Review Paper on Energization of Clutch Using Spool Valve & Electro Hydraulic Control

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Abstract — This paper including a description on electro hydraulic control system comprising a spool valve including a body having a bore. A spool is positioned in the bore for reciprocating movement within the bore. The valve body has an inlet, an outlet and an exhaust port. An electro hydraulic three-way normally closed pulse width the inlet to the valve body and an outlet communicating with one end of the spool. An electro hydraulic three way normally closed ON/OFF valve has an inlet communicating with the other end of the spool. A spring yieldingly urges the spool towards the pulse width modulated valve. The spool is positioned so that it normally obstructs a path from the inlet to the outlet.

Keywords — Electro hydraulic control system, Spool valve, PWM valve.

I. INTRODUCTION

Control of the gear shift points for changing from one gear to another in heavy duty automatic transmissions of the type used in trucks, buses and off road equipments, historically have been controlled by mechanical inputs such as centrifugal governors monitoring engine speed and drive shaft speed along with throttle position and, in some instances, output shaft torque.

The shift point from transmission to transmission for any given set of conditions varies significantly due to the inherent manufacturing tolerances and the calibration of the various mechanical linkage components. The mechanical inputs activate pilot spool valves which in turn, control main spool valves to energize and de-energize the various clutches as the transmission shifts from one gear to the next. Since the spool valves are activated mainly in an ON/OFF mode with little or no pressure regulation between the extremes, the shifts tend to be quite abrupt causing torque spikes in the transmission output and high pressure clutch slippage resulting in clutch face wear.

The present paper is directed to an electro hydraulic control device to energize and de-energize clutches through electrical commands from a microcomputer.

This paper includes the details about an electro hydraulic control system which comprises a spool valve including a body having a bore. A spool is positioned in the bore for reciprocating movement within the bore. The valve body has an inlet, an outlet and an exhaust port. An electro hydraulic three way normally closed pulse width modulated valve has an inlet communicating with the inlet to the valve body and an outlet communicating with the one end of the spool. An electro hydraulic three-way normally closed ON/ OFF valve has an inlet communicating with the outlet of the valve body and an outlet communicating with the other end of the spool. A spring yieldingly urges the spool towards the pulse width modulated valve. The spool is positioned so that it normally obstructs path from the inlet to the outlet.

II. OPERATION OF CLUTCH:

By electronically monitoring engine speed, output speed and torque, and throttle position, it is possible with an inexpensive microcomputer to calculate the exact shift point required for any set of conditions and to control an electro hydraulic device to energize or/ and de-energize the appropriate clutches when shifting from one gear to another. The clutch for the desired gear is engaged as the clutch for the undesirable gear is being de-energized. In energizing a clutch of this type, it is necessary to first fill the clutch hydraulic cavity with hydraulic fluid at a low pressure, such as 10-20 PSI, which compresses the clutch return springs and brings the clutch faces into low pressure sliding engagement. The hydraulic volume necessary to fill the clutch can be up to 10 cubic inches and is variable within any given clutch depending on the amount of residual oil in the clutch at the beginning of the fill and the amount of wear on the clutch faces and components. It is desirable to fill the clutch volume rapidly, for example, in 0.5 seconds or less, therefore, an initial high flow rate is required(for example, 10-20 gallons per minute).

Once the clutch is full, the pressure in the clutch must be linearly increased from the low (10-20 PSI) fill pressure to line pressure, to bring the clutch faces into non-slipping high pressure engagement. Line pressure is normally high, on order of 150 PSI, but may vary from 60 PSI to 350 PSI.

After the clutch is fully applied, it is necessary to "latch" or hold the clutch in this position without an electrical signal to the electro hydraulic valve. This "latching" of the clutch is a safety measure to insure that the transmission will remain in gear in the event of electrical power loss.

To de-clutch, it is necessary to linearly reduce the pressure within the clutch from line pressure to zero.

Among the objective of the paper are to provide an electrohydraulic control system which comprises a spool valve including a body having a bore. A spool is positioned in the bore for reciprocating movement within the bore. The valve body has an inlet, an outlet and exhaust port. An electrohydraulic three-way normally closed pulse width modulated valve has an inlet communicating with the inlet to the valve body and an outlet communicating with one end of the spool. An electrohydraulic three-way normally closed ON/OFF valve has an inlet communicating An electro hydraulic three way normally closed pulse width modulated valve has an inlet communicating with the inlet to the valve body and an outlet communicating with the one end of the spool. An electro hydraulic three-way normally closed ON/ OFF valve has an inlet communicating with the outlet of the valve body and an outlet communicating with the other end of the spool. A spring yieldingly urges the spool towards the pulse width modulated valve. The spool is positioned so that it normally obstructs path from the inlet to the outlet.

III. ELECTRO-HYDRAULIC VALVE SYSTEM:

The device consists generally of the body with spool located in bore and a normally closed three-way pulse width modulated (PMW) valve and a normally closed three-way ON/OFF valve closing the ends of the bore. A band functions to hold valves and in position in the bore. The spool functions to selectively open or close inlet port and main exhaust port through the relative axial movement of spool within bore. Within the range of spool movement, a clutch feed port remains full open. Fig.1 shows the device in its fully de-energized state with a spring holding spool fully to the right side against the outlet end of valve. In this position, inlet is fully covered and residual pressure in the clutch will be relieved through spool cavity from port to exhaust port to the sump. O-rings provide a seal between each of the valves, and the body. The PWM valve is configured so that line pressure fluid enters through a radial opening from conduit and is modulated to produce a fluid pressure output directly proportional to the electrical signal through outlet end into a cavity formed at the end of valve and the bore. Exhaust fluid from the PWM valve exits to the sump through an axial bore in a protrusion. In this configuration, when the PWM is fully de-energized, the inlet is held closed and any fluid in cavity is forced out through exhaust port as the spring urges the spool to the extreme right position again end.

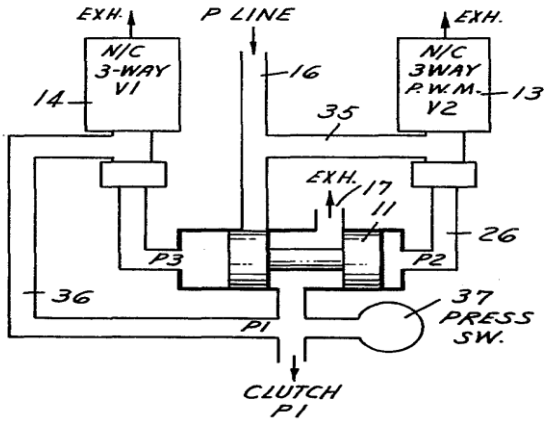

Fig.-1 longitudinal sectional view of an electro-hydraulic valve system.

The ON/OFF valve is configured so that fluid pressure applied to the clutch through port also enters the inlet port (29) through conduit (30). When the ON/OFF valve (14) is de-energized, the inlet port (29) is held closed so that no fluid can flow into valve from the clutch port and any fluid in the valve or in the cavity (30a) formed by the end, the bore and the spool is vented to sump through an axial exhaust port (32) through protrusion. When the valve is energized, the exhaust port (32) is held closed and the inlet port (29) is opened so that any fluid pressure applied to the clutch enters through inlet to cavity (30a).

The device is mounted to the transmission with surface in sealing engagement on a like surface in the transmission with the ports corresponding to ports 16, 17 and 18 in block (10) and with corresponding threaded holes aligning with mounting holes (34) for receiving bolts. As shown in Fig. 2. Channels 35 and 36 are cast in block and form conduits for linking inlet port with conduit (25) and clutch port (18) with conduit (30) when block (10) is secured in sealing engagement with the transmission.

The operating sequence of the device is as follows: To fill the clutch, PWM valve is activated to a predetermined duty cycle in the range of 30% to 100% which produces a fluid output into cavity (26) causes a force to act to the left on spool overcoming the force of spring (19) causing spool to move to the left exposing inlet port and allowing it to communicate with the clutch port (18) and closing off exhaust (17). In this position, fluid is flowing in through port (16) into cavity (21) out through port 18 to the clutch at a pressure of 15-40 PSI depending on the back pressure caused by compressing the springs in the clutch and the rate of fill of the clutch cavity. When the clutch is filled, the pressure will very rapidly rise toward line pressure as flow is dead headed into the full clutch. At this point, a pressure transducer (37) installed in taped hole 37 will sense the rise in pressure and simultaneously energize ON/OFF valve 14 causing fluid at clutch port pressure to fill cavity 30 and

exert a balancing force on the end of the spool and reduce the duty cycle input to valve 13 and 15% to 30%.

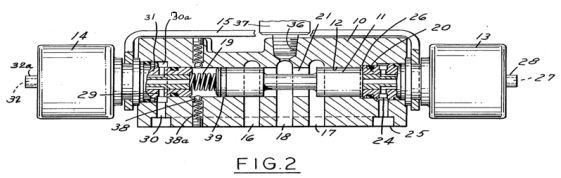

FIG.2

Fig.-2 is a plan view of a monitoring surface of the valve system

Alternatively, instead of using a pressure transducer 27 to sense the clutch full condition, the fill cycle can run on a time cycle so that after a predetermined period of time, ON/OFF valve 14 is switched ON and the PWM duty cycle to valve 13 is reduced to 15% - 30%. This method does not take into account variations in clutch volume and can tend to give poor quality shifts compared to the transducer monitored fill cycle.

The force on spool from the fluid pressure in cavity 30 pulse the force due to spring 19 will overcome the force due to the fluid in cavity 26 and cause the spool to move to the right restricting the inlet port 16 and consequently the flow through port 18 to the clutch. The spool 11 will assume a position where fluid will be metered at the intersection of spool and port 16 such that output pressure to the clutch and thus fluid pressure force in cavity 20 will equal the PWM valve 13 input pressure into cavity 26 less the pressure necessary to equal the force due to spring 10. The spool will remain in this equilibrium position maintaining the clutch pressure as long as the PWM output remains constant. To increase pressure in the clutch, the duty cycle to the PWM valve 13 is increased increasing the pressure in cavity 26 causing a force imbalance on spool moving it to the left allowing the clutch pressure to increase until the pressure force in cavity 30 again causes the spool to balance with the clutch pressure again equal to PWM pressure less the spring force.

Once the clutch is filled and equilibrium is attained which takes about 0.1 – 0.3 seconds, the clutch is engaged smoothly by linearly increasing the duty cycle of the PWM valve, in a preset value of 15 % - 30% to 100% which due to the balancing effect of the clutch feedback pressure into cavity 30 linearly increases the clutch pressure up to line pressure less the spring force equivalent pressure which is approximately 10 PSI. At this point, the ON/OFF valve 14 is de-energized which reduces the pressure in cavity 30 to zero while the pressure cavity 26 is still at line pressure, the force imbalance which is nearly 150 PSI line pressure moves the spool to the left end stop which is the end 20, fully opening port 16 to communicate with port 22 via cavity 21 supplying full line pressure to the clutch.

Detents are provided through the action of springs 38a urges balls 38 into bore 12. The spool is provided with a detent groove 39 around its circumference so that when the spool is in the extreme left position, the detent balls 38 engage detent groove 39 and hold the spool securely enough to withstand the force of spring 19 urging it to the right.

With the spool 38 thus détentes, the PWM valve can be turned off so that the pressure in cavity 26 is vented to sump through exhaust port 25 and the output to the clutch remains at line pressure.

The electro hydraulic valve control system set forth in any of claims wherein said body of said spool valve is provided with a passage providing communication between the inlet of said pulse width modulated valve and the inlet to said valve body and a passage providing communication between the inlet of said ON/ OFF valve and the outlet of said body.

The electro hydraulic valve control system set forth in any of the conditions including a pressure transducer for monitoring the fluid pressure in the outlet of the spool valve for sensing the increase in pressure due to a filled condition of a device to which the fluid is being delivered by said outlet.

IV. CONCLUSION:

It can thus be seen that there has been provided an electro hydraulic system which can be operated to fill a device such as a clutch cavity with hydraulic fluid at a low pressure, thereafter increase the pressure to line pressure, to bring the clutch faces into non-slipping high pressure engagement and to hold the clutch in this position, followed by de-clutching by reducing the pressure within the clutch from line pressure to zero.

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