastic seal separates said intermediate pressure area from said load pressure area.

6. The hydrostatic flow-amplifier as defined in claim 4, including means (20) for mounting said control seat to be movable to vary the control throttling gap so as to remove part of the control flow from the throttling action of said throttling disc.

7. The hydrostatic flow-amplifier as defined in claim 4, including a plurality of said elastic seals (16, 28) for so dividing up the pressure within said poppet valve so as to make the position of said throttling disc independent of the pressure in said load loop.

8. The hydrostatic flow-amplifier as defined in claim 4, including means for delivering supply pressure, and wherein said servo loop divides the supply pressure by a constant ratio independent of the control flow, for use of said servo loop as a pressure divider with low output impedance.

9. The hydrostatic flow-amplifier as defined in claim 4, wherein said elastic seals seal said servo loop from said load loop to permit use of different fluids in the different loops.

10. The hydrostatic flow-amplifier as defined in claim 4, including a plurality of said elastic seals on each side of said throttling disc for enabling the said servo loop to control a plurality of said load loops.

11. The hydrostatic flow-amplifier as defined in claim 4, wherein said valve means is a viscothermic throttle, and including an electric resistance wire arranged coaxially in the opening of said valve means for electrically heating the fluid of the control flow to change its viscosity in order to regulate the hydraulic resistance of said throttle.

12. The hydrostatic flow-amplifier as defined in claim 11, and further including a second hydrostatic flow-amplifier connected in series.

13. A hydrostatic flow-amplifier with a poppet valve as the throttling means comprising housing means formed with an axially extending cylinder; a throttling disc forming the poppet of said valve, said disc being received in said cylinder and axially reciprocable therein, said disc including an axial bore and defining with said housing a first pressure area, a second pressure area, and a third pressure area, intake means communicating with said first pressure area and defining a first force-transmitting path; outlet means communicating with said second pressure area and defining a second force-transmitting path; intake means communicating with said third pressure area and defining a third force-transmitting path; a first seat for said disc formed in said housing coaxial with said axial bore of said disc, said seat separating said first and said third pressure area; a second seat for said disc formed in said housing, said second seat including an annular surface concentric with said first seat and separating said first and second pressure areas, said first and said second seat confronting the same side of said disc, control means for establishing effective portions of displacement of said disc simultaneously with respect to said first and second seats, said control means including a source of fluid at adjustable reference pressure, passage means connecting said source and said intake means of said third pressure area, and adjustable valve means disposed intermediate said source and said third pressure area.

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