

Design & Development of Electro Hydraulic Control Valve for Integration of Hoist and Steering System of a Dump Truck (35t)

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ABSTRACT

The intent of this paper is to propose a system to control the steering operation and hoist operation of the Dump truck through combination of electro hydraulic valves and priority valve housed in Integrated manifold block. Electro hydraulic control valve(EHCV), and Electronic controller unit (ECU) for steering and hoist operation of the dump truck. The orbitrol valve consists of load sensing line, when the Orbitrol valve sense an effort on the steering wheel by the operator, the load sensing line will give a feedback signal to the electro hydraulic valve, which will divert the pressurized hydraulic oil to the steering system for steering operation, else the hydraulic oil is available for hoist operation. The hoist operation is control through Electronic Controller Unit

(ECU). If there is no signal from the controller for hoist operation the hydraulic oil will flow back to tank. The Electronic controller will energize the combination of solenoid operated valves, depending upon the input received from operator through the momentary switch (Raise Switch, Lower/Float Switch, Hold Switch) mounted inside the cabin, which will allow the flow of pressurized hydraulic oil to the hoist cylinder for body raise and lower operation through electro hydraulic control valve. The electronic controller memorizes the signal from momentary switch and energizes the solenoids as per the logic till the next input signal receive by controller.

KEYWORDS: Electro Hydraulic Control Valve (EHCV) Steering Control Unit (SCU), Electronic Controller, Load Sensing Unit, Priority Valve, Dump Truck.

Introduction

In the existing hoist system, hoist operation is carried out through air over hydraulic system. As air is the primary source for hoist operation, operator has to wait for the pressurized air to build up required for hoist operation. The system having external priority valve to control the flow of pressurized oil for hoist or steering operation. With the recent advancement in the hydraulic system the hoist and steering operation along with priority valve is integrated into the single unit. The introduction of Electro Hydraulic Control Valve (EHCV) in dump truck will control the hoist and steering operation. The EHCV unit consist of inbuilt priority valve which will provide the pressurized oil for steering or hoist operation depending upon the operator input.

Objective

- To reduce the operator effort require for steering operation using EHCV.

- To easily control the position of dump body by using EHCV, ECU and momentary electric switch
- To provide safety for hoist operation during equipment movement.
- Modular family concept to increase the interchangeability of individual valves.
- To make Hoist system more reliable and rugged.
- Soft buttons/switches to apply / release Hoist system.

Steering System:

The steering system consists of Steering Wheel, Steering Control Unit (SCU) and Electro Hydraulic Control Valve (EHCV) for steering operation of the dump truck. The SCU consists of load sensing valve, which is connected to the electro hydraulic control valve (EHCV). When the SCU sense an effort on the steering wheel by the operator, the load sensing line will get pressurize (125bar) and will give a feedback signal to the electro hydraulic control valve. The priority valve in EHCV will sense the load from SCU then it will divert the

ABBREVIATIONS: ECU - Electronic Control Unit; EHCV - Electro Hydraulic Control Valve; SCU - Steering Control Unit.

Hoist System:

The hoist system is used to control the position of dump body. The hoist system consist of momentary hoist switch button (Raise, Lower/Float, Hold), Electronic Controller Unit (ECU), and Electro Hydraulic Control Valve (EHCV). The Electro Hydraulic Control Valve with five solenoid S1, S2, S3, S4 and S5 valve is used for hoist operation (Refer Table-I). During hoist operation the pressure on the load sensing line from SCU is zero. As there is no demand for steering operation, the pressurized oil is available for hoist operation. Based on the input from the operator for hoist operation priority valve in EHCV will divert the pressurized oil to hoist cylinder. When there is No load from SCU and no command from operator for hoist operation then the pressurized oil will be diverted back to tank.

Raise Operation:

When the Raise Switch is pressed by the operator the ECU will receive the signal, which will generate a command to energize S1 solenoid on EHCV for raising the body. The EHCV will divert the pressurized oil (175 bar) to hoist cylinder for dump body raise operation.

Lower Operation:

When the operator press the Lower/Float Switch, the signal will be received by ECU, which will generate a command to energize S2, S3, S5 solenoid valve on EHCV. The EHCV will divert the pressurized oil (175 bar) to hoist cylinder for dump body lower operation. The operator has to continuously press the lower button for lowering the body. During the lower operation hydraulic pump is loaded and body will come to rest position by pressurized oil within less time.

Float Operation:

When the operator press and release the Lower/Float Switch, the ECU will generate a command to energize S3, S4, S5 solenoid on EHCV which will divert the pressurized oil from hydraulic cylinder to tank to lower the body due to gravity. During float operation hydraulic oil from the pump is sent back to tank via EHCV and the pump is not loaded. The time taken by the body to come to rest position is more in float operation compare to lower operation.

Hold Operation:

When the operator press the Hold switch the ECU, will de-energize all the solenoid of EHCV and the dump body will remains in hold position.

TABLE I

Operation	S 1	S 2	S 3	S 4	S 5
	1	2	3	4	5
Raise	Y	N	N	N	N
Lower	N	Y	Y	N	Y
Float	N	N	Y	Y	Y
Hold	N	N	N	N	N

Salient Features of Control Valve:

Following are the features of cartridge type hoist control valve.

1. Solenoid operated cartridge type control valve.

2. Elimination of air system and its related components.
3. This is a custom designed valve using cartridge valve.
4. The valve is functionally identical to the existing spool type control valve.

Engineering of EHCV on dump truck

Electro Hydraulic Control valve (EHCV) was fitted on dump truck.

Following are the pressure relief settings made available on the EHCV.

Steering & Hoist line Relief Settings:

Steering & Hoist relief pressures was set to 125 bar & 175 bar respectively by pressure adjustment procedure.



Fig. 2. Hoist line relief Pressure adjustment screw.

No- Load Testing:

The dump truck was initially tested in no load condition and the steering & hoist operation is working satisfactorily. The dump body hoist & lowering time are recorded.

Body Raise time : 12 ± 2 sec
Body Lowering time : 17 ± 2 sec

Load testing:

Dump truck was loaded with mud to its rated payload of and load test was carried at the test track shown in Figure 2.



Fig. 3. Loading of Dump Truck.

Following are the data captured during load trials of dump truck fitted with EHCV and is mentioned in the graphs.

1. Steering effort(Graph.no.01)
2. Steering Pressure during lock to lock (Graph.no.02)
3. Hoist pressure during body raising (Graph.no.03)
4. Temperature of the hydraulic oil Graph.no.04)



Fig. 4. Steering effort measurement.

Advantages of EHCV:

Following are the Advantages of cartridge type hoist control valve :

1. Ease of enabling safety interlocks to avoid accidents shown in Figure 05 & Figure 6.
2. Electrically operated: Elimination Pneumatic components.
3. Improved Operator Comfort: No need to hold the switches continuously for hoisting and independent of air system.
4. Easy serviceability: Individual cartridge valve can be replaced.
5. Diagnostics: Ease of diagnostics, pressure measuring ports along with minimes couplings are provided in block.
6. Manual lowering : Manual override option provided to lower the dump body in case of pump or engine failure.

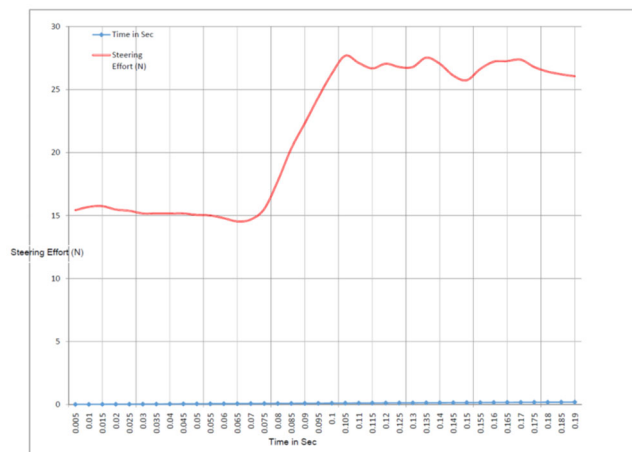
7. Hoist assist ports: are provided to operate dumping/hoisting during engine or pump failure
8. Inbuilt load sense relief valve for Steering circuit.
9. Ease of introducing interlock option.



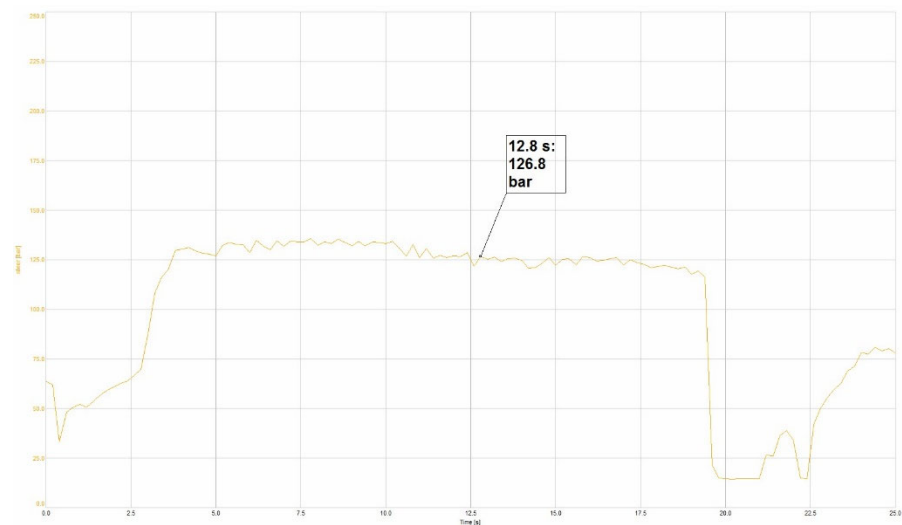
Fig. 5. Accident due to forward movement of truck with body in raised condition



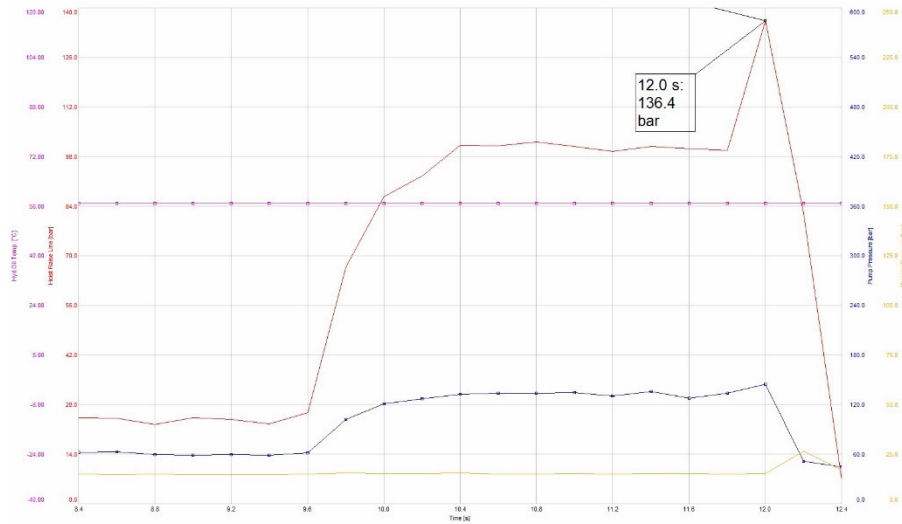
Fig. 6. Accident due to Roll over of truck while dumping(Hoist operation).



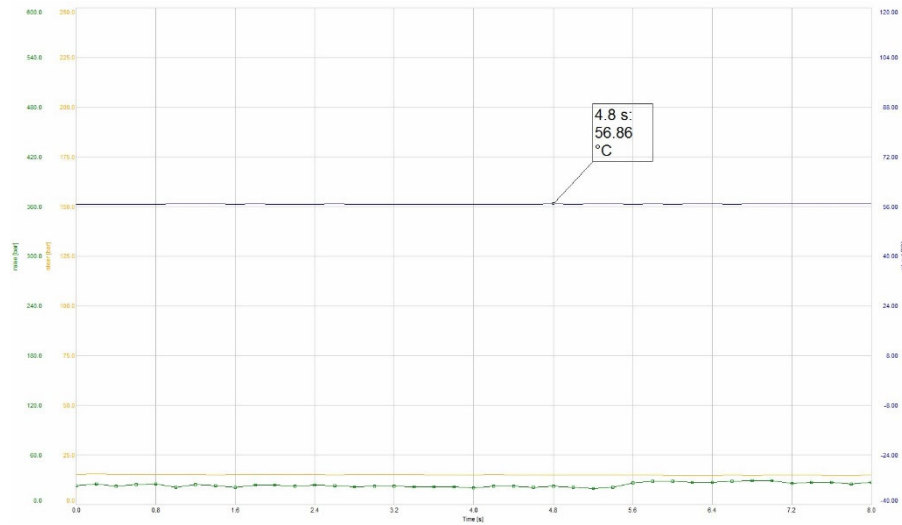
Graph 1. Steering Effort.



Graph 2. Steering pressure measurement during lock to lock operation.



Graph 3. Hoist Pressure while dumping.



Graph 4. Hydraulic oil temperature.

TABLE 1:

Comparison of the EHCV with pneumatically operated hoist control valve -test results

Sl.No.	Parameter	Pneumatically controlled Hoist valve	Electro hydraulic control valve (EHCV)
01	Total no. of linkages to operate hoist valve	04	No linkages, only electrical wire harness
02	Waiting time to operate hoist	02 min to build pneumatic pressure to 8bar initially	No waiting time, since controlled electrically.
03	Reliability	Less reliable	More reliable
04	Body raising time	15 sec	12 sec
05	Lowering time	19 sec	17 sec
06	Hoist relief pressure	175 bar	175 bar
07	Response of hoist system	slow	fast
08	Provision for interlocks	Difficult to make interlocks	Easy for making interlocks

Conclusion

EHCV is more reliable and modular type when compared to other type of hoist control valves which are operated by pneumatic. EHCV allows to enable safety interlocks for the dump truck. Also it is easy for diagnosis of the problem in the hoist circuit. Safety interlocks will help to avoid accidents. The average steering effort measured is around 20N against the recommended maximum steering effort of 115 N as per ISO 5010

Literature Survey

The following researches deal with the on/off solenoid valves used for hoist valves.

01. Malaguti and Pregnotato. Proportional control of on/off solenoid operated hydraulic valve by nonlinear robust controller. Proceedings of the 2002 IEEE international symposium.

They investigated about continuous and proportional control of on/off solenoid driving spool directly by nonlinear control using variable structure control VSC and using solenoid model to estimate spool position. Magnetic model of solenoid and hydraulic flow forces of valve were carried out without to use FEM techniques. The spool position was estimated without a sensor by using the derivative of current method.

02. Venkatesh Babu, K. Sathish kumar. Design and fabrication of dump truck tilting system. International journal of pure and applied Mathematics volume 116 no.14 2017, 327-334 ISSN(printed version):1311-8080.

Presented about the types of dump body tilting doors and their design.

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