HYDRAULIC REACTION POWER AMPLIFICATION

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There have long been many instances in which heavy apparatus or a heavy force must be controlled by a delicate control force, so that some form of amplification of force is necessary. According to the present invention, a simple hydraulic mechanism is devised by which it is possible to amplify or increase a relatively small primary input force, to any degree, so that it will proportionally move a heavy output shaft or secondary force by hydraulic reaction power.

The specific arrangements of the invention disclosed herein, lend themselves best to the use of high pressure hydraulic reaction amplification, and yet it avoids the problem of oil foaming which is encountered even in some low-pressure jet-moving apparatus now in use.

The invention disclosed herein has few parts, is rugged mechanically, and should have low or negligible upkeep costs.

It may have a valuable application wherever it is desirable to move heavy apparatus from a weak primary force.

As an example of almost necessary usage, my Patent 2,657,327, “Adjusting System for Furnace Controls,” has in its structure a piston valve which must be moved accurately in reversing angular motions, with a “block” position at its movement mid-point. This high pressure valve piston is not easy to move, yet the more satisfactory operation under that line patent depends on my ability to amplify the small signal of a free-moving current-voltage torque motor, so that the heavy valve piston will follow every angular movement of the torque motor.

Another example of the use of this invention is that of a power “assist” to ease hand power in vehicular steering.

This power “assist” design lends itself to steering with a “feet” of the road.

The illustrations herein show the primary force shaft in line and rotative with the secondary or output shaft.

This permits simple reserve mechanical coupling, which is useful in the case of hydraulic failure. It is not intended, however, that a relative change of position of these two shafts will avoid this invention.

Although the illustrations with this disclosure all show rotative or angularly moving primary and secondary output shaft arrangements, this invention may be applied to non-circular movements.

Among the objects of this invention is an arrangement which amplifies the small power or force applied to turn an angular moving input shaft hydraulically, so that its associated “heavy” output shaft, having either a leading or lagging load, will always follow every change in the position of the input shaft.

Another object of this invention is that arrangement wherein the hydraulic “assist” power is applied to the output shaft in a varying degree of power value, as is needed to always keep the output shaft rotatively aligned with the input shaft.

Another object of this invention is to associate the input shaft with the output shaft mechanically, so that in the case of hydraulic power failure, one shaft can still be used to move the other.

Another important object of this invention is that of a power “assist” suitable to help move a vehicle steering apparatus.

Another object of some forms of this invention, when used as a steering wheel “assist,” is that of giving a “feel” to the steering effort, as will be described later.

The foregoing and other important objects, advantages and inherent functions of this invention will become apparent as the same is more fully understood from the following description and the accompanying drawings, which disclose preferred embodiments of the present invention.

Designation of figures

Fig. 1 is a side elevation partially in section, of a representative industrial hydraulic load moving system, containing one form of my invention.

Figs. 2, 3 and 4 show side, plan and end views, in larger detail of the form of my invention shown in small scale in Fig. 1. Fragmentary views 3a and 3b show the parts positioned for counterclockwise control.

Figs. 5, 6 and 7 illustrate details of another arrangement of my invention. Fig. 5 shows an end or face view. Fig. 6 shows an axial sectional view approximately along line 6—6 of Fig. 5. Fig. 7 shows a longitudinal cross section through the reaction unit, approximately through section 7—7 of Fig. 6.

Figs. 8, 9 and 10 illustrate a third arrangement of this invention in enlarged detail. Fig. 8 shows a fragmentary end elevation, with a section through the input shaft. Fig. 9 is a view from the same direction but with the enclosure removed, and with the input shaft and the reaction blades positioned for clockwise power assist. Fig. 10 shows a cross section approximately in an axial plane.

All of the above figures show arrangements of hydraulic reaction power amplifying, to illustrate their operation.

Although the law requires a full and exact description of at least one form of the invention, such as that which follows, it is, of course, one purpose of a patent to open each new inventive concept therein no matter how it may later be disguised by variations in form or additions of further improvements; and the appended claims are intended to accomplish this purpose by particularly pointing out the parts, improvements, or combination in which the inventive concepts are found.

Description and operation

One example of the use of the hydraulic reactive power amplifying system is disclosed by Fig. 1. Here the standard hydraulic equipment illustrated comprises a fluid pressure generating system. This includes a reservoir or liquid holding tank 6, a fluid gear pump 7, its driving motor 8, electrical power source 9, fuse and switch unit 10, and pressure holding device 11, oil filter 12, and the necessary hydraulic piping as shown.

A piston valve generally designated as 13 may be located in tank 6 to avoid dust. The tank will receive the used oil, and catch leakage oil and the reaction unit oil.

An operating cylinder generally designated as 37 carries heavy load W on its ram type piston. The hydraulic units described function in cooperation as follows:

Pump 7 generates fluid power, which delivers a desired pressure by operation of the pressure holding or relief device 11. Fluid pressure is supplied on one side of valve 13. Valve 13 consists of a valve body 14, which contains angularly moving piston 15. The valve body 14 and piston 15 may be ported in many standard combinations, but
in this case, they are arranged so that in a mid-angular position, passage is blocked; and in a clockwise rotation of the piston 15, the pressure supply port is opened from a crack to full, for speed-controlled raising of the heavy load W. In a counterclockwise rotation from the block position, piston 15 progressively opens the discharge port to bleed fluid at adjustable speeds, from under the piston of cylinder 37 to lower load W.

Now valve pistons like piston 15, when under high fluid pressure, are not moved easily with small power. "Breakaway" or starting friction, adds to the friction from the high pressures.

We however wish to move such a piston 15 to position a typical heavy load W, with a small power electrical signal, such as, for example, the torque motor M of Fig. 1. The torque motor shaft 16, forms the input shaft of one form of my hydraulic reaction power amplifier, generally designated as 17, to have its small power increased so as to be able to easily change the "heavy" piston 15, in its load controlling functions as are described above.

Fig. 1 shows fluid pressure from the pressure source 7, as being piped to the jet arm, of the amplifying unit 17, through up pipe 18, swivel joint 19, and flexible hose 20. Figs. 2, 3 and 4 show an enlargement of the form of my invention generally as shown as 17 on Fig. 1. Here I show reaction base 21 mounted on output shaft 22, axially in line with input shaft 16. This base 21 contains guide blocks 21a, fixed to base 21. In these bored guide blocks 21a, are parallel shafts 23 and 24. These two shafts are normally centered in base 21 by lugs 25, fastened at the center of each shaft 23 and 24. Two centering springs 26, per shaft, are arranged between blocks 21a and the associated lug 25, on each shaft so as to center each shaft in its guide block 21a, when the jet impingement is at zero. A pair of reaction blocks 27 are fastened to the opposite ends of shaft 23. A similar pair of blocks 27 are also fastened to the opposite ends of the shaft 24. These blocks have their adjacent faces shaped to efficiently receive jet fluid impingement in their functioning usage.

Cradled between guide blocks 21a and fastened to the input shaft 16, is jet discharging arm 28. This arm has fluid under pressure supplied to its interior from pipe 20 on Fig. 1. The latter fluid fluid base 20 is moved around joint 19 as the system changes its angular positions by means of a stiff arm 29 fastened to one end of the output shaft base 21. Here the major bending of the fluid hose is by output power, and the slight flexibility needed between the reaction base 21 and the jet arm 28, is supplied by the relatively long hose section 30 with minimum resistance.

If this design is used to automatically move its output shaft piston to a mid-point or "block" position when the opposing torque motor powers are equal, a special centering device may be used to bias the input shaft to said mid-point "block" position, similar to that shown on my Patent No. 2,637,927, and the reason may be the same as there.

In Fig. 3, plan view, the jet arm is shown centered, as if at the moment there is no rotative effort. Jet arm 28 discharges fluid under high pressure at its opposite ends and so balances jet reaction thrust which would cause pivoting shaft 24. A static jet arm holds its output arm still, and exactly in its angular line, with the high pressure jets discharging clearly between, but closely to, the adjacent impingement blocks 27.

A slight counterclockwise movement of the jet arm will start impingement against two of the blocks 27 diagonally disposed, causing shaft 24 to instantly slide ¼ of an arm length, or so outwardly by impingement against reaction block 27 thereon, at the same time, shaft 23 instantly slides in the opposite direction by the same amount from the opposite end impingement. This slight endwise shifting, is so that the discharge fluids will miss the adjacent reaction blocks not being used. Extended Figures 3a and 3b show the above shifted relations of the reaction blocks at each end of unit 17, when there is counterclockwise effort of the input shaft 16 driven by the small torque motor M, or by a return spring if provided.

At the instant of completion of the shaft shifting as above, a heavily amplified counterclockwise power "assist" begins. The amount of the power "assist" over depends on the angular displacement of the jet arm 28 and in turn its control of minimum to full impingement.

The output shaft will therefore be moved in a counterclockwise direction by a power assist of a value limited only by the hydraulic design.

The above movement will continue because the output shaft and its reaction arms will move to follow the jet arm lead all of the time, up to the rotative limits of the system.

Similarly, clockwise movement of the jet arm from a position centered in block 21 will cause instant shifting of the slidable shafts 23 and 24, with clockwise reaction power "assist" in that direction for the duration of that jet arm displacement. Again, the amount of the clockwise power "assist" will be governed by the degree of minimum to full bias lead of the jet arm, as is described.

The arrangement of the invention as described above allows the small power of the shiftable high pressure jet arm to lead its reaction power output shaft in any angular movements within the range of the design.

Shoulders 31 limit the displacement of jet arm 28 in case output response is sluggish. If the input shaft 16 is subject to manual actuation, as in vehicle steering, shoulders 31 also serve as reserve coupling means in case of failure of the fluid reaction power.

While Fig. 1 illustrates a usage and hydraulic hose arrangement for less than 360 degrees of rotation, the full 360 degrees, or more, can be had by using a standard revolving joint centered on the axis of shafts 16 and 22.

While the above reaction blocks are slidably mounted to miss the discharge of spent fluid, they can be individual ly pivoted to the base 21, for the same reason, but may have lower power reaction efficiency.

Figs. 5, 6 and 7 illustrate enlarged details of another arrangement of the invention. Here again is shown an input shaft 50 in axial alignment with a power-moved output shaft 51, both centered and held in position mechanically but loosely coupled by a nesting valve bar 52 fastened to the input shaft 50, and nested in the reaction base 57, which is attached to the output shaft. This coupling gives safety in the case of hydraulic pressure failure.

Valve bar 52 controls the division of flow of liquid between vanes or ducts 53 and 56 for one movement and vanes or ducts 54 and 55 for the opposite movement.

In this arrangement, fluid under pressure enters at housing port 58, thence around annular space 59 and through holes 61, and so into the hollow end of the output shaft 50, and into the inside of the reaction base 57.

Fluid 67 is thus delivered to the reaction base 57 in a manner to avoid a flexing head.

Input shaft 59 is fixed to the sweep valve 52, which is balanced by fluid under high pressure all around it. A fixed housing 62 is made to enclose the above reaction parts, and is provided with outlet 63 to which a pipe may be connected so that the spent reaction fluid will return to the reservoir. This housing 62 may be lined with cellular rubber 64 to absorb used fluid noise. The balanced sweep valve 52 has clearance on both sides at 65, and sweep clearance, without friction, over the discharge ports. This valve sweeps over its ports in its fluid directing movements. It does not have to be tight, and to avoid friction, should not quite touch. Raised portions 66 do not serve as valve seats, but as stops.

Packing glands 68 are preferably provided, except that the outer one may be omitted if there is a surrounding
tank as in Fig. 1, and the inner one can be omitted if extreme ease of actuating the input shaft 50 is required.

Fig. 5 is an end view showing housing 62 enclosing the reaction units as above. It illustrates valve 52 as static with no rotative effort. In this condition, the reaction base 57 stays in an angular position which centers exactly about the static valve 52. This is because, when the valve 52 has no lead, it divides the fluid pressure into four equal and power-cancelling forces. Hence, there is zero rotative effort for the output shaft 51.

If and when the input shaft 50 has slight angular rotative displacement, there is immediate valving for reaction power to move base 57, and its shaft 51, always in a direction tending to center it about valve 52. This power movement will continue until the reaction base is again centered about the valve 52, or nearly so enough so that the reaction force remaining cannot move shaft 51.

The value of the power thus added to move the output shaft is limited only by the design. In Fig. 5, the valve 52 is shown static, thus it divides the fluid reaction flow in equal and opposing directions, which yields zero output shaft rotation.

Suppose the input shaft is static from zero rotational effort, and there is sufficient foreign effort to overcome and move the output shaft angularly. Then, and in that case, if the valve static, the reaction vanes will be opened whatever amount is needed to oppose such a foreign force. If the foreign force is terminated before the valve moves, the reaction will restore the output shaft to its former position with the valve in neutral or balanced position.

In other words, this invention makes a "master" out of the input shaft, and a "slave" out of the output shaft, with the latter controlled by greatly amplified power.

It is vital to realize that any bias of the valve 52 angularly, will yield a powered action to move base 57 instantly in that same direction, in an effort to maintain centering about valve 52, for neutralizing its hydraulic reaction.

Figs. 8, 9 and 10 show and illustrate an arrangement wherein input shaft 75 is again in axial alignment with output shaft 76, both rotating in the same instantaneous direction, and again being loosely coupled.

In this arrangement fluid pressure enters at 77, into annular chamber 78, thence into the recessed part of shaft 75, thru holes 79, and into the chamber of jet arm 80. The liquid in jet arm 80 is under full pressure at all times that the equipment is being used because the jet oriﬁces at each end are of much smaller area than the cross-section of the liquid pressure piping at any point as to make the piping resistance negligible.

Under static conditions of this unit, output shaft 75 will remain centered, with its jets dividing equally between the two sides of the reaction blades 83 and 84, at both ends, thus neutralizing the reaction thrust.

If input shaft 75 is biased to lead in a clockwise rotation, the control arm 81 moves with it. At each end of arm 81 is a blade 82, fastened to the end of arm 81, and acting as a tooth engaging a notch 85 in arm 86 on reaction blade 83 or 84. Various means may be used to avoid play. For example, blade 8 may be a bendable member snugly engaged by both associated parts. Also, gear segments could be used.

Reaction blades 83 and 84 are pivoted mounted on pins, in opposite end extensions 87 of jet arm 80.

This combination of arm 81, and blades 82 fastened in its opposite ends, engaging reaction arms 86 functions, so that a clockwise bias of the shaft 75, rocks the reaction blades 83 and 84 in the opposite angular direction, and so shifts the knife edge, that more jet fluid is received by the blades on one side thereof than the other. This provides a reaction power assist, to output shaft 76, of slight to maximum force depending on the degree of the bias lead of shaft 75.

Similarly, when input shaft 75 is biased in a counterclockwise direction, it moves its associated reaction blades so that fluid will impinge more on the other sides of blades 83 and 84, to move the output shaft in a counterclockwise direction by reaction power assist.

The pivotal axis for reaction blades 83 and 84 should be located in their various positions so that the forces of the jet stream on them will be substantially balanced. If any departure from balance is to be encountered, it is preferable for most uses that it be in the direction tending to swing the reaction blades toward their neutral positions. If this is not accomplished by the form shown, the pivot axis should be moved closer to the knife edge until it is accomplished.

The arrangements shown in Figs. 5 to 10 require a fluid pressure source such as that represented by gear pump 7 in Fig. 1.

The designs of Figs. 5 to 10 have high reaction efficiency, since they lend themselves to a vane shape which will yield 90 degrees plus, change in the direction of the fluid flow. All spent fluid discharges almost perpendicular to the plane through the point of discharge and coinciding with the axis.

Now, in all of the arrangements disclosed herein, the amount of the power "assist" in a particular design, is a function of the angular "lead" of the input shaft over the output shaft, in any movements. A "thin" lead means small power amplification because of minimum reaction. A strong lead means full power assist and fast output shaft movements therefrom.

In using any of the arrangements of this invention as a steering "assist," we may install centering springs between the input and output shafts, as 69 in Fig. 7 and 91 in Fig. 9. Such centering springs should center the valve (or jet arm) when lead (moving) effort is discontinued. It is contemplated that, for steering "assist" the unit might be installed in an existing type of steering column, between the worm assembly and the steering wheel. Present steering column shafts have road "feel" at the wheel now, from slight road wheel changing. The use of centering springs such as 69, on Fig. 7 will retain the road "feel," while using the steering "assist," which so many drivers like.

The amount of fluid assist can be limited by the fluid pressure.

In all of the illustrated forms, the gradations of reaction thrust provide smooth action and substantially eliminate hunting. At the same time, full available power is instantly available when needed, and is called forth by a minute movement of the input shaft.

All of the illustrated forms are suitable for use with high hydraulic pressures which with some apparatus might be subject to foaming trouble and resultant non-uniformity. Here any foam formed is immediately drained from the unit and returned to the reservoir where it has time to release its air and return to the "solid" liquid state. In all of the units, this quick removal of foam may be ensured by providing vanes or sloping surfaces on the periphery of the housing directing all the jet liquid outwardly or downwardly to beyond the path of the movable control parts. There may be a deeper drainage bowl than illustrated.

I claim:

1. A hydraulic-reaction control device, including means for supplying liquid under pressure; reaction means receiving said liquid from said means, pivotable about a main axis, designed to discharge jets in either direction about the axis and balanced as to forces other than torque about the axis; and output means driven by said reaction means; said device also including a control device readily pivotable about said main axis and associated with said reaction means to be relatively displaceable as to it in either direction angularly from a neutral relative position, in which neutral position it causes the jets to be neutralized as to rotational force about the axis, displacement of said control means in either direction
from said neutral relative position causing said jets to be predominantly discharged in a direction to exert a force on the reaction means in the same direction as the direction of said displacement, the hydraulic forces on said control means being substantially balanced and its control being exerted free from valving contact so as to permit its control by delicate forces.

6. A hydraulic-reaction control device, including means for supplying liquid under pressure; reaction means receiving said liquid from said means, pivotable about a main axis, designed to discharge jets in either direction about the axis and balanced as to forces other than torque about the axis; and output means driven by said reaction means, said device also including a control device readily pivotable about said main axis and associated with said reaction means to be relatively displaceable as to it in either direction angularly from a neutral relative position, in which neutral position it causes the jets to be neutralized as to rotational force about the axis, displacement of said control means in either direction from said neutral relative position causing said jets to be predominantly discharged in a direction to exert a force on the reaction means in the same direction as the direction of said displacement, the hydraulic forces on said control means being substantially balanced and its control being exerted free from valving contact so as to permit its control by delicate forces.

7. A hydraulic-reaction control device, including means for supplying liquid under pressure; reaction means receiving said liquid from said means, pivotable about a main axis, designed to discharge jets in either direction about the axis and balanced as to forces other than torque about the axis; and output means driven by said reaction means, said device also including a control device readily pivotable about said main axis and associated with said reaction means to be relatively displaceable as to it in either direction angularly from a neutral relative position, in which neutral position it causes the jets to be neutralized as to rotational force about the axis, displacement of said control means in either direction from said neutral relative position causing said jets to be predominantly discharged in a direction to exert a force on the reaction means in the same direction as the direction of said displacement, the hydraulic forces on said control means being substantially balanced and its control being exerted free from valving contact so as to permit its control by delicate forces; and said input means being biased toward said neutral relative position, and said input means being loosely coupled mechanically to the output means to exert thrust thereon independently of the hydraulic thrust if the output means fails to be moved by the hydraulic thrust alone within the range of relative movement permitted by the loose coupling.

8. A hydraulic-reaction control device, including means for supplying liquid under pressure; reaction means receiving said liquid from said means, pivotable about a main axis, designed to discharge jets in either direction about the axis and balanced as to forces other than torque about the axis; and output means driven by said reaction means, said device also including a control device readily pivotable about said main axis and associated with said reaction means to be relatively displaceable as to it in either direction angularly from a neutral relative position, in which neutral position it causes the jets to be neutralized as to rotational force about the axis, displacement of said control means in either direction from said neutral relative position causing said jets to be predominantly discharged in a direction to exert a force on the reaction means in the same direction as the direction of said displacement, the hydraulic forces on said control means being substantially balanced and its control being exerted free from valving contact so as to permit its control by delicate forces; and said input means being loosely coupled mechanically to the output means to exert thrust thereon independently of the hydraulic thrust if the output means fails to be moved by the hydraulic thrust alone within the range of relative movement permitted by the loose coupling.
control by delicate forces; and said input means being biased toward said neutral relative position.

9. A hydraulic-reaction amplifying device including a liquid conduit; reaction means, pivotable about a main axis, receiving liquid from said conduit and designed to discharge jets balanced about the axis as to radial thrust and directed to provide reaction torque about the axis selectively in either direction; output means driven by said reaction means; and input means; said device including control means readily movable by the input means for selectively effectuating the reaction means for discharging the jets in one direction about said axis, or in the opposite direction about the axis, or with a neutral effect as to movement about said axis.

10. A hydraulic-reaction control device of high output power, including a master shaft and a slave shaft both mounted to be pivotable more than a full revolution about a main axis, a control element carried by the master shaft to be moved by it and reaction means carried by and moving the slave shaft, means for delivering to the reaction means liquid under pressure and subject to control by the control element; the control element having a neutral relative position with respect to the reaction means, in which any rotational force exerted by the liquid on the reaction means is neutral, and being relatively shiftable from the neutral position in opposition directions by minute force and, as it shifts, causing the liquid to exert progressively increased effective rotational thrust on the reaction means in the direction of the shift, whereby the power available from the liquid in its coaction with the reaction means makes the slave shaft substantially follow the movements of the master shaft.

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