HYDRAULIC AIRCRAFT-CONTROL ACTUATOR


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8 Claims. (Cl. 121—40)

This invention comprises improvements in or relating to fluid pressure operated actuators, such as are used in the movement of flying control surfaces in aircraft.

Aircraft are nowadays often designed with all-moving tailplanes, and hydraulic jack servos actuators have been proposed for operating them. However, the hydraulic jack has a disadvantage in so far as it operating large control surfaces of this nature in that it is, not, in itself, an irreversible mechanism; that is to say, unless some additional means for locking the jack is provided the action of external force on the tailplane can cause jack displacement and tailplane movement.

To overcome this drawback, hydraulic jacks have been used instead of hydraulic jacks. A screw jack with a suitably chosen screw pitch is an irreversible mechanism, and therefore tailplanes or like control surfaces operated by such irreversible screw jacks remain locked in any position to which they are moved. Nevertheless, screw jack actuators tend to have greater weight and bulk than equivalent hydraulic jack actuators, and furthermore they have a comparatively low mechanical efficiency.

It is therefore an object of the invention to provide an improved actuator such as can be used for moving flying control surfaces, especially all-moving tailplanes.

According to the present invention, in an actuator for flying control surfaces, and the like powered by a fluid-pressure-operated jack, there is provided in association with the jack a rotary member, a mechanical transmission between the jack and said rotary member for converting relative reciprocating movement of the jack ram and cylinder into rotary movement of said rotary member, means for braking said rotary member to render the jack irreversible under the conditions of a predetermined maximum reversing load thereon with minimum working fluid pressure in the pressure chamber of the jack opposing said load, and means for progressively decreasing the braking with increase of fluid pressure in the jack cylinder.

The transmission between the jack and the rotary member may comprise a reversible screw-thread mechanism. Preferably the means for braking the rotary member comprises a friction clutch capable of slip and having one element rotatable with said rotary member and a non-rotary element to co-operate therewith which is axially slidable with respect to the rotary element.

The clutch may be spring loaded into engagement, and there may be a fluid-pressure-actuated clutch-operating piston to off-load the clutch progressively as the fluid pressure to the jack cylinder increases. In the preferred form, the jack is controlled by a servo jack-control valve arranged to admit fluid pressure to a cylinder in which the clutch-operating piston works, at the same time as it admits fluid pressure to the jack cylinder, and there is provided a fluid exhaust line from the clutch-control cylinder, and a clutch-control valve in said line responsive to variations in fluid pressure in the jack cylinder so as to shut off said exhaust line progressively as the jack cylinder pressure builds up.

One form of hydraulic actuator in accordance with the invention will now be described by way of example, and with reference to the accompanying diagrammatic drawing which is a longitudinal section through an actuator intended for use in the control of a tailplane of a part which must always be locked in any position to which it is moved; for example, in the control of an all-moving aircraft tailplane.

The actuator unit comprises a casing 11, one end of which is provided with an extension 12 which is pivotally connected to the tailplane 13 (or connected to a tailplane operating rod). The casing 11 has a longitudinal internal cylindrical cavity 14 which is divided into two chambers 15, 16 by a transverse partition 17. Within the chamber 15 farther from the forementioned extension 12 a jack piston 18 is slidable mounted, which piston has an integral rod 19 passing to the exterior of the casing 11 through a gland 20 on the casing end remote from said extension 12 and pivotally connected at its extremity 21 to the aircraft structure 22. The jack rod 19 has a longitudinal screw-threaded bore 23 which is extended through the jack piston itself.

The partition 17 between the two chambers 15, 16 in the casing has a central opening 24 around which is a gland 25 and which is provided with an annular recess 26 in its wall. The partition supports a rod-like member 27 that fits through the opening 24 and has a small radial flange 28 to enter the annular recess 26 therein and thereby retain the member 27 against axial displacement with respect to the casing 11. The part of the rod-like member 27 that lies on the same side of the partition 17 as the jack piston 18 extends into the bore 23 in the jack piston and jack rod, being screw threaded to cooperate with the screw thread 29 of said bore. It will be appreciated that the rod-like member 27 is rotatable by virtue of the thread (which is a reversible thread of quick pitch) upon relative displacement of the jack piston and casing.

In the chamber 16 on the opposite side of the partition 17, which is shorter than the jack cylinder chamber 15, the screwed rod member 27 carries an increased diameter head 30 which forms one of the co-operating engageable parts of a friction clutch 34 in said chamber associated with the screw mechanism. At its end remote from the partition 17, this chamber 16 which is hereinafter referred to as the clutch chamber, has an extension 32 of smaller bore, and in this extension there slides a clutch rod member 33 extending into the clutch chamber 16 where it carries a head 31 constituting the second co-operating part of the clutch end of the same diameter as the first head 30 on the screwed rod 27. A clutch lining 35 of a suitable material is interposed between the two co-operating heads 30, 31, which are spring-urged toward one another to hold the clutch engaged, as will be described later, the clutch being only released when the fluid pressure on a clutch-operating piston acting in opposition to the spring is high enough to overcome the spring pressure.

The small bore extension 32 of the clutch chamber 16 leads into a clutch control cylinder 36 in which slides the clutch-operating piston 37 situated on the end of the clutch rod 33 remote from the clutch chamber. A coil spring 38 in the clutch-control cylinder 36 bears on said piston 37 and urges it in the direction of the clutch chamber 16, thereby serving to engage the clutch. A bleed passage 39 is provided in the clutch-operating piston 37 to place both sides of the clutch control cylinder 36 in communication. A key 40 is provided in the bore 32 between the clutch chamber 16 and clutch control cylinder 36, which key co-operates with a longitudinal slot 41...
in the clutch rod 33 to prevent rotation of this member while permitting it to slide endwise.

Also within the casing 11, and displaced laterally from the partition cavity 14 constituting the jack cylinder 15 and clutch chamber 16, is a second cavity 42 constituting a valve bore which is provided at each end with glands 43 through which a pilot's control or input rod 44 passes, one end 45 of this rod being pivotally connected to pilot's control linkage. Slidably mounted within said bore 42 is a hollow jack-control valve plunger 46 which surrounds the input rod 44 and is secured thereto by a transverse pin 47, the diameter of the input rod being less than the internal diameter of the valve spool. This valve spool 46 is provided with six longitudinally-spaced annular lands 49, 50, 51, 52, 53, and radial ports 57, 58 in the spool between the first and second lands 49, 49, and again between the third and fourth lands 50, 51, place the spaces between these lands in communication with the hollow interior 54 of the valve spool which in turn opens into the end chamber 55 of the valve bore beyond the second land 53 from which chamber leads a return duct 56 in the casing connecting with exhaust. A passage 59 in the valve spool 46 interconnects the spaces between the second and third lands 49, 50, the fourth and fifth lands 51, 52, and the fifth and sixth lands 52, 53. The second and third lands 49, 50 are arranged, when the apparatus is in equilibrium, to place annular ports 60, 61 at the ends of ducts 62, 63, in the casing which respectively lead to the spaces in the jack cylinder 15 on opposite sides of the jack piston 18. The fifth land 53 is similarly arranged to close the annular port 64 at the end of a duct 65 which leads to the clutch control cylinder 36 on the side of the clutch-operating piston 37 nearer the clutch. Pressure fluid is admitted to the actuator through a non-return valve 66 and a passage 67 in the casing opening into the space between the second and third lands 49, 50, of the spool 46 of the jack control valve.

This valve 11 is provided with another valve bore 69 that houses an automatic clutch-control valve member 70 slidable therein against the action of a coil spring 71. This valve member 70 is provided with two longitudinally spaced lands 72, 73, and an extension 74 at one end, the extension being of smaller diameter than the lands and slidable in a bore 75 formed in a bore 69 which opens into a bore 76 opened into the smaller diameter extension 75. The space between the two lands 72, 73 communicates via a duct 78 in the casing 11 with the clutch chamber 16, and this chamber in turn communicates with exhaust through a further duct 79 leading to the end 80 of the bore 42 of the jack control valve to which the exhaust line 56 is connected. The end of the clutch control cylinder 36 remote from the clutch communicates with the exhaust through a duct 80 leading to the clutch chamber 16, said duct incorporating a fixed orifice or restriction 81.

The clutch-control valve spring 71 acts on the valve member 70 to urge it in a direction toward the end of the valve bore 69 at which the smaller diameter extension 75 is situated. The land 72 near said extension serves, when the valve member is moved by fluid pressure in the opposite direction against the action of the spring, to cover progressively the variable orifice 82, thereby progressively closing the exhaust connection for the clutch control cylinder 36 through the valve. The result is that the pressure in the chamber of the clutch control cylinder nearer the clutch increases and eases back the clutch-operating piston 37 against the spring pressure, thereby off-loading the clutch 34 somewhat and freeing the screwed rod assembly sufficiently to permit it to be rotated by relative movement of the jack piston 18 and actuator casing 11 which can now take place for the purpose of moving the tailplane.

It will be appreciated that, as is usual in servo-mechanisms, the jack movement follows up the jack control-valve movement and tends to restore said valve to its neutral position. As the jack control valve is returned to neutral the pressure fluid in the clutch-control cylinder is exhausted and the spring loading on the clutch accordingly increases to render the screw thread irreversible and lock the tailplane in the position in which it has been moved.

If now the opposite end of the jack cylinder 15 remote from the clutch 34 is subject to pressure, a similar action takes place except that, whereas formerly the clutch-control valve member 70 was actuated by pressure on the end face of its extension 74, it is now actuated by pressure in the end of the main part of the valve bore 69 around said extension 74 acting on an annular area of the adjacent land 72, on the valve member. It will be noted that the pressure in the clutch control cylinder 36, after reduction on passing through the fixed orifice 83 in the passage connecting said cylinder to the clutch control valve, is effective on the end of the valve member 70 opposite to the extension 74 thereon, and opposes closing of the variable orifice 82.

From the foregoing description it will be seen that the clutch pressure is controlled progressively by automatic adjustment of the variable orifice 82 of the clutch control valve. The movement of this valve is a function of the pressure difference across the jack piston and the clutch pressure load so that the clutch is released progressively with increase in jack force. By automatically comparing the pressures of the jack and clutch, smooth actuator movement is ensured. No snatch or reversibility is possible since the clutch is not fully unloaded until the jack is generating maximum force. For normal operation the clutch is never completely disengaged. To ensure a clutch action free from shudder damping is provided by the bleed 39 in the operating piston.
The non return valve 66 in the supply line ensures that should the hydraulic supply fail when the jack is moving, then a large proportion of the kinetic energy in the system will be destroyed hydraulically, the remainder being handled by the clutch. Omission of this return valve would mean that the clutch would have to be very much more robust as it would have to take the form of a brake capable of destroying the kinetic energy of the tailplane system.

We claim:

1. An actuator powered by a fluid-pressure-operated jack, wherein there is provided in association with the jack a rotary member, a mechanical transmission between the jack and said rotary member for converting relative reciprocating movement of the jack ram and cylinder into rotary movement of said rotary member, braking means for said rotary member to render the jack irreversible under the conditions of a predetermined maximum reversing load thereon with minimum working fluid pressure in the pressure chamber of the jack opposing said load, a braking control cylinder with a fluid-pressure-actuated brake-operating piston working therein, a servo jack-control valve arranged to admit fluid pressure for off-loading the braking means to a supply line leading to the brake-control cylinder at the same time as it admits fluid pressure to the jack cylinder, a fluid exhaust line from the brake-control cylinder, and a brake-control valve in said exhaust line responsive to variations in fluid pressure in the jack cylinder so as to shut off said exhaust line progressively as the jack cylinder-pressure builds up.

2. An actuator comprising a fluid-pressure-operated jack with a screw-threaded axial bore in the jack piston, a slipping friction clutch with cooperating rotary and non-rotary clutch elements in axial alignment with the jack cylinder at the end remote from the jack piston, a rotary rod that engages end screw-threaded and engaged in the bore in the jack piston and carries at its other end for rotation therewith the rotary clutch element, the screw-threaded connection between the jack and rotary rod being of reversible pitch so that relative straight line motion of the jack piston and cylinder produces rotation of said rod, a clutch control cylinder in axial alignment with the clutch and jack and situated on the side of the clutch opposite to the jack, a clutch-operating piston working in said control cylinder, an axially-extending clutch rod carrying the non-rotary clutch element and coupling it to the clutch-operating piston which rod is keyed against rotation but slidable axially together with the clutch element and operating piston, spring-means to load the clutch into engagement sufficiently to prevent rotation of the rotary element by the jack and thereby lock the jack under the conditions of a predetermined maximum external jack-reversing loading with minimum working fluid pressure in the pressure chamber of the jack opposing said loading, a servo-valve for controlling the jack arranged to admit fluid-pressure to the clutch-control cylinder, on the side of the clutch-operating piston nearer the clutch, at

same time as it admits fluid pressure to the jack cylinder, a fluid exhaust line from the clutch-control cylinder on the same side of the operating piston, and a clutch-control valve in said line responsive to variations in fluid pressure in the jack cylinder so as to shut off said exhaust line progressively as the jack cylinder pressure builds up.

3. An actuator as claimed in claim 2, further comprising a bleed passage through the clutch-operating piston, a further exhaust line leading from the clutch-control cylinder on the side of the operating piston remote from the clutch, and fixed area restriction orifices in both the exhaust line between the clutch-control cylinder and clutch-control valve and said further exhaust line.

4. An actuator as claimed in claim 1 wherein the transmission between the jack and the rotary member comprises a reversible screw-thread mechanism.

5. An actuator as claimed in claim 1, wherein the means for braking the rotary member comprises a spring-loaded friction clutch capable of slip and having one element rotatable with said rotary member and a non-rotary element to co-operate therewith which is axially slidable with respect to the rotary element.

6. An actuator as claimed in claim 1, wherein the jack is of the double-acting kind and the brake-control valve is responsive to the pressures in both chambers of the jack cylinder.

7. An actuator as claimed in claim 6, wherein the brake-control valve comprises a valve-bore with a valve spool sliding therein spring-urged toward one end of the bore, a port in the wall of the valve-bore for establishing the communication with exhaust of the line from the brake-control cylinder, which port is progressively obturated as the valve spool slides away from the end of the bore toward which it is spring-urged, a smaller diameter extension of the valve bore at said end thereof and a smaller diameter extension of the valve spool sliding in said bore extension, and fluid pressure connections from the two jack pressure chambers, one leading to the end of the valve bore extension and the other to the aforesaid end of the main or larger diameter part of the bore.

8. An actuator as claimed in claim 7, wherein the line between the brake-control cylinder and the brake-control valve has a branch leading to the end of the brake-control valve bore opposite to that toward which the valve spool is spring-urged so that the pressure in said line acts on the valve spool to assist the spring action.

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