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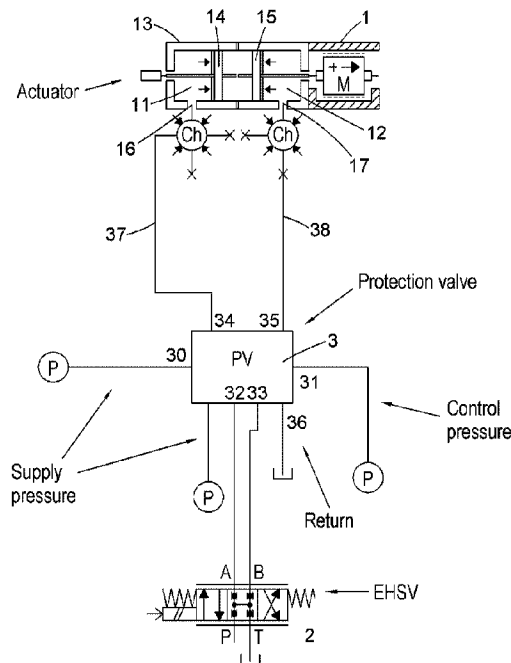
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(54) Title: BLADE PITCH CONTROL



(57) **Abrégé/Abstract:**

A blade pitch control assembly comprising a pitch control actuator (1) having a coarse actuator chamber having a coarse chamber area and a fine actuator chamber having a fine chamber area, the coarse chamber area being biased to a feather position, and a primary pitch control valve (2) configured to control the flow of pressurised fluid to the coarse actuator chamber and the fine actuator chamber, respectively via a coarse fluid line and a fine fluid line; the assembly further comprising a hydraulic protection system located between the actuator and the primary pitch control valve, configured to bypass the primary pitch actuator in response to a trigger; wherein the hydraulic protection system comprises a hydraulic protection system valve located between the coarse fluid line and the fine fluid line, wherein activation of the hydraulic protection system valve fluidly connects the coarse fluid line and the fine fluid line so as to balance fluid pressure between the coarse chamber and the fine chamber.

ABSTRACT

BLADE PITCH CONTROL

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A blade pitch control assembly comprising a pitch control actuator (1) having a coarse actuator chamber having a coarse chamber area and a fine actuator chamber having a fine chamber area, the coarse chamber area being biased to a feather position, and a primary pitch control valve (2) configured to control the flow of pressurised fluid to the coarse actuator chamber and the fine actuator chamber, respectively via a coarse fluid line and a fine fluid line; the assembly further comprising a hydraulic protection system located between the actuator and the primary pitch control valve, configured to bypass the primary pitch actuator in response to a trigger; wherein the hydraulic protection system comprises a hydraulic protection system valve located between the coarse fluid line and the fine fluid line, wherein activation of the hydraulic protection system valve fluidly connects the coarse fluid line and the fine fluid line so as to balance fluid pressure between the coarse chamber and the fine chamber.

BLADE PITCH CONTROL

TECHNICAL FIELD

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The present disclosure relates to controlling the pitch of blades of a rotary body e.g. a propeller.

BACKGROUND

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Rotary bodies such as propellers e.g. on aircraft or other propeller-driven vehicles have a plurality of blades mounted around a rotating hub. Variable pitch propellers are known whereby the blades of the propeller can be adjusted to different angles relative to the flow of air over them. The angle of the blades can thus be adjusted to optimise engine performance for given flight conditions or ground operations. For example, during flight, the angle of the blades may be 'coarse, whereas for taxiing, the blades may be adjusted to a 'fine angle or pitch.

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In more recent applications, the blade pitch is controlled by a pitch control unit which typically includes an electrohydraulic valve (EHSV) assembly. The EHSV receives pressurised fluid and controls the flow of fluid to an actuator that hydraulically adjust the blade pitch based on control commands. Depending on the state of the EHSV, the flow of hydraulic fluid is controlled into and out of the actuator to move the actuator piston in the required direction and by the required amount to set the angle of the blades.

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Some control units are also provided with a protective valve to switch the blades to a 'feathering' state e.g. when the propeller engine or the hydraulic system fails. In the case of such an event, following the triggering of the protective valve the blades are naturally driven to the feathered state i.e. they are rotated to lie essentially parallel to the airflow to stop rotation of the propeller and to reduce drag. A conventional protective valve is located between the EHSV and the actuator (as shown in Fig. 1 and described further below). In a normal operating mode, the protective valve is configured such that there is full fluid communication between the EHSV and the actuator on the coarse and fine pressure lines – i.e. for the fluid paths between the

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EHSV and both actuator chambers. The actuator, and thus the blade pitch, is therefore directly controlled by the EHSV. In a protected operating mode e.g. in the event of an overspeed condition or engine failure, the protection valve operates such that the actuator coarse line is connected to the supply pressure and the fine line is
5 connected to the return line of the pressure system such as to cause the actuator to move to the safe, neutral, feather position. Protection valves are typically hydraulically piloted responsive to a variable input pressure. The protection valve can be a simple on/off valve or can be a proportional valve.

10 Known protective valves, however, are complex and bulky and add to the overall size and weight of the pitch control assembly. They require many hydraulic ports (as seen in Fig. 1) for piloting and control. Such valves have a high envelope, are heavy and expensive, particularly for proportional protection valves.

15 There is, therefore, a need for a simpler, smaller, lighter and less expensive protection assembly whilst maintaining reliability and responsiveness.

SUMMARY

20 According to one aspect of the present disclosure, there is provided a blade pitch control assembly comprising a pitch control actuator having a coarse actuator chamber having a coarse chamber area and a fine actuator chamber having a fine chamber area, and a primary pitch control valve configured to control the flow of pressurised fluid to the coarse actuator chamber and the fine actuator chamber,
25 respectively via a coarse fluid line and a fine fluid line; the assembly further comprising a hydraulic protection system located between the actuator and the primary pitch control valve, configured to bypass the primary pitch actuator in response to a trigger; wherein the hydraulic protection system comprises a hydraulic protection system valve located between the coarse fluid line and the fine fluid line,
30 wherein activation of the hydraulic protection system valve fluidly connects the coarse fluid line and the fine fluid line so as to balance fluid pressure between the coarse chamber and the fine chamber.

The trigger may be a pilot command or may be responsive to an event or condition such as a failure of the primary pitch actuator, e.g. being jammed in a propeller overspeed state, or a low pitch state, or a need for auto-feather protection.

5 According to another aspect, there is provided a method of controlling the pitch control of one or more blades, comprising controlling flow of hydraulic fluid to an actuator via a primary pitch control valve, and, in the event of a trigger event, activating a shut-off valve to provide a fluid flow path between the actuator fine and coarse chambers bypassing the primary control valve to bring the actuator to a
10 neutral position.

Optionally, the hydraulic protection valve is configured to be driven between a normal mode position in which it blocks fluid flow between the coarse and fine fluid lines via the hydraulic protection valve, such that fluid flows directly between the primary pitch
15 control valve and the actuator, and a protected mode position in which it permits the flow of fluid directly between the coarse and fine fluid lines via the hydraulic protection valve, so as to drive the actuator to feather due to the coarse chamber area being greater than the fine chamber area and/or due to external counterweight forces such as blade counterweights as known in the art, biasing the actuator to a feather
20 position.

The hydraulic protection valve may include a piloting mechanism such as a hydraulic system or some other biasing means and a drive means e.g. a solenoid or some other drive to operate the hydraulic protection valve.

25 In an example, the primary pitch control valve is an electrohydraulic valve, EHSV. The EHSV should be configured to ensure some leakage from the EHSV to the actuator even when the hydraulic protection valve is activated.

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BRIEF DESCRIPTION OF THE DRAWINGS

An example of a system of the disclosure will now be described in more detail, by
35 way of example only, with reference to the drawings.

Figure 1 is a schematic view of a conventional blade pitch control assembly.

5 Figure 2 is a schematic view of a blade pitch control assembly according to the disclosure.

DETAILED DESCRIPTION

10 Referring first to Fig. 1, a conventional system for controlling blade pitch will now be briefly described.

15 The pitch of the blades (not shown) is adjusted by means of an actuator 1 having a moveable member such as a piston 10 which is connected to the blades. The actuator comprises two chambers – a coarse chamber 11 and a fine chamber 12 defined by the actuator housing 13 and piston heads 14, 15. The actuator housing 13 has a coarse port 16 to the coarse chamber 11, and a fine port 17 to the fine chamber 12. When pressurised fluid is provided to the coarse chamber 11, the higher pressure in that chamber pushes the piston head further into the fine chamber, forcing fluid out of the fine chamber and causing corresponding movement of the piston 10 and, thus, the blade into the coarse position. Conversely, when pressurised fluid is provided to the fine chamber 12, the higher pressure in that chamber pushes the piston head further into the coarse chamber, forcing fluid out of the coarse chamber and causing corresponding movement of the piston 10 and, thus, the blade into the fine position. The pressurised fluid is provided from a pressure supply (not shown) via the EHSV 2.

20 The EHSV is controlled by a command from the electronic control unit, in a manner known in the art, to move between different mode positions depending on the desired pitch of the blade. In one position, flow channels are established such that 30 pressurised fluid from the supply flows through the EHSV to the coarse chamber and fluid flows from the fine chamber to the return line. In another position, the flow will be in the opposite direction. This known manner of operation will not be described in more detail.

To ensure safe operation, with the blades being brought to a feathering position, a conventional blade pitch control system includes a protection valve 3 located in the flow paths between the EHSV 2 and the actuator 1. The protection valve 3 has eight ports; a supply port 30 for supply pressure to pilot the protection valve 3 and a control
5 port 31 for piloting the protection valve, two ports 32,33 for the two fluid paths from the EHSV, two ports 34, 35 for fluid flow to the coarse and fine ports of the actuator, and a return port 36.

The protection valve is controlled, by a control pressure at port 31 to take up a normal
10 mode position or a protected mode position, as required. In normal mode, the fluid flow channels are open to allow direct fluid communication from the EHSV to the actuator, thus controlling the actuator by the position of the EHSV set according to the command from the ECU.

15 In the event of an overspeed condition or a system or engine failure, the protection valve transitions to the protected mode in which the actuator coarse line 37 is connected directly to supply pressure and the actuator fine line 38 is connected to return causing the actuator to drive the blades to the safe feather position – i.e. the actuator is then not driven by the EHSV.

20 As mentioned above, the aim of the present disclosure is to replace the heavy, complex, large and expensive protection valve with a smaller, lighter and simpler protection mechanism.

25 The system of this disclosure will be described, by way of example only, with reference to Fig. 2. The components and general operation of the actuator and EHSV are the same as for the conventional systems and for these parts the same reference numerals are used as for Fig. 1.

30 In place of the protection valve described above, the assembly of the present disclosure utilises a simple hydraulic protection system including a hydraulic protection valve, e.g. a shut-off valve 4 positioned across the fluid flow lines between the EHSV and the actuator.

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5 The shut-off valve is located, as shown, between the coarse line 37' and the fine line 38'. In the example shown, the shutoff valve 4 is hydraulically piloted 40 between normal mode and protected mode positions. This is just one example, and the shut-off valve could be driven in other ways e.g. electrically, mechanically, hydraulically or a combination thereof.

The operation of a shut-off valve according to the disclosure will now be described.

10 In normal operation, the shut-off valve is driven to be in the position shown in Fig. 2. In this example, the shut-off valve 4 is biased to this position acting against the hydraulic pilot 40. The valve 4 may be biased by a hydraulic system 41 in a way similar to the way in which the conventional valve is positioned, or by means of another biasing means e.g. a spring. In this position, the shut-off valve 4 does not allow any fluid flow between the coarse line 37' and the fine line 38'. As a
15 consequence, the actuator system operates as if the shut-off valve 4 were not there and there is a direct fluid flow from the EHSV and the actuator along the coarse and fine lines.

20 In the event that the blades need to be brought to the feathering position, as described above, the shut-off valve is driven to the protected mode position. In the example shown in fig. 2, this would involve the hydraulic pilot 40 applying pressure to the valve that exceeds the force of the spring 41 such that the shut-off valve channel 42 aligns with flow paths 43,44 fluidly connected, respectively, to the coarse and fine lines 37', 38' between the EHSV and the actuator. This creates a closed
25 fluid path from the actuator coarse chamber to the actuator fine chamber thus bypassing the EHSV 2 and the actuator will move to the feather position. The area of the coarse chamber is slightly larger than that of the fine chamber. When the shut-off valve is enabled, the pressure in the two chambers is equalised. Due to the difference in area, and assisted by external loads e.g. counterweights, e.g. blade
30 counterweights, the actuator will tend towards the feather position.

35 The shut-off valve will be enabled to operate in the protected mode when triggered by failure of the EHSV. If, for example, the EHSV is jammed in a centred position, pitch control via the EHSV is no longer possible. In this case, propeller overspeed or propeller low pitch protection will be triggered and the shut-off valve will be enabled

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and the coarse and fine chamber will be connected to each other via the shut-off valve. Due to an external load or counterweight that biases the actuator towards the feather position, and due to the area of the coarse chamber being greater than that of the fine chamber, the actuator will move towards feather. Full movement to the feather position will, in fact, only be possible if some fluid is allowed to flow to the actuator from the EHSV regardless of its position, and when the shut-off valve is activated, so as to compensate for the change of total fluid volume.

If the EHSV becomes jammed in the position to drive the actuator towards feather, no triggering action is actually needed by the shut-off valve, but it will still be enabled so that the EHSV is bypassed.

In the event that the EHSV is jammed in the actuator low pitch position, again, the shut-off valve will be enabled and, again, due to the external forces and the larger coarse chamber area, the actuator will move towards feather.

The shut-off valve may be fully hydraulically driven. The areas of the left and right sides of the valve may be slightly different. For example, assume that the left (lower) area is smaller than the other side and is always at supply pressure. The right side (top in the drawings) is piloted by a drive means e.g. a solenoid (not shown). In normal mode, the supply pressure pushes the shut-off valve to the off position. In protected mode, return pressure is applied to the other side, acting against the supply pressure, to move the valve to the activated position.

Whilst the example shows a simple on/off shut-off valve 4, the protection valve could also be designed as a proportional valve (not shown) varied.e. that the degree of opening/closing of the protection valve can be proportionally controlled. This allows a difference in pressure between the actuator chambers to be controlled, such that the speed at which the actuator moves toward feather can be controlled.

In another example, not shown, slots can underlap on the EHSV in its centre position so as to ensure a minimum flow rate whatever the EHSV position. In the event of activation of the shut-off valve 4, this minimum flow rate will ensure avoidance of cavitation in the actuator chamber due to piston displacement. Here, the fine chamber volume is decreasing and the coarse chamber volume is increasing. If the EHSV is

in its centered position, and assuming no leakage, no flow rate can be added or removed from the actuator. Due to the difference in areas of the chambers, the global pressure in the actuator is decreasing with the motion of the rod. At a certain displacement value, pressure is low and the blade will continue to move towards feather. Additional hydraulic fluid (oil) is required to avoid a negative relative pressure and therefore some leakage is needed when the EHSV is in a centered position.

The EHSV should be designed to guarantee a minimal pressure inside the actuator chambers in the case of shut-off valve activation. This pressure ensures a hydraulic load towards feather. Consequently, the actuator is driven toward feather by external and hydraulic loads.

The shut-off valve of this disclosure is much simpler than the conventional protection valve. It only requires four ports for, respectively, the piloting/control pressure, supply pressure, for the line to the fine chamber and for the line to the coarse chamber. The assembly is smaller, lighter and less expensive and complex compared to the known protection valves. Auto-feather and emergency feathering can be commanded by activating both the shut-off valve and the EHSV to feather. The proper operation of the shut-off valve can be easily tested e.g. before and/or after each flight of an aircraft, while the aircraft is on the ground.

CLAIMS

1. A blade pitch control assembly comprising a pitch control actuator (1) having
a coarse actuator chamber having a coarse chamber area and a fine actuator
5 chamber having a fine chamber area, and a primary pitch control valve (2)
configured to control the flow of pressurised fluid to the coarse actuator
chamber and the fine actuator chamber, respectively via a coarse fluid line
and a fine fluid line; the assembly further comprising a hydraulic protection
system located between the actuator and the primary pitch control valve,
10 configured to bypass the primary pitch actuator in response to a trigger;
wherein the hydraulic protection system comprises a hydraulic protection
system valve located between the coarse fluid line and the fine fluid line,
wherein activation of the hydraulic protection system valve fluidly connects
the coarse fluid line and the fine fluid line so as to balance fluid pressure
15 between the coarse chamber and the fine chamber.
2. The blade pitch control assembly of claim 1, wherein the trigger is a pilot
command or a failure event requiring overspeed protection or low pitch
protection or auto-feather protection.
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3. The blade pitch control assembly as claimed in claim 1 or 2, wherein the
hydraulic protection system valve is configured to be driven between a normal
mode position in which it blocks fluid flow between the coarse and fine fluid
lines via the hydraulic protection system valve, such that fluid flows directly
25 between the primary pitch control valve and the actuator, and a protected
mode position in which it permits the flow of fluid directly between the coarse
and fine fluid lines via the hydraulic protection valve, so as to drive the
actuator to feather due to the coarse chamber area being greater than the
fine chamber area and/or due to external counterweight forces biasing the
30 actuator to feather.

4. The blade pitch control assembly as claimed in any preceding claim, wherein the hydraulic protection system includes a piloting mechanism to operate the hydraulic protection system valve.
- 5 5. The blade pitch control assembly as claimed in claim 4, wherein the piloting mechanism comprises a hydraulic load to bias the hydraulic protection valve in a first position and a drive means to force the hydraulic protection valve to a second position.
- 10 6. The blade pitch control assembly as claimed in claim 4, wherein the piloting mechanism comprises a spring to bias the hydraulic protection valve in a first position and a drive means to force the hydraulic protection valve to a second position.
- 15 7. The blade pitch control assembly as claimed in claim 5 or 6, wherein the drive means is a hydraulic drive means.
8. The blade pitch control assembly as claimed in claim 5 or 6, wherein the drive means is an electrical drive means.
- 20 9. The blade pitch control assembly as claimed in claim 5 or 6, wherein the drive means is a mechanical drive means.
10. The blade pitch control assembly as claimed in any preceding claim, wherein the primary pitch control valve is an electrohydraulic valve, EHSV.
- 25 11. The blade pitch control assembly of claim 10, wherein slots underlap the EHSV in its centred position to ensure some leakage from the EHSV to the actuator when the hydraulic protection valve is enabled.
- 30 12. The blade pitch control assembly of claim 10 or 11, wherein the hydraulic protection valve is configured to ensure a small pressure difference between the coarse chamber and the fine chamber if the EHSV is jammed in a low pitch position.
- 35 13. The blade pitch control assembly of claim 10 or 11, wherein the hydraulic protection valve is configured to be proportionally driven such that a pressure

difference is created between the coarse chamber and the fine chamber if the EHSV is jammed in a low pitch position.

- 5 14. An aircraft propeller assembly comprising a plurality of blades mounted on a hub and a blade pitch control assembly as claimed in any preceding claim, arranged to vary the pitch of the blades, wherein activation of the hydraulic protection system valve fluidly connects the coarse fluid line and the fine fluid line so as to balance fluid pressure between the coarse chamber and the fine chamber to drive the blades to a feather position.
- 10 15. A method of controlling the pitch control of one or more blades, comprising controlling flow of hydraulic fluid to an actuator via a primary pitch control valve, and, in the event of a trigger event, activating a hydraulic protection valve to provide a fluid flow path between the actuator fine and coarse chambers bypassing the primary control valve to bring the actuator to a neutral position.
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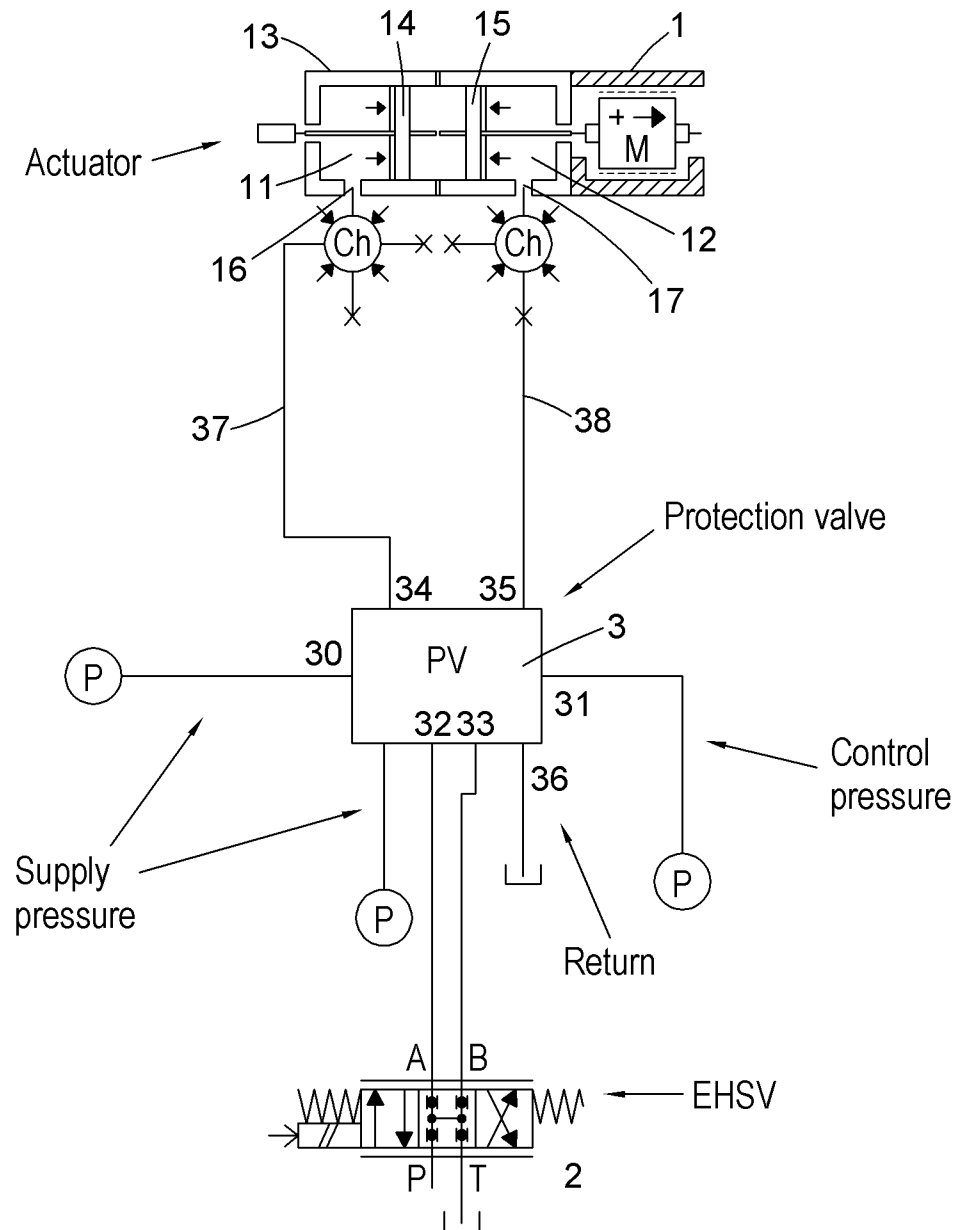


FIG. 1

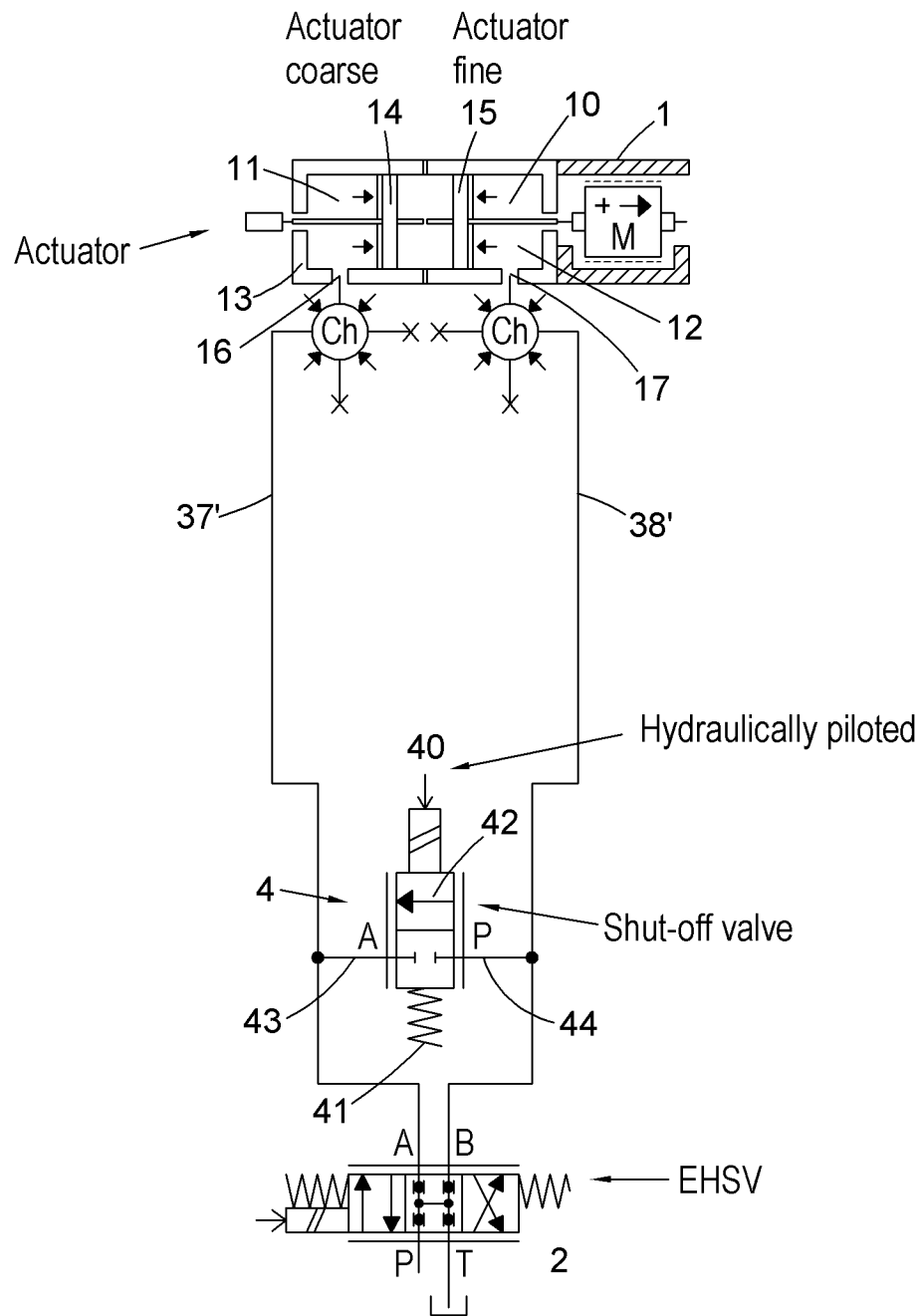


FIG. 2

