FAIL-FIXED SERVOVALVE WITH POSITIVE FLUID FEEDBACK

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Abstract
The servovalve includes a primary jet of fluid. A variable control signal is adapted to vary the angular position of the primary jet from its maximum recovery position. A first fluid path is adapted to supply fluid to a servopiston at a variable pressure determined at least in part by the control signal. A second fluid path is adapted to receive a predetermined portion of the primary jet fluid when the control signal reaches a predetermined value. The second fluid path terminates in the vicinity of the primary jet and is adapted to direct a secondary jet of fluid at the primary jet to deflect the primary jet toward the input orifice of the second fluid path. The resultant positive fluid feedback in the second fluid path causes the primary jet to latch in a first angular position relative to the maximum recovery position when the control signal reaches a predetermined value. The servovalve may further include a means to discharge the fluid and a means to block the first fluid path to the servopiston when the control signal falls below a second predetermined value. A method of operating a fail-fixed servovalve is also described.

8 Claims, 6 Drawing Figures
FAIL-FIXED SERVOVALVE WITH POSITIVE FLUID FEEDBACK

This invention herein described 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).

BACKGROUND OF THE INVENTION

The present invention relates in general to servovalves and in particular to fail-fixed servovalves which use positive fluid feedback.

It is known to use servovalves at the interface between an electrical control system and different types of mechanical or hydraulic actuating devices. For example, in a gas turbine engine fuel control system the servovalve may control the movement of a servopiston in response to an electrical control signal.

In certain types of control systems, it is desirable to use a fail-fixed servovalve for controlling the movement of the servopiston. The expression fail-fixed servovalve, as used herein, designates a servovalve which has no mechanical output in the event the electrical control signal is either lost or exceeds a maximum rated control signal value, i.e., the servopiston is locked in position when these situations occur. An example of a servovalve which is fail-fixed when the control signal is lost is described in U.S. Pat. No. 4,276,809, assigned to the assignee of the present invention. The fail-fixed servovalve described in the above-mentioned patent utilizes a shuttle piston which blocks the flow of fluid to a servopiston chamber when the control signal falls below a predetermined value. Such a servovalve is, however, fail-fixed only for control signals which do not exceed a predetermined value.

OBJECTS OF THE INVENTION

It is a primary object of the present invention to provide a new and improved fail-fixed servovalve.

It is a further object of the present invention to provide a simple and reliable fail-fixed servovalve which can be fabricated at relatively low cost.

It is an additional object of the present invention to provide a new and improved fail-fixed servovalve which is less sensitive to contaminate in the fluid than heretofore available servovalves of this kind.

It is another object of the present invention to provide a new and improved fail-fixed servovalve which employs positive fluid feedback to lock the servopiston in position when the control signal exceeds a predetermined value.

These, as well as additional objects of the present invention, together with the features and advantages thereof will become apparent from the following detailed specification when read together with the accompanying drawings.

SUMMARY OF THE INVENTION

In one form of the invention, I provide for a fail-fixed servopiston comprising a means for providing a primary jet of fluid and a means responsive to a variable control signal for varying the angular position of said primary jet from a maximum recovery position. First and second fluid paths include first and second input orifices respectively. The first fluid path is adapted to supply fluid to the servopiston at a variable pressure determined at least in part by the control signal. The first input orifice is positioned to substantially maximize the amount of primary jet fluid received by the first fluid path when the primary jet is in the maximum recovery position.

The second orifice is positioned to receive a predetermined portion of the primary jet of fluid when the control signal reaches a predetermined value. The second fluid path terminates in the vicinity of the primary jet and directs a secondary jet of fluid at the primary jet to produce positive fluid feedback in the second fluid path. Additionally, a third fluid path for discharging fluid entering the third fluid path through a third input orifice may be part of the servovalve. The third input orifice is positioned to substantially maximize the amount of primary jet fluid received by the third fluid path when the primary jet is on the opposite side of the maximum recovery position relative to a first angular position.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of one embodiment of a fail-fixed servovalve in accordance with the principles of the present invention.

FIG. 2 is a graphical representation of the percentage of the ratio of recovered pressure to supply pressure as a function of the maximum rated control signal.

FIG. 3 is a cross-sectional view of another embodiment of the fail-fixed servovalve in accordance with the invention.

FIG. 4 is a detailed view of a portion of the servovalve of FIG. 1 which schematically illustrates the direction of the primary jet when the latter is in its maximum recovery position.

FIG. 5 is a detailed view of a portion of the servovalve which schematically illustrates a first angular position of the primary jet when the control signal is at its predetermined value.

FIG. 6 is a detailed view of a portion of the servovalve which schematically illustrates a second angular position of the primary jet pipe when the control signal is at zero.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. 1 of the drawings, there is illustrated a preferred embodiment of a fail-fixed servovalve which includes a housing 18. The servovalve comprises an angularly moveable jet pipe 12 having a nozzle 14 which is capable of delivering a primary jet 15 of fluid into a primary chamber 16 in housing 18. Jet pipe 12 receives fluid at a pressure P2 from a source of high pressurized fluid not shown in FIG. 1. The angle of jet pipe 12 may be varied from its maximum recovery position shown in FIG. 1 by means of a conventional torque motor 13 or other means responsive to a selectively variable control signal applied at terminals 7 and 9.

As shown in FIG. 1, there are three input orifices, conventionally known as receivers, toward which jet pipe 12 may direct the pressurized fluid, each adapted to admit fluid to a separate fluid path. A first fluid path includes a receiver tube 22, a shuttle piston 34 and it terminates at servopiston bore 66. Receiver tube 22 receives fluid through a first input orifice or receiver 20. In the preferred embodiment of the invention, the diameter of receiver 20 is about 1.2 times the relatively small inside diameter of nozzle 14.
A second receiver 24 or input orifice admits fluid to a second fluid path which includes a feedback receiver tube 26 and an output orifice or nozzle 28 positioned in the vicinity of nozzle 14. The second fluid path is adapted to provide a secondary jet 29, which is seen to be directed at primary jet 15. A third input orifice or receiver 30 is adapted to admit fluid to a third fluid path which includes a discharge tube 32 adapted to communicate with a fluid sump not shown in the drawing. The sump pressure P_s is relatively low compared to supply pressure P_r.

Shuttle piston 34 is moveably disposed in a chamber within housing 18. The shuttle piston includes first and second piston heads 38 and 42 respectively, each affixed to a piston rod 40 at opposite ends of the rod. Piston heads 38 and 42 include piston faces 44 and 46 respectively. The area A_2 of piston face 44 is selected to be larger than area A_1 of piston face 46. In one embodiment of the invention, these areas are selected such that A_2/A_1 = 6.

Piston head 38 is adapted to reciprocate in a bore 36. This piston head includes a groove 47 which holds one or more O-rings 48. The O-rings are adapted to make sealing contact with the wall of bore 36 in which piston head 38 is moveably disposed. Similarly, piston head 42 is moveably disposed in a bore 58 and sealingly engages the wall of the latter bore by means of one or more O-rings 50. The latter are retained in a groove 51 of piston head 42.

Bore 36 includes an output port 54, as well as an input port 52 which communicates with receiver tube 22. Shuttle piston 34 essentially divides the chamber in which it is disposed into three spaces of variable volume. The first of these spaces, to the left of piston face 44 in FIG. 1, communicates between receiver tube 22 and output port 54 and thus forms part of the first fluid path. The second space, disposed between piston heads 38 and 42, communicates with the low pressure fluid sump at pressure P_r through a fluid vent 60. The third space, positioned to the right of piston face 46 in FIG. 1, communicates with the high pressure fluid supply at pressure P_r through a supply passage 64.

Housing 18 includes a further bore 66 which communicates with port 54 through a passage 80. Thus, passage 80 extends the first fluid path to bore 66, in which servopiston 68 is moveably disposed. Servopiston 68 may be coupled to a mechanical fluid metering valve, not shown, or to another actuating device, by means of a piston rod 70. Servopiston 68 sealingly engages the wall of bore 66 by means of O-rings 72 and 74 which reside in grooves 71,73 disposed in servopiston head 69 and housing 18 respectively. High pressure fluid is supplied to bore 66 at pressure P_r through a supply passage 76 which communicates with the high pressure fluid supply in FIG. 1 and in greater detail in FIG. 4. Jet pipe 12 is in its maximum recovery position. In a preferred embodiment of the invention, this position corresponds to slightly less than 80% of the maximum rated control signal applied to torque motor 13 within prescribed limits.

In the example under consideration, at 0% maximum rated control signal, primary jet 15 occupies a second angular position, which is roughly symmetrically opposite the extreme angular position to the right of the maximum recovery position. In the second angular position, the primary jet fluid enters the jet pipe 12, thereby forcing its second jet to enter the output orifice 28. The reinforcing effect of the positive feedback action finally causes the primary jet 15 to latch in an extreme angular position, or first angular position, with respect to the maximum recovery position. When latching occurs, fluid flow through the first fluid path quickly diminishes and hence the recovered pressure P_x falls. When the force determined by the relationship 6A_1P_x falls below the leftward-directed force applied to the shuttle piston, (A_2P_r) the latter moves to the left in FIG. 1 and blocks passage 80 by closing port 54. With the first fluid path thus blocked, servopiston 68 is locked in position. Thus, the positive feedback action provided in accordance with the present invention produces fail-safe operation of the servopiston when the control signal reaches or exceeds the predetermined value of 80% the maximum rated control signal.

When the control signal decreases from a value slightly below 80% of the maximum rated control signal, jet pipe 12 will pivot angularly to the left in FIG. 1. This movement of the jet pipe continues as the amplitude of the control signal decreases, until the jet pipe assumes an angular position on the opposite side of the aforementioned position as illustrated in FIG. 6. In the example under consideration, at 0% maximum rated control signal, primary jet 15 occupies a second angular position, which is roughly symmetrically opposite the extreme angular position to the right of the maximum recovery position. In the second angular position, the primary jet fluid enters the jet pipe 12, thereby forcing its second jet to enter the output orifice 28. The reinforcing effect of the positive feedback action finally causes the primary jet 15 to latch in an extreme angular position, or first angular position, with respect to the maximum recovery position. When latching occurs, fluid flow through the first fluid path quickly diminishes and hence the recovered pressure P_x falls. When the force determined by the relationship 6A_1P_x falls below the leftward-directed force applied to the shuttle piston, (A_2P_r) the latter moves to the left in FIG. 1 and blocks passage 80 by closing port 54. With the first fluid path thus blocked, servopiston 68 is locked in position. Thus, the positive feedback action provided in accordance with the present invention produces fail-safe operation of the servopiston when the control signal reaches or exceeds the predetermined value of 80% the maximum rated control signal.

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Apparatus in accordance with claim 1 wherein said second fluid path is positioned to substantially maximize the amount of primary jet fluid received by said first fluid path when said control signal reaches a predetermined value.

3. Apparatus in accordance with claim 2 wherein said second fluid path is positioned to substantially maximize the amount of primary jet fluid received by said first fluid path when said control signal reaches a predetermined value.

4. Apparatus in accordance with claim 2 wherein said second fluid path is positioned to substantially maximize the amount of primary jet fluid received by said first fluid path when said control signal reaches a predetermined value.

5. Apparatus in accordance with claim 4 and further comprising:

a. a shuttle piston cylinder having input and output ports communicating with said first fluid path and said servopiston respectively;

b. a shuttle piston slidably disposed in said cylinder; and

c. means for controlling the secondary jet of fluid at said primary jet adapted to produce positive fluid feedback in said fluid path.

6. A method for the fail-fixed operation of a servopiston comprising:

a. a shuttle piston cylinder having input and output ports communicating with said first fluid path and said servopiston respectively;

b. a shuttle piston slidably disposed in said cylinder; and

c. means for controlling the secondary jet of fluid at said primary jet adapted to produce positive fluid feedback in said fluid path.
supplying fluid to said servopiston through a first fluid path at a variable pressure determined at least in part by the angular position of said primary jet; varying said angular position relative to a maximum recovery position in response to a selectively variable control signal, said primary jet being adapted to direct at least a portion of its fluid into a second fluid path beyond a predetermined angular position of said primary jet, said second fluid path being adapted to terminate in a secondary jet directed at said primary jet; and

producing positive fluid feedback in said second fluid path when said control signal reaches a predetermined value by causing said secondary jet to deflect said primary jet toward said second fluid path.

7. A method as recited in claim 6 wherein said step of producing positive fluid feedback further includes the step of latching said primary jet in an extreme angular position beyond said predetermined angular position.

8. A method as recited in claim 6 or 7 and further including the step of blocking said first fluid path when said variable pressure in said first fluid path falls below a predetermined value.