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Reduction of Noise Level in Hydraulic Power Steering in Commercial Vehicles

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Abstract*: To achieve low levels of noise and vibration in the interior of a vehicle, the noise levels from major sources such as the engine and transmission have been greatly reduced in recent years. Unfortunately, this has meant that the noise from ancillary components has become relatively more prominent. One such component is the power assisted steering system, the noise from which is a problem on nearly all vehicles. In this paper, a study of a hydraulic directional valve using a tridimensional fluid-dynamic approach will be shown. During the valve spool displacement, the fluid-dynamics inside the valve creates forces that could reduce the valve performance. The oil passing through orifice area of spool opening causes sudden compression and decompression of oil The spools are machined with control notches of different shapes at the end of land. These grooves are designed to change the valve throttle area in relation with spool displacement. This is intended for gradual compression and decompression of oil. The grooves of notches of hydraulic spool valves are usually designed into various shapes for their desired flow characteristics. The aim of this paper is to clarify the effects of the groove shape on the flow characteristics through computational fluid dynamics (CFD) and experimental investigations. The k–e turbulence model is used to simulate the pressure distributions of the flow fields inside notch with its corresponding typical structural grooves in order to analyze the changes of restricted locations along with the openings and, furthermore, to calculate the flow areas of the notches.

***Keywords*: Hydraulic Power Steering**

1. Introduction

The steering system is a group of parts that transmit the movement of the steering wheel to the front, and sometimes the rear, wheels. The primary purpose of the steering system is to allow the driver to guide the vehicle. When a vehicle is being driven straight ahead, the steering system must keep it from wandering without requiring the driver to make constant corrections. The steering system must help to maintain proper tire-to-road contact. The driver should be able to turn the vehicle with little effort, but not so easily that it is hard to control.

Power steering pumps used in automotive power assisted steering application can, as a result of their mechanical and hydrodynamic operation, combine with other system components to generate undesirable noise that originates from a pressure pulse wave in the hydraulic fluid. This wave has the ability to propagate through the fluid and system boundary, causing structural vibration which can produce noise which is audible to a vehicle occupant at particular operating conditions. This noise level is much higher in case of commercial vehicles such as trucks, buses, etc. This noise generation mainly takes place due to flow of high pressure ATF through the spool valve, its grooves and holes made in the piston of hydraulic power steering gear. Noise can also be produced because of the error in the geometry of spool valve or manufacturing defects in the spool valve. This error and manufacturing defects causes noise generation which should be compensated.

2. Problem statement

"Reduction of noise level in Hydraulic Power Steering in Commercial Vehicles." In present hydraulic power steering system, the noise was found on the assembly line of Ashok Leyland. It was found that spool valve inside the piston is the major source of noise generation in Hydraulic steering gear when the vehicle is running on the road.

A. *Objectives*

1. Reduction of noise in hydraulic power assisted steering in commercial vehicles produced during its operation under certain working conditions.
2. Gradual Discharge of Automatic transmission fluid through spool valve inside the piston in steering gear.
3. To achieve the smooth and noiseless working of hydraulic power steering under various operating conditions

3. Methodology

When the pressurized oil is passing through the small opening of the spool valve causes the sudden compression and decompression of oil, which induces the pressure pulses and noise in the system. Triangular notch is providing on the land of spool valve which increases the valve opening area. The CFD simulation is done before and after the notch to determine the flow velocity and pressure distribution.

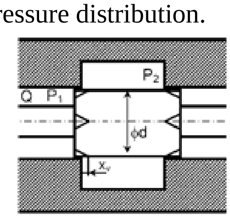

Fig. 1. A spool Valve with control edges (Notches) [3]

Sometimes, the spools are machined with control notches or grooves of different shapes at the edge of the spool land. These grooves are designed to change the valve throttle area in relation with the spool displacement according to certain laws. This may be intended for gradual compression or decompression of oil. Triangular notch is selected for the modification of spool valve in our project.

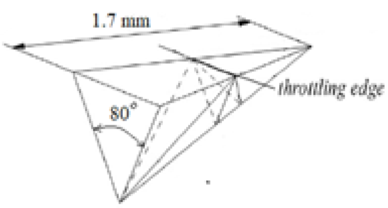

Fig. 2. Geometry of Notch [2]

4. Analysis

Noise testing of the hydraulic steering gear was conducted in ZF steering gear plant at vadhu-budruk by Welan Technologies. Test was done on two steering gears at two different locations in the plant.

Instrument used for the test was “SMI See SV Acoustic Camera”

A. Noise testing before notch

In the given images the source localization is done with help of Acoustic Camera. The captured frequency range is from 50 Hz to 1400 Hz which is further reduced to 100 Hz to 2000 Hz with help of post processing software. The 1/3 octave data is given in the table 1.

B. Testing results

Table 1
Testing Results in Service Department (before Notch)

Frequency (Hz)	Band power (dB)
20	83.4
25	81.2
32	85.1
40	83.7
50	85
63	84.1
80	79.2
100	78.7
125	73.4
160	75.1
200	70.3
250	71.4
315	77.3
400	75
500	81.3
630	79.8
800	77.2
1000	76.4
1250	75.3

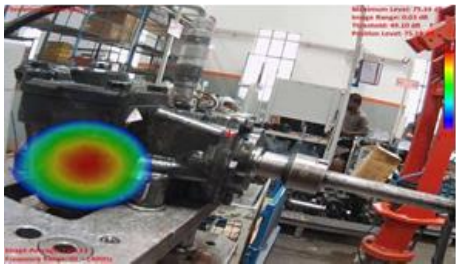

Fig. 3. Localization of noise source

C. Noise testing after notch

In the given images the source localization is done with help of Acoustic Camera. The captured frequency range is from 50 Hz to 1400 Hz which is further reduced to 100 Hz to 2000 Hz with help of post processing software. The 1/3 octave data is given in the table 2.

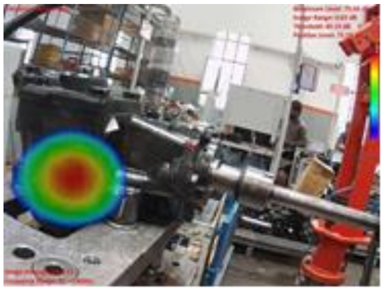

Fig. 4. Localization of noise source

Table 2
Testing Results in Service Department (after Notch)

Frequency (Hz)	Band power (dB)
20	69
25	66.1
32	69.8
40	68.7
50	69.4
63	68.1
80	65.3
100	65.2
125	60.9
160	64.6
200	58.2
250	59.6
315	66
400	64.6
500	69.4
630	66.3
800	65.7
1000	63.5
1250	63.2

D. CFD simulation of spool valve

CFD analysis is done for the flow and volume of oil inside the piston and spool valve. Grid model is established using the flow field inside the spool valve and piston. It is divided by the application of tetrahedral mesh. The k–epsilon turbulence model is selected.

CFD Analysis of the spool valve with and without notch is as follows,

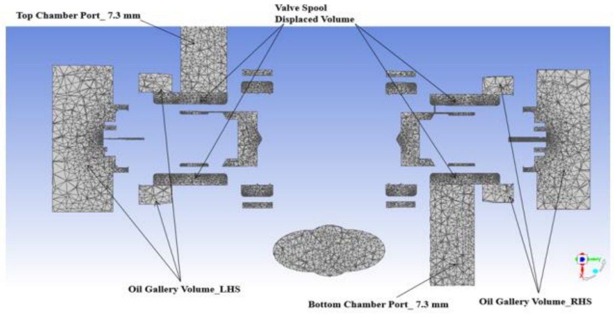

Fig. 5. Meshing of Valve Spool Fluid Domain SAP Condition (without notch)

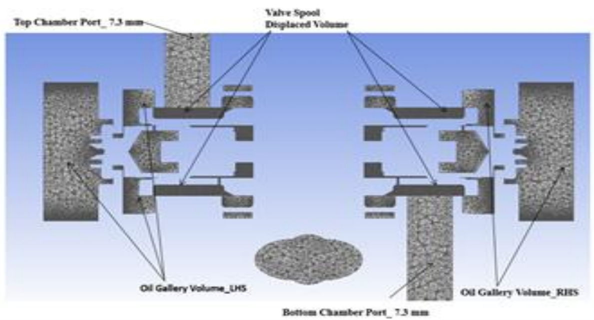

Fig. 6. Meshing of Valve Spool Fluid Domain SAP Condition (with notch)

Table 3
Boundary Conditions for Valve Spool

S. No.	Naming of Parts	Boundary Condition Type	Values
01	Inlet	Velocity Inlet	6.69 m/s
02	Outlet_1 (Top Chamber)	Pressure Outlet	150 bar
03	Outlet_2 (Bottom Chamber)	Pressure Outlet	Atmospheric Condition
04	Outlet_3 (Return Line)	Pressure Outlet	Atmospheric Condition
05	Wall Domain	No Slip Condition	NA

5. Result and discussion

Steering Gear analysis was done by noise testing as well as CFD analysis. Results of both testing are discussed as follows.

A. Noise test results

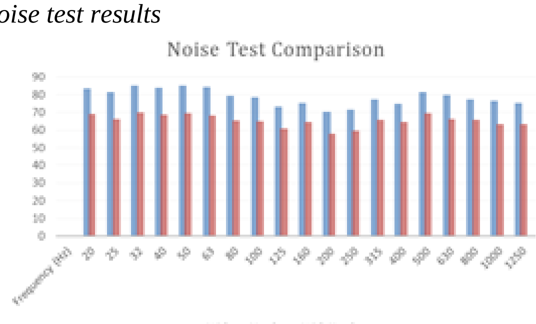

Fig. 7. Noise test comparison

B. CFD analysis results

In this maximum pressure in the steering gear for the spool valve with and without notch is analysed which is as follows:

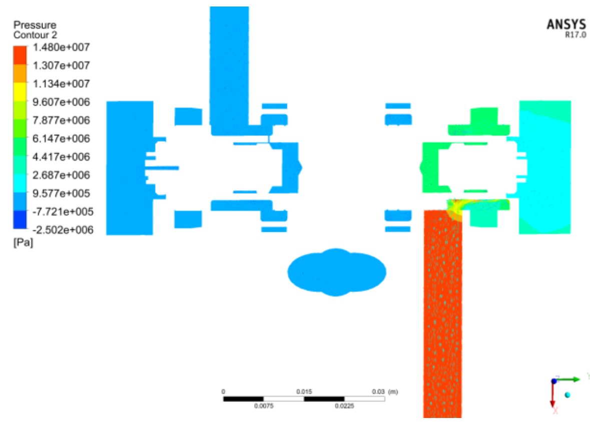

Fig. 8. Total Pressure Contour (148 bar) (before Notch)

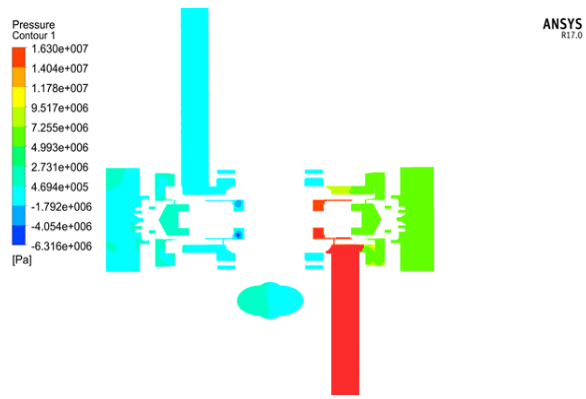

Fig. 9. Total Pressure Contour (163 bar) (After Notch)

Maximum velocity contour for the spool valve with and without notch is as follows:

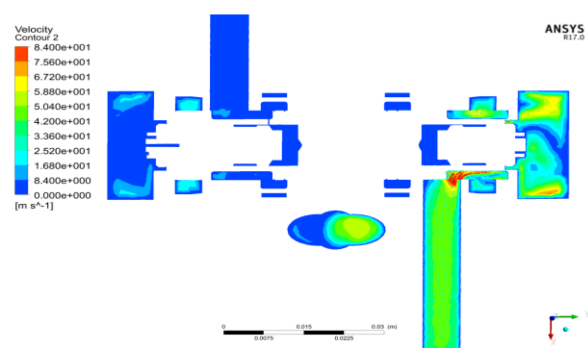

Fig. 10. Velocity Contour (max Velocity 84 m/s) (before notch)

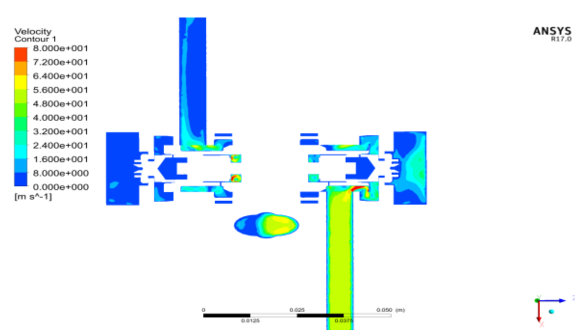

Fig. 11. Velocity Contour (max Velocity 80 m/s) (after notch)

C. CFD analysis comparison

Table 4
CFD Analysis Comparison

Parameters	Regular Spool Valve	Spool Valve with Notch	Comparison
Maximum Static Pressure	148 (bar)	163 (bar)	10.12% (increase)
Fluid Maximum Velocity	84 (m/s)	80 (m/s)	4.8% (decrease)

6. Conclusion

1. Hydraulic power steering in automobiles produces noise during its working conditions. This noise level is much higher in the case of commercial vehicles such as trucks, buses, etc. Therefore, it causes Discomfort to the occupant in the driving cabin. The main source is sudden compression and decompression of oil in small openings of a spool valve, which causes the generation of noise due to pressure and power loss.
2. Pressure and power losses are reduced by increasing the valve opening area by providing the triangular notch on the lands of the spool valve which increases the valve opening area and improves the flow of the hydraulic oil in valve spool.
3. The noise level measured with the help of an acoustic camera, which uses the 1/3 rd octave band get reduced average sound level in the range of 10-15 dB.
4. The CFD simulation of the spool valve is done which shows the reduction in velocity from 84 m/s to 80 m/s and total static pressure is increased from the 148 bar to 163 bar after modification of spool valve which is helpful in the hydraulic power steering gear.

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