The invention relates to a hydraulic fluid actuator configuration with a working piston (2) that is guided in an actuating cylinder (4), with this piston being supplied pressure on both sides. In order to prevent an excursion of the working piston (2) from its neutral position ($x=0$) due to leakage, a hydraulic fluid displacement device (20) is suggested, which supplies a control volume over a period of a harmonic movement of the working piston (2) to the side of the working piston (2) to which it traveled.
PRESSURE FLUID ACTUATED DEVICE

[0001] The invention relates to a hydraulic fluid operated actuator configuration in particular for usage in a helicopter rotor blade control system pursuant to the preamble of the main claim.

[0002] Such an actuator configuration is suitable especially for use in a single-blade control system for helicopter rotor blades, a higher harmonic rotor blade control system or, also, in a system for active structure spin.

[0003] Such actuator systems are subject to heavy demands with regard to weight, space, and performance needs. Strong forces must be able to be transmitted, while being able to maintain high level of actuating accuracy. In particular in the case of a rotor head where each rotor blade is allocated at least one actuator of its own it must be ensured that an adjusted neutral position, does not change during operation. Since leakage can never be completely prevented in a hydraulic fluid system, measures must be taken that will guarantee maintenance of the neutral position. Therefore, existing approaches include an electro-hydraulic control circuit. Here, the position of the actuator is constantly monitored and compared to a target position. In case of a deviation from the target, a control signal is issued for the selection of a leakage-equalizing valve, which feeds or removes hydraulic fluid compensating volume. Such a control system however is extremely complex. It takes great efforts to ensure the safety of the electronic systems.

[0004] DE G 89 09 165.5 shows a pressure-operated actuator configuration for rotor blades where a working piston, that is guided in an actuating cylinder, is supplied with pressure from both sides and is axially displaceable through hydraulic fluid volume flows, which can be increased or reduced through fluid chambers arranged on both sides of the piston. So as to generate the hydraulic fluid volume flows a displacement body configuration is provided, which interacts with an adjustable control curve system with several adjustable control curve elements. When rotating the rotor, the displacement bodies perform harmonic stroke movement in order to generate the hydraulic fluid volume flows. The hydraulic fluid volume flows are then fed to the actuators via a line system. The cam elements of the cam system are scanned by displacement bodies arranged at offset angles according to the rotor blade configuration, wherein these displacement bodies are allocated to the respective rotor blades. Accordingly, not every actuator is allocated an independent control system. Leakage, which can take on different values on the actuators of the various rotor blades, can thus not be compensated by the central control system without difficulty.

[0005] The invention is based on the goal of providing a hydraulic fluid actuator configuration, which maintains a neutral position during operation with high accuracy once that position has been set.

[0006] According to the invention, this task is resolved with a hydraulic fluid actuator configuration that contains the features of the characterizing portion of the main claim. Beneficial embodiments as well as applications for the invention are revealed in the dependent claims.

[0007] A back and forth movement between a first final position and a second final position of the working piston guided in the actuating cylinder is composed of a first and a second partial stroke movement. A back and forth movement from the neutral position in the direction of the first final position and back corresponds to a first partial stroke movement, and a back and forth movement from the neutral position in the direction of the second final position and back corresponds to a second partial stroke movement. The working piston is supplied with pressure from two sides, wherein each side is assigned a hydraulic fluid chamber. The first hydraulic fluid chamber has a minimum volume in the first final position, and the second hydraulic fluid chamber does in the second final position.

[0008] According to the invention, a hydraulic fluid displacement device is provided, which during the first partial stroke movement of the working piston bleeds hydraulic fluid volume from the second hydraulic fluid chamber and which during the second partial stroke movement of the working piston feeds hydraulic fluid volume to the second hydraulic fluid chamber. The hydraulic fluid volumes fed to or bled from the second hydraulic fluid chamber by the hydraulic fluid displacement device is such that the same volumes are fed or bled as long as the harmonic stroke movement of the working piston takes place around the neutral position. If a leakage occurs, which causes the working piston to move out of the neutral position, then the amplitude of a partial stroke movement is increased while the amplitude of the other partial stroke movement is reduced. The amounts of required volumes that are fed are dependent upon the amplitudes of the partial stroke movements. The amplitude difference between the partial stroke movements causes hydraulic fluid to be supplied to or be removed from the second hydraulic fluid chamber over a period in the case of a working piston that has moved out of the neutral position. This ensures that the actuator assumes the correct neutral position again.

[0009] If the hydraulic fluid displacement device is mechanically coupled with the working piston through transfer means, the power absorbed by the hydraulic fluid displacement device can be read directly from the movement of the working piston. No other control or supply device is required for the hydraulic fluid displacement device. The actuator configuration with the hydraulic fluid displacement device can then be used as a quasi autonomous, self-adjusting module, which is very well suited for installation in a rotating system of a helicopter main rotor. In case of a helicopter rotor blade control for several rotor blades that are evenly advantageously distributed on the periphery of a rotor hub each rotor blade is allocated at least one actuator configuration according to the invention. Each actuator configuration maintains its neutral position with great accuracy once it has been set to this position, so that a combination with a control system in the form of a hydraulic displacement control system, which is arranged in the rotor head of the helicopter, is especially advantageous. With regard to the set-up and circuitry of the hydraulic displacement control system reference is made to the above-mentioned publication DE G 89 09 165, whose content should be included in the disclosure of the present application.

[0010] Between the piston rod configuration of the working piston and the rotor blades of the rotor head transfer means are provided so that the blade angle movement can be controlled.

[0011] Further beneficial designs of the invention are explained on the hand of the attached drawings. They show
FIG. 1 is a diagrammatic view of a first design of an invented actuator configuration, FIG. 2 is a time progression curve of an actuator movement and the allocated hydraulic fluid volume flows of the hydraulic fluid displacement device in the neutral position, FIG. 3 is a time progression curve of an actuator movement and the allocated hydraulic fluid volume flows of the hydraulic fluid displacement device for a deviation from the neutral position, and FIG. 4 is a diagrammatic view of a second design of an invented actuator configuration.

In FIG. 1 a working piston that is guided in an actuating cylinder 4 has been labeled with 2 The working piston 2 separates a first hydraulic fluid chamber D1 from a second hydraulic fluid chamber D2 in the actuating cylinder 4. The hydraulic fluid chamber D1 is connected with a controllable, hydraulic control system 8 via the line 6. The hydraulic control system 8 can consist of a controllable pump and/or in an advantageous version of a hydraulic displacement control device, as shown in DE-G 89 09 165. The first hydraulic fluid chamber D1 is connected via the line 10 with a hydraulic fluid source 12 with at least roughly constant pressure, which e.g. can take on the design of a pressure-regulated pump. This creates a hydraulic pre-stress so that the actuator configuration can absorb forces in two directions although only the second hydraulic fluid chamber D2 is actively selected. Due to a positive volume flow Qp from the control system 8 to the hydraulic pressure chamber D2, the working piston 2 performs a movement to the right with the piston rod 14. A negative volume flow Qp affects a movement of the working piston 2 and the piston rod 14 to the left. Volume control of the hydraulic pressure chamber D1 occurs via the line 10 to the hydraulic fluid source 12.

FIG. 1 depicts the working piston 2 in its neutral position, in which the excursion x is equal to 0. The neutral position forms the center between a first final position 16 and a second final position 18 between which the piston is axially displaceable. In the first final position 16 the first hydraulic fluid chamber D1 has minimal volume, and in the second final position 18 the hydraulic fluid chamber D2 has minimal volume.

In order to explain the invention, a back and forth movement from the neutral position in the direction of the first final position 16 and back has been marked as a first partial stroke movement, and a back and forth movement from the neutral position in the direction of the second final position 18 as a second partial stroke movement.

If leakages bleeding from the system occur in the hydraulic fluid system connected with the hydraulic fluid chamber D2, this leads to an unwanted movement of the working piston 2 to the left. In order to avoid this, a hydraulic fluid displacement device 20 is provided which, during the first partial stroke movement of the working piston 2, removes hydraulic fluid volume from the second hydraulic fluid chamber D2 and which during the second partial stroke movement of the working piston 2 feeds hydraulic fluid volume to the second hydraulic fluid chamber D2. As long as the working piston 2 performs a harmonic movement around the neutral position, the volumes fed to or bled from the hydraulic fluid chamber D2 are compensated over a period of movement of the working piston 2. If the working piston in relation to the neutral position is too far right during a period, then the first partial stroke movement is performed with a greater amplitude, while the second partial stroke movement is executed with a reduced amplitude. This means that the hydraulic fluid displacement device 20, when viewed over the entire period, removes a control volume from the hydraulic fluid chamber D2. This in turn corrects the mean position of the piston in the direction of the neutral position.

In the design shown in FIG. 1, additionally during the first partial stroke movement of the working piston 2 a hydraulic fluid volume QD1 is supplied to the first hydraulic fluid chamber D1 and during the second partial stroke movement a hydraulic fluid volume is removed from the first hydraulic fluid chamber D1, wherein in the case of deviation from the neutral position over a period in turn a control volume is supplied, which corrects the mean position of the piston in the direction of the neutral position.

The hydraulic fluid displacement device 20 comprises a first displacement cylinder 22 and a second displacement cylinder 24. A working volume V1 of the first displacement cylinder 22 is connected via a line 26 with the second hydraulic fluid chamber D2. In the line 26, a one-way valve is arranged, which allows a flow in the direction to the first displacement cylinder 22. The working volume V1 of the first displacement cylinder 22 is connected via a line 29 also with the first hydraulic fluid chamber D1. In the line 29, a pre-stressed one-way valve 30 is arranged, which allows a flow in the direction away from the first displacement cylinder 22 towards the hydraulic fluid chamber D1.

A working volume V2 of the second displacement cylinder 24 is connected via a line 32 with the first hydraulic fluid chamber D1. In the line 32 a one-way valve 34 is arranged, which allows a flow in the direction to the second displacement cylinder 24. The line 36 connects the working volume V2 of the second displacement cylinder 24 with the second hydraulic fluid chamber D2. In the line 36 a pre-stressed one-way valve 38 is arranged, which allows a flow in the direction away from the second displacement cylinder 24 towards the hydraulic fluid chamber D2. The pre-stress of the pre-stressed one-way valves 30, 38 is large enough that it cannot be overcome by the pressure level dominant in the hydraulic fluid chambers D1, D2.

The displacement cylinders 22, 24 each have a piston 40, 42. The front surfaces 44, 46 of these pistons 40, 42 are provided with dominant pressures in the displacement cylinders 22, 24.

The amount of the front surfaces 44, 46 is considerably lower than the amount of the front surfaces 48 of the working piston 2. A beneficial value for the amount of the end faces 44, 46 is 3% of the amount of the front surfaces 48. This makes it possible via the tappets 50, 52, which are connected to the pistons 40, 42, to build up high pressure levels with little actuation forces, which overcome the pre-stress of the pre-stressed one-way valves 30, 38. In accordance with the scale of the front surfaces, the control volume flows from the displacement cylinders 22, 24 are small compared to the volume flows created by the control system 8. The correction of a deviation of the working piston from the neutral position thus occurs in a very sensitive and accurate manner.
During the first partial stroke movement, i.e. during a back and forth movement of the working piston 2 from the neutral position in the direction of the first final position 16, the piston 40 of the first displacement cylinder 22 is coupled to the movement of the working piston 2. In doing so, the tappet 50 is located with its left end on the axial stop surface 54 of the driver 56. The driver 56 is pressed against the axial stop surface 54 by the pressure applied onto the piston 40.

While the piston 40 of the first displacement cylinder 22 follows the first partial stroke movement of the working piston, the piston 42 of the second displacement cylinder 24 is uncoupled from the movement of the working piston. It remains in its right final position, wherein the axial stop surface 58 of the driver 60 is lifted, i.e. it is no longer in contact with the tappet 52. It is only when the working piston 2 has reached its neutral position again and is moved from there to the left that the tappet 52 rests again on the axial stop surface 58.

During the second partial stroke movement, the piston 42 of the second displacement cylinder 24 is accordingly coupled to the movement of the working piston 2, while the piston 40 of the first displacement cylinder 22 is uncoupled.

The neutral position of the working piston 2 in the actuating cylinder 4 can be adjusted in a simple manner in that adjusting means for adjusting the position between the pistons 40, 42 of the displacement cylinders 22, 24 and the axial stop surfaces 54, 58 are included. For this, the axial position of the drivers 56, 60 on the piston 14 can be adjusted. Alternatively however also the length of the tappets 50, 52 can be changed through a threaded connection or the like.

An actuating configuration that is equipped with adjusting means permits very simple adjustment of the blade angles of the individual rotor blades of a helicopter rotor during tracking.

In FIG. 1 the volume flow, which is supplied to the first hydraulic fluid chamber D1 from the hydraulic fluid displacement device 20, is labeled with Q_{D1}, and the volume flow, which is supplied to the hydraulic fluid chamber D2 from the hydraulic fluid displacement device 20, is labeled with Q_{D2}. The progression of these hydraulic fluid volume flows Q_{D1}, Q_{D2} is represented in FIG. 2 over a period t/T. The time progression of the excursion of the working piston 2 corresponds to a harmonic movement around the neutral position χ=0. From t/T=0 to t/T=0.5, the working piston 2 performs its first partial stroke movement.

From t/T=0.5 to t/T=1 the working piston performs its second partial stroke movement. From t/T=0 to t/T=0.25 a positive volume flow Q_{D3} flows to the hydraulic fluid chamber D1, with this flow coming from the first displacement cylinder 22. At t/T=0.25 the second part of the first partial stroke movement commences, where the displacement cylinder 22 is again filled with a hydraulic fluid volume flow Q_{D2} from the second hydraulic fluid chamber D2. In relation to the hydraulic fluid chamber D2 this corresponds to a negative volume flow Q_{D2}.

During the first part of the second partial stroke movement from t/T=0.5 to t/T=0.75 a positive hydraulic fluid volume flow Q_{D2} is supplied to the hydraulic fluid chamber D2, with this flow coming from the second displacement cylinder 24. During the second part of the second partial stroke movement from t/T=0.75 to t/T=1, a hydraulic fluid volume flow Q_{D1} is removed again from the first hydraulic fluid chamber D1, which serves the filling of the second displacement cylinder 24.

As can be seen in FIG. 2, the time integrals [formula] and [formula] are equal zero. The hydraulic fluid volumes fed to or removed from the hydraulic fluid chambers D1, D2 are thus balanced during a period so that the neutral position of the working piston 2 is maintained.

The process 64 of the wandering movement x of the working piston 2 shown in FIG. 3 is offset by the amount Δx compared to the progression 62 (FIG. 2). That means that the mean position of the working piston 2 in relation to the depiction in FIG. 1 is offset to the right by the amount Δx compared to the neutral position. The amplitude of the first partial stroke movement 66 is greater by the amount Δx compared to the progression 62, while the amplitude 68 of the second partial stroke movement is smaller by the amount Δx. The progression of the volume flows Q_{D1}, Q_{D2} shows that on average a control volume is supplied to the hydraulic fluid chamber D1, while a control volume is removed from the hydraulic fluid chamber D2. This is also reflected in the depiction of the time integrals [formula] and [formula]. These control volumes cause the mean position of the working piston 2, which is Δx during the progression 64, to be shifted in the direction of the neutral position (χ=0).

FIG. 4 shows an alternative design of the invention, in which the line 29 is connected with a hydraulic fluid reservoir. This causes the hydraulic fluid displacement device 20 to feed a hydraulic fluid volume QR to the reservoir 70 during the first partial stroke movement of the working piston 2 and to remove a hydraulic fluid volume QR from the reservoir 70 during the second partial stroke movement of the working piston 2.

In this design, the hydraulic fluid displacement device 20 comprises a first displacement cylinder 22 and a second displacement cylinder 24, wherein a working volume V1 of the first displacement cylinder 22 is connected via a line 26 comprising a one-way valve 28 that allows a flow in the direction to the first displacement cylinder 22 with the second hydraulic fluid chamber D2 and via a line 29 comprising a pre-stressed one-way valve 30 that allows a flow in the direction away from the first displacement cylinder 22 with the reservoir 70.

The working volume V2 of the second displacement cylinder 24 is connected via a line 32 comprising a one-way valve 34 that allows a flow in the direction to the second displacement cylinder 24 with the reservoir and via a line 36 comprising a pre-stressed one-way valve 38 that allows a flow in the direction away from the second displacement cylinder 24 with the second hydraulic fluid chamber D2.

In this design, the mean position of the working piston is corrected by feeding to or bleeding a control volume from the second hydraulic fluid chamber D2, while the volume of the first hydraulic fluid chamber is automatically compensated through the hydraulic fluid source.
1. Hydraulic fluid actuator configuration with a working piston (2) guided in an actuating cylinder (4), with this piston separating a first hydraulic fluid chamber (D1) from a second hydraulic fluid chamber (D2) in the actuating cylinder (4) and due to hydraulic fluid volume flows \( Qp \), which can be fed to or removed from the hydraulic fluid chambers (D1), (D2), being axially displaceable between a first final position (16) and a second final position (18), wherein in the first final position (16) the first hydraulic fluid chamber (D1) has a minimum volume and in the second final position (18) the second hydraulic fluid chamber (D2) has a minimum volume, and wherein the working piston (2) can assume a neutral position \( x=0 \) between the two final positions (16), (18), wherein a back and forth movement from the neutral position in the direction of the first final position (16) and back corresponds to a first partial stroke movement and a back and forth movement from the neutral position in the direction of the second final position (18) and back corresponds to a second partial stroke movement, characterized by the fact that a hydraulic fluid displacement device (20) is provided, which during the first partial stroke movement of the working piston (2) removes a hydraulic fluid volume (formula) from the second hydraulic fluid chamber (D2) and during the second partial stroke movement of the working piston (2) supplies a hydraulic fluid volume (formula) to the second hydraulic fluid chamber (D2), wherein the fed or removed hydraulic fluid volumes are dependent upon the amplitude of the respective partial stroke movement.

2. Actuator configuration pursuant to claim 1, characterized by the fact that the hydraulic fluid displacement device (20) during the first partial stroke movement of the working piston (2) feeds a hydraulic fluid volume (formula) to a reservoir (70) and during the second partial stroke movement of the working piston (20) removes a hydraulic fluid volume (formula) from the reservoir (70).

3. Actuator configuration pursuant to claim 2, characterized by the fact that the hydraulic fluid displacement device (20) comprises a first displacement cylinder (22) and a second displacement cylinder (24), wherein a working volume (V1) of the first displacement cylinder (22) is connected via a line (26) comprising a one-way valve (28) that allows a flow in the direction away from the first displacement cylinder (22) with the reservoir (70), and wherein a working volume (V2) of the second displacement cylinder (24) is connected via a line (32) comprising a one-way valve (38) that allows a flow in the direction away from the second displacement cylinder (24) with the second hydraulic fluid chamber (D2).

4. Actuator configuration pursuant to claim 1, characterized by the fact that the hydraulic fluid displacement device (20) during the first partial stroke movement of the working piston (2) feeds a hydraulic fluid volume (formula) to the first hydraulic fluid chamber (D1) and during the second partial stroke movement of the working cylinder (2) removes a hydraulic fluid volume (formula) from the first hydraulic fluid chamber (D1).

5. Actuator configuration pursuant to claim 4, characterized by the fact that the hydraulic fluid displacement device (20) comprises a first displacement cylinder (22) and a second displacement cylinder (24), wherein a working volume (V1) of the first displacement cylinder (22) is connected via a line (26) comprising a one-way valve (28) that allows a flow in the direction to the first displacement cylinder (22) and via a line (32) comprising a one-way valve (38) that allows a flow in the direction away from the first displacement cylinder (22) with the first hydraulic fluid chamber (D1) and wherein a working volume (V2) of the second displacement cylinder (24) is connected via a line (32) comprising a one-way valve (38) that allows a flow in the direction away from the second displacement cylinder (24) with the second hydraulic fluid chamber (D2).

6. Actuator configuration pursuant to one of the claims 1 through 5, characterized by the fact that transfer elements (14), (56), (58) are provided, which mechanically couple the hydraulic fluid displacement device (20) with the working piston (2).

7. Actuator configuration pursuant to one of the previous claims, characterized by the fact that the displacement cylinders (22), (24) each contain a piston (40), (42), which can be displaced by an actuating device (50), (52) guided outward, wherein during the first partial stroke movement of the working piston (2) guided in the actuating cylinder (4), the actuating device (50) of the first displacement cylinder (22) is coupled with the movement of the working piston (2) and the actuating device (52) of the second displacement cylinder (24) is uncoupled from the movement of the working piston (2), and wherein during the second partial stroke movement of the working piston (2) guided in the actuating cylinder (4) the actuating device (52) of the second displacement cylinder (24) is coupled with the movement of the working piston (2) and the actuating device (50) of the first displacement cylinder (22) is uncoupled from the movement of the working piston (2).

8. Actuator configuration pursuant to claim 7, characterized by the fact that the working piston (2) of the actuating cylinder (4) is connected with a piston rod configuration (14, 
which has axial stop surfaces (54, 58), which are allocated to the actuating devices (50, 52) of the displacement cylinders, wherein each actuating device (50, 52), respectively, rests against the axial stop surfaces (54, 58) only during a partial stroke movement of the working piston (2) and is carried along by it and during the other partial stroke movement of the working piston (2) lifts away from it.

9. Actuator configuration pursuant to claim 8, characterized by the fact that adjusting means for adjusting the position between the pistons (40), (46) of the displacement cylinders (22), (24) and the axial stop surfaces (54), (58) are provided.

10. Actuator configuration pursuant to one of the previous claims, characterized by the fact that the first hydraulic fluid chamber (D1) is connected via a line (10) to a hydraulic fluid source (12) with at least nearly constant pressure and the second hydraulic fluid chamber (D2) is connected via a line (6) with a control system (8) that can be controlled.

11. Module, comprising an actuator configuration pursuant to one of the previous claims for installation in a rotating system of a helicopter main rotor.

12. Helicopter rotor blade control for several rotor blades arranged evenly on the periphery of a rotor hub, wherein each rotor blade is allocated at least one actuator configuration or one module pursuant to the previous claims, wherein a control system in the form of a hydraulic displacement control system is provided, which is arranged in the rotor head of a helicopter, and wherein transfer elements are provided, which couple the piston rod configuration of the working piston with a helicopter rotor blade, for the purpose of controlling a blade angle movement of the helicopter rotor blade.

13. Usage of the adjusting means of an actuator configuration pursuant to claim 6 for adjusting the blade angles of the rotor blades of a helicopter rotor.

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