SHEAR MODULATED FLUID AMPLIFIER

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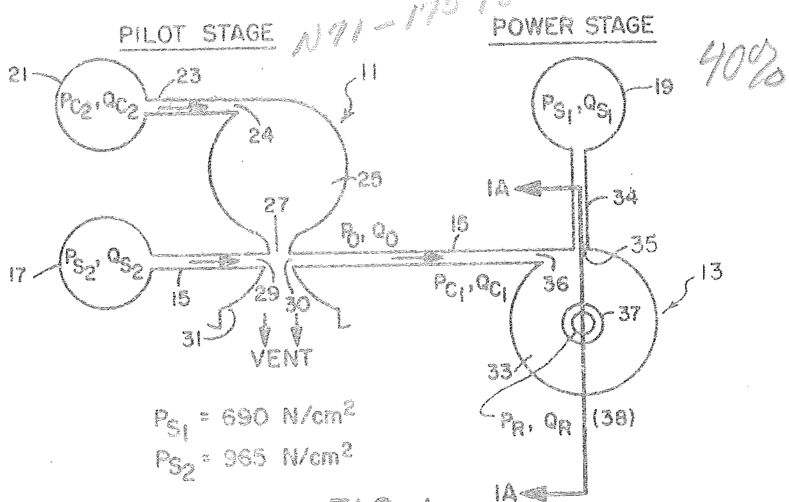

FIG. 1

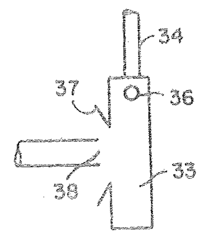

FIG. 1A

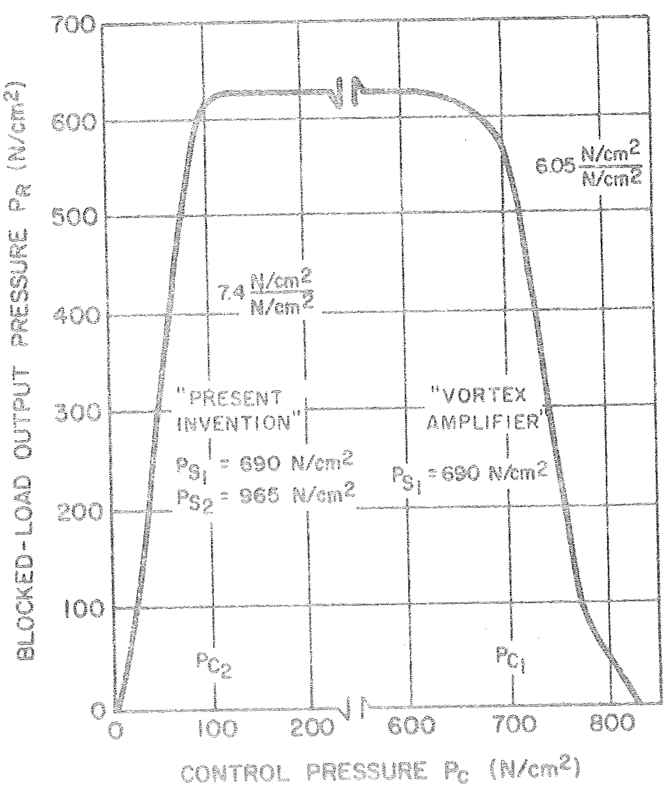

FIG. 2

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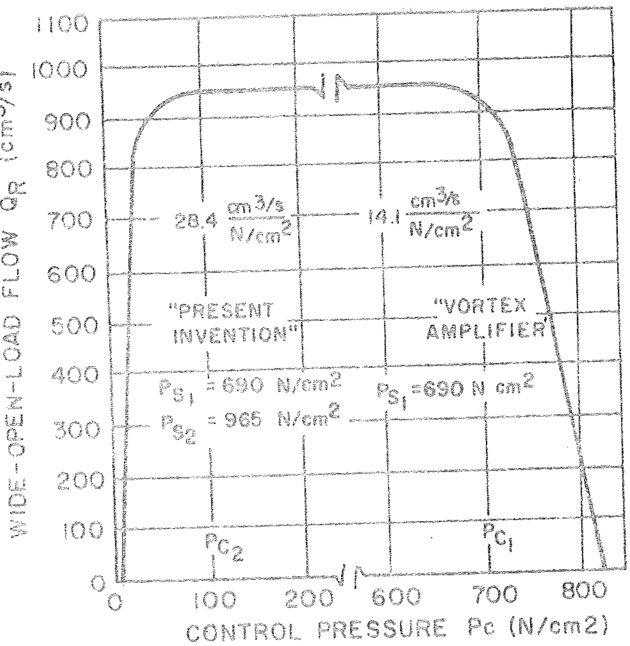

FIG. 3

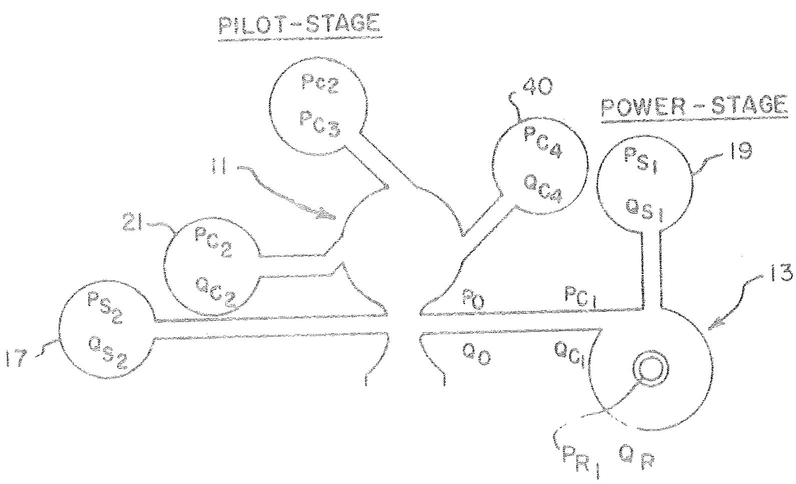

FIG. 4

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SHEAR MODULATED FLUID AMPLIFIER

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U.S. Cl. 137—81.5 4 Claims

ABSTRACT OF THE DISCLOSURE

A fluidic high pressure hydraulic amplifier composed of a fluidic vortex amplifier as a power stage and a vortex-shear modulator as a pilot stage. The vortex amplifier's control stream input is modulated by the vortex-shear modulator which has an input of much lower pressure. The modulation is accomplished by the shearing or deflecting effect of the vortex-shear-modulator on the supply jet within the venting gap between a power nozzle and a jet receiver. The low pressure input of the vortex-shear-modulator thereby controls the larger pressure of the hydraulic control stream of the vortex amplifier which in turn controls the final hydraulic output of the vortex amplifier from zero to a given high pressure. The initial low pressure input may be hydraulic or pneumatic and it may be single or multiple.

BACKGROUND OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.C. 2457).

The invention relates to fluidic amplifiers of the hydraulic vortex amplifier type and has particular relation to modulation of the control stream of a high pressure vortex amplifier by a vortex-shear modulator.

Previously, mechanical servovalves, subject to contamination and requiring mechanical moving parts with close tolerances, were used as mechanical switches in hydraulic control circuits. These mechanical servovalves can be replaced by fluidic vortex bridges or devices utilizing vortex amplifiers. These vortex amplifiers have no moving mechanical parts and are less effected by contamination.

Vortex amplifiers usually consist of a closed cylindrical interaction chamber into which is introduced an annular centripetal, radially directed supply stream which is deflected into spiral flow by a tangentially injected control input. The annular flow is axially discharged from the interaction chamber. To completely shut off the flow of a vortex amplifier, the control pressure is increased until it is substantially higher than the supply pressure. Also, the control pressure range, i.e., at full turndown versus wide open flow, is of the order of 20 percent of the supply pressure. The output flow is further characterized by strong pressure fluctuations of defined frequency. These high control pressure requirements and output pressure fluctuations make a fluidic vortex servovale impractical in most instances.

When large flows are involved as against high pressure, e.g., of rocket propellants from ground to vehicle or to the rocket motor, control of the flow would require tremendous control flows if vortex amplifiers were used. Further, the pressure fluctuations of vortex amplifiers would cause erratic performance of the rocket motor, by preventing propellant flow control in direct relation to the control input to a vortex amplifier acting as a servovalve.

SUMMARY OF THE INVENTION

The present invention is a shear modulated fluid amplifier composed of a vortex-shear modulator positioned across the control stream flow channel leading to the tangential input of a vortex amplifier. This control stream flow is injected at a constant pressure (high enough to effect full turndown of the vortext amplifier) into the vortex-shear modulator. The vortex-shear modulator output can deflect all, a portion, or none of the control stream flow depending on the input to the vortex shear modulator. Thus, varying the vortex-shear modulator input varies the control stream flow reaching the vortex amplifier, and, therefore, varies the vortex amplifier output.

The present invention has high power gain (output/control input ratio) because the vortex-shear modulator utilizes an input at low pressure to deflect the control stream of higher pressure which actually controls the vortex amplifier. Thus, the "control" input to the integrated system is the vortex-shear modulator input. This smaller input of the vortex-shear modulator can deflect the larger control stream flow because it is augmented by the centrifugal force generated by the annular flow in its interaction chamber.

While the output of the vortex amplifier is intended to be always hydraulic, from zero to some high pressure of the order of thousands lb./in.^{2}, the vortex-shear modulator input may be hydraulic or pneumatic, single or multiple. Thus, a fluidic interface is achieved between low-pressure pneumatic logic and high pressure hydraulic power and a signal adding capability is obtained without extra components.

As the input to the vortex-shear modulator is increased, more of the control stream flow is deflected and the output of the vortex amplifier is increased. Instead of varying inversely as do the vortex amplifier control flow and the vortex amplifier output, the vortex-shear modulator input and the vortex amplifier output vary directly.

Further, the shear modulated fluid amplifier has much smaller output fluctuations and better linearity than a usual vortex amplifier. This enables smooth control of the output over its entire range.

Therefore, it is broadly an object of this invention to provide a hydraulic control system of high power gain.

It is still another object of this invention to provide a hydraulic control system whose output fluctuations are dampened significantly and whose response is significantly improved.

A further object is to provide a hydraulic control system capable of accepting a pneumatic input without additional components and also capable of accepting multiple inputs for signal summation.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of a preferred embodiment thereof, especially when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a flow diagram of the present invention;

FIG. 1A is a vertical cross section of the power stage of FIG. 1;

FIG. 2 is a chart comparing performance at blocked load of a vortex amplifier and the invention;

FIG. 3 is a chart comparing performance at wide open load of a vortex amplifier and the invention;

FIG. 4 is a flow diagram as shown in FIG. 1 but with two additional inputs added in parallel to the vortex-shear modulator.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It should be understood that the term channel as used herein refers to a closed channel, duct, pipe or other closed means for conveying fluid under pressure different from that of the external environment. The fluid may be a gas or hydraulic oil or another liquid either with or without particles entrained therein. The accompanying FIGS. 1, 1A, and 4 do not show the specific construction of such channels but merely indicate the necessary paths of fluid flow.

With more particular regard to the drawings, FIG. 1 shows a flow diagram of the present invention which is a compound fluid valve including a pilot stage 11 which is a vortex-shear modulator and a power stage 13 which is a vortex amplifier. The pilot stage 11 is connected to the power stage through control flow channel 15 and tangentially directed input orifice 36 which connects control supply 17 (Ps_2, Qs_2) to the vortex amplifier. A power supply 19 (Ps_1, Qs_1) is provided for the vortex amplifier or power stage.

The vortex-shear modulator 11 includes a control supply 21 (Pc_2, Qc_2) connected via channel 23 and second tangentially directed orifice 24 to a circular flow chamber 25 having a radial venting gap 27 across channel 15. Circular flow chamber 25 imparts centrifugal force to the control supply flow Qc_2 and this added impetus allows pressure Pc_2 to be in the pressure range of 0–100 N/cm.^{2}. The circular flow of Qc_2 in chamber 25 has a shearing action on the flow in channel 15 as it crosses gap 27 that results in deflection of the flow from supply 17. The portion of the flow deflected is carried out vent 31 together with control flow Qc_2. This interaction in gap 27 modulates the flow from the control supply 17. The flow from supply 17 is at a high enough pressure Ps_2 (965 N/cm.^{2} for prototype tested) to cause full turndown of the vortex amplifier 13 if no deflection of flow from power nozzle 29 is caused by interaction in orifice 27. Pressure flow Ps_2 enters channel 15 again at jet receiver 30, whether modulated by pilot stage 11 or not, becoming outlet pressure Po and outlet flow Qo which is actually the control flow Qc_1 and control pressure Pc_1 of the vortex amplifier 13. Pc_1 enters tangentially into vortex chamber 33 to co-act with supply pressure Ps_1 channelled thereto via conduit 34 and radially directed input orifice 35.

Interaction of Pc_1 and Ps_1 in vortex chamber 33 creates spiral flow which varies according to the magnitude of Pc_1. At a pressure of 965 N/cm.^{2}, Pc_1 after interacting with Ps_1 at 690 N/cm.^{2} would cause full turndown of the prototype tested by causing the vortex amplifier output to spin out axially disposed conical orifice 37. At lower annular velocities, portions of the outflow would enter orifice 37 and portions would enter probe orifice 38 (Qr, Pr), see FIG. 1A. At still lower spiralling velocities, the outflow is through orifice 38 alone.

It should be understood that through the flow diagrams shown illustrate use of a vortex-shear modulator in conjunction with a vortex amplifier, it could be used in conjunction with other fluid amplifiers such as beam elements or momentum exchange devices.

A prototype was built and tested which had the following dimensions analogous to numbered elements in FIG. 1:

Element	Reference numeral	Dimension (in.)
Tangentially directed orifice (diameter)	24	≈.250
Circular flow chamber (diameter)	25	≈.500
Circular flow chamber (depth)	25	≈.504
Venting gap (width)	27	≈.314
Power nozzle (diameter)	29	≈.086
Jet receiver (diameter)	30	≈.111
Vortex chamber (diameter)	33	≈.500
Vortex chamber (depth)	33	≈.069
Tangentially directed input orifice	36	.015
Conical orifice	37	≈.125
Probe orifice	38	≈.187

It should be understood that the invention is in no way limited to the above dimensions which are intended merely to be useful in interpreting the following descriptions of test charts generated when testing the prototype.

Referring to FIG. 2 that compares performance of the vortex amplifier or power stage 13 along (shown on the right in FIG. 2) to performance of the invention (shown on the left), both being tested under blocked load conditions. The chart compares the control pressure Pc (Pc_2 for the invention and Pc_1 for the power stage) to the output pressure Pr of each. It is seen that the invention with a control pressure range of from 0–100 N/cm.^{2} can control output pressures of 0–625 N/cm.^{2} while the power stage requires a large control pressure range, from 650–825 N/cm.^{2}. The chart further shows that the invention control pressure varies directly to the output pressure while the power stage control pressure varies inversely. Further, upon closer examination of the chart, one sees that the output pressure of the invention is almost an exact straight line with no output pressure fluctuations. This is not true in the case of the power stage alone. The pressure gain at blocked load is seen to be 6.4:1 for the invention and .96:1 for the power stage alone (pressure gain=output pressure/control pressure).

FIG. 3 is a chart similar to that of FIG. 2 which compares the compound valve and the power stage alone at wide open flow according to control pressure versus flow rate. The flow rate is directly proportional to pressure and the pressure gain at wide open flow is seen to be 10:1 for the compound valve and for the power stage alone it is 1.46:1. Again, the high pressure gain of the invention is evident and upon studying the chart the smaller control pressure range is seen (0–90 versus 650–825).

FIG. 4 shows the addition of two new control inputs 39 (Pc_3, Qc_3) and 40 (Pc_4, Qc_4) to the pilot stage 11 of the device shown in FIG. 1. In some control situations it will be advantageous to achieve multiple inputs in such a way that their signal strength will be added linearly as for instance with a command signal and a feedbck signal.

This completes the description of the invention and although one preferred, as well as possible alternate embodiments employing the principle of the present invention has been shown and schematically diagrammed, it is apparent that modification may be made thereto by one skilled in the art without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. A two-stage shear modulated fluid amplifier comprising:
   - a power stage that includes a fluid vortex amplifier means having a control supply flow, a power supply flow and an output flow, said output flow being dependent upon the interaction of the power supply and control supply flows;
   - said fluid vortex amplifier means including:
     - a closed, cylindrical shaped vortex chamber;
     - a radially directed input orifice for introducing said power stage power supply flow into said chamber;
     - a tangentially directed input orifice for injecting said power stage control supply flow into said chamber to interact with the power stage power supply flow causing spiral flow;
     - an axially disposed output orifice at one end of said vortex chamber for emitting said power stage output flow;
   - a pilot stage connected to said power stage that includes a vortex shear modulator means having a control supply flow, said shear modulator means being connected to said vortex fluid amplifier means so that the output flow of the power stage is in effect controlled by the pilot stage control supply flow;

said vortex shear modulator means including:

a closed, cylindrical shaped circular flow chamber having a tangentially directed orifice means for injecting a control supply flow that results in a spiral flow in said chamber thereby increasing the force of the control flow through centrifugal force;

a radial venting gap disposed on the circumference of said chamber, said venting gap being in communication with said power stage control supply flow whereby a shearing force may be exerted on said power stage control supply flow flowing across said gap to deflect at least a portion of said power stage control flow away from said power stage.

2. A device according to claim 1 wherein said radial venting gap is disposed so that flow therefrom is at substantially a right angle to the power stage control supply flow.

3. A device according to claim 2 wherein the pilot stage control supply flow is a pneumatic flow, and the power stage control flow is hydraulic.

4. A device according to claim 3 wherein the tangentially directed orifice means in said vortex shear modulator means is a plurality of tangentially directed orifices used to provide a plurality of hydraulic inputs that exert a shearing effect on the power stage supply flow projected across said venting gap in such a way that the total input is equal to the sum of the several inputs.

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