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Study for Whoop Noise Reduction in passenger vehicle with Clutch Hydraulic System

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ABSTRACT

The noise, vibration and harshness (NVH) is an important aspect in improving driving comfort. Low noise and vibration is one of the primary requirements of passenger cars and plays an important role in the perception of customers. It includes a silent cabin with minimum vibrations and smooth and quite operation of the parts.

In Diesel vehicle, Engine vibrations are transferred to clutch pedal through fluid pulsation inside the clutch operating system. In some cases, while operating clutch, vibration gets amplified and a noise is generated which is called a whoop noise. Level of whoop noise generated during clutch operation should be as low as possible to avoid uneasiness to the customers. To strike a balance between cost and good NVH is the biggest challenge for NVH engineers in present scenario.

This paper elaborates the study for root cause analysis and reduction in whoop noise generated during clutch pedal operation

INTRODUCTION

In recent years, customers' sensitiveness is growing for quiet and smooth operating vehicles. Customers look for the product from the aspects of comfort and effortless driving experience. Noises inside the passenger cabin and vibrations perceived while operating the clutch pedal gives an insight about vehicle quality.

The excitations to clutch system come due to deformation of crank shaft generated because of combustion. Deformations of crankshaft generate the axial displacement and vibrations of flywheel over its equatorial line. These vibrations are transmitted to the clutch and from clutch to clutch pedal through fluid pulsation, causing clutch pedal vibration. Sometimes vibrations are amplified by clutch pedal housing and low frequency noise is generated during clutch operation in idle or during driving, is called whoop noise. fig no.1 shows when clutch is operated between 9 to 9.5 sec, 11 to 11.5 sec, 13 to 13.5 sec then low frequency (200-400 Hz) noise is generated, it is whoop noise.

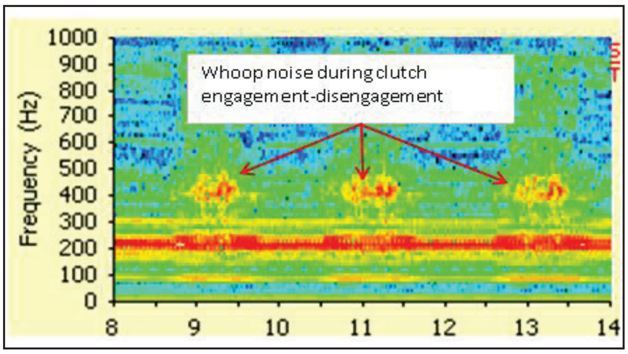

Figure 1 – Noise near clutch pedal during clutch operation

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The Whoop noise level is affected by several parameters like; Engine vibrations, Clutch dimensions, flywheel concavity, flywheel run out fluid Pipe material. Figure 2 shows the hydraulic clutch operating System layout

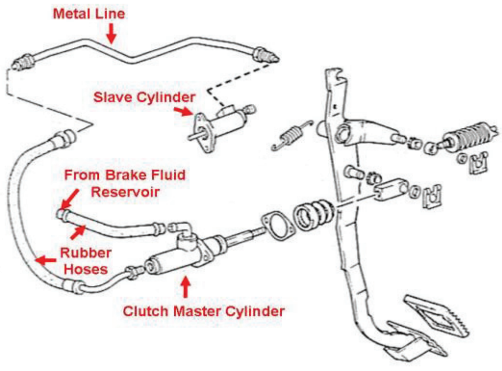

Figure 2 – Clutch Operating System

The paper describes a research on root cause of Whoop noise and possible methods to reduce Whoop noise in a vehicle.

1. WHOOP NOISE PHENOMENON DURING CLUTCH OPERATION

1.1 Vehicle Parameters

Table 1 – Testing vehicle detail

Name	Parameter or Type
Vehicle type	Hatchback
Vehicle Kerb weight	963 kg
Drive mode	FWD
Transmission	5-Speed Manual Transmission
Fuel type	Diesel
Engine	4-Cylinder , 1300cc

1.2 Problem Statement

Engine Vibration due to combustion are Transferred to Clutch Pedal through Clutch Release System. Transfer path of vibration and noise is shown in in Figure 3. When Pressing Clutch Pedal, fluid under pressure causes the piston of slave cylinder to move Release bearing, thus disengaging the Clutch. When the pedal is released, the diaphragm spring pushes the slave cylinder back, which forces the hydraulic fluid back into the master cylinder and in the process clutch engages.

Most NVH related problems are reported during the process of clutch engagement, disengagement or while holding the clutch pedal. Whoop noise is a phenomenon, caused due to transfer of Engine vibration to clutch pedal through fluid pulsation inside clutch pipe. The noise can be heard during clutch engagement and disengagement.

In this particular case, clutch fluid pipe was replaced from metallic and rubber to plastic pipe for cost reduction. One vehicle was prepared with rubber and metal fluid pipe and other vehicle was prepared with plastic pipe. Whoop noise was observed in vehicle having plastic pipe in idle condition as well as driving condition during clutch operation.

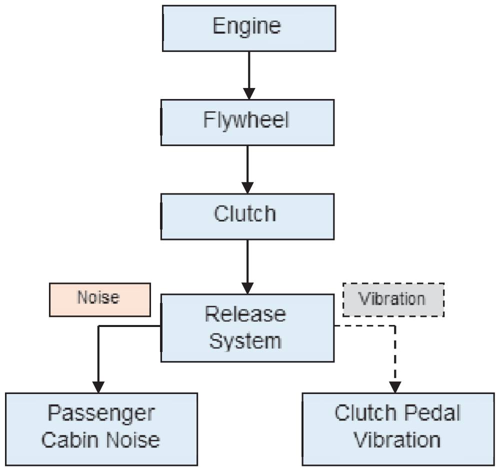

Figure 3 – Transfer Path of Vibration and Noise

2. Objective data measurement in Vehicle

Objective data measurement was done in vehicle at different locations. Sensors type and locations has been described in table no.2.

Table 2 – Sensors Positions

NO.	Sensors type	Sensors locations
1	Microphone	Near CSC and CMC
2	Microphone	Near clutch pedal (passenger cabin)
3	Microphone	Vehicle center position (passenger cabin)
4	Accelerometer	Fluid pipe
5	Accelerometer	Clutch pedal
6	Accelerometer	E/G cylinder head

During clutch operation whoop noise was not observed in vehicle with metal and rubber pipe, noise near clutch pedal (inside passenger cabin) is shown in figure 4. X axis of graphing is showing time in second, Y axis is showing frequency while color is showing magnitude of noise in dBA.

During clutch operation whoop noise was observed in vehicle with plastic pipe, noise near clutch pedal (inside passenger cabin) is shown in figure 5.

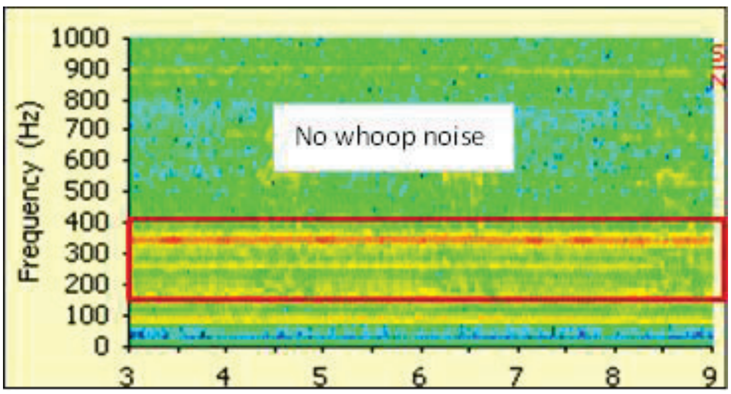

Figure 4 – Noise near clutch pedal with rubber and metal

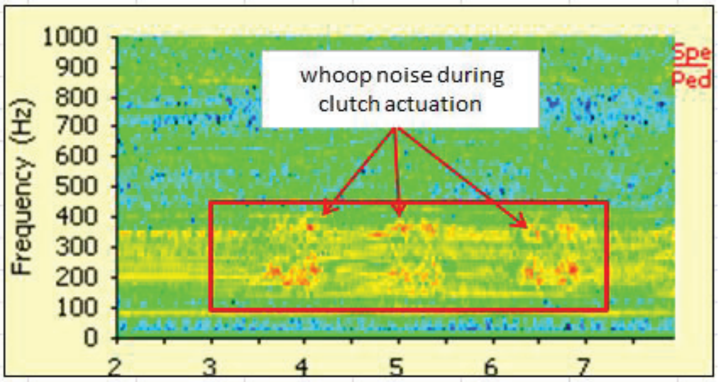

Figure 5 –Noise near clutch pedal with plastic pipe

Whoop noise was not observed in both vehicles near clutch master cylinder (CMC) and near clutch salve cylinder (CSC). Engine vibration level was also similar in both vehicles. Cylinder head vibration (Peak to peak) of both vehicles has been shown in figure 6.

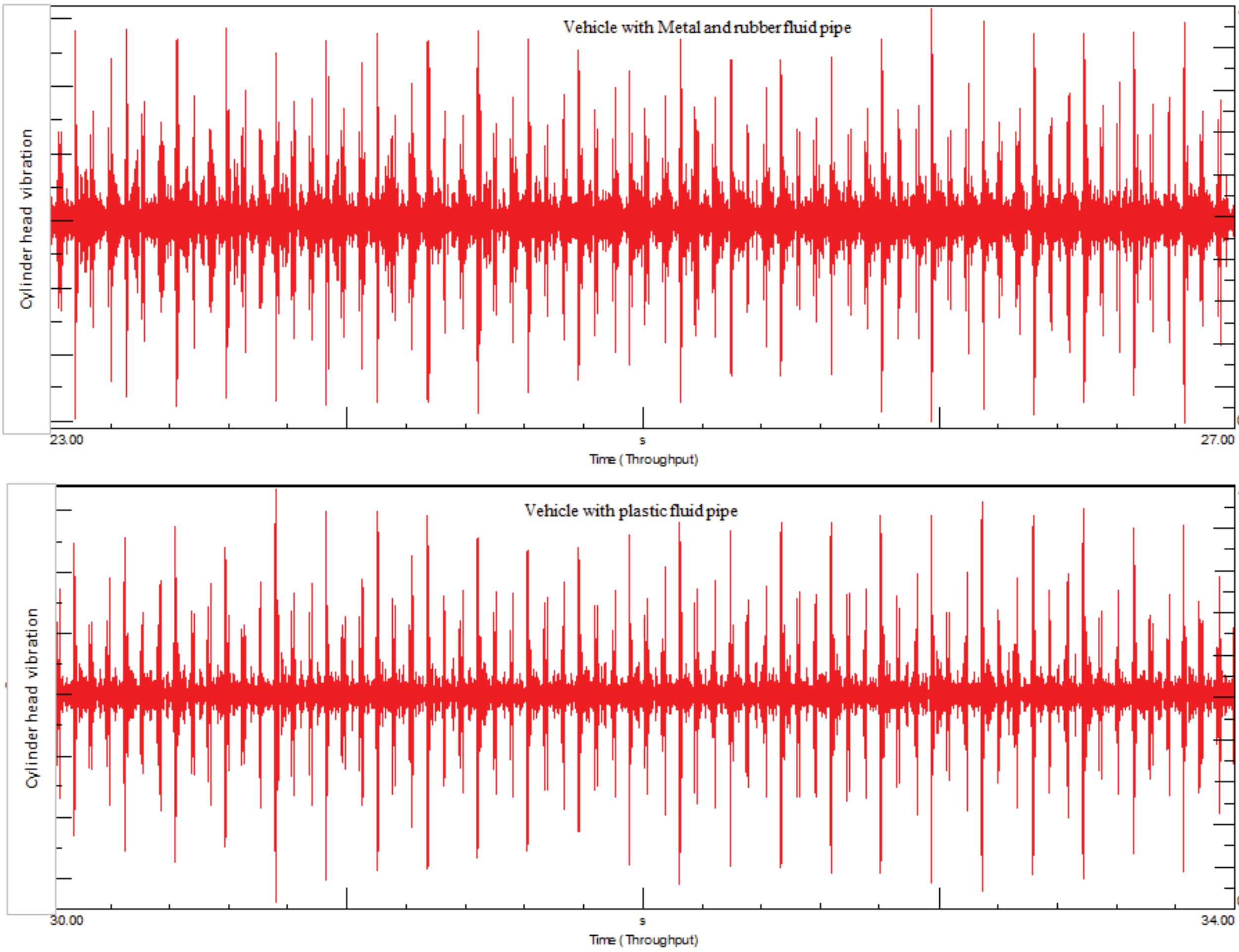

Figure 6 – Cylinder head vibration (Peak to peak 0-500 Hz)

Vibration data was also measured on plastic fluid pipe and on rubber portion of metal and rubber pipe. Vibration data was measured in all 3 directions but difference was observed in fluid flow direction. High Vibrations is observed on plastic pipe in comparison to rubber pipe. Vibration data of plastic pipe has been shown in figure 7 and vibration data of rubber pipe has been shown in figure 8.

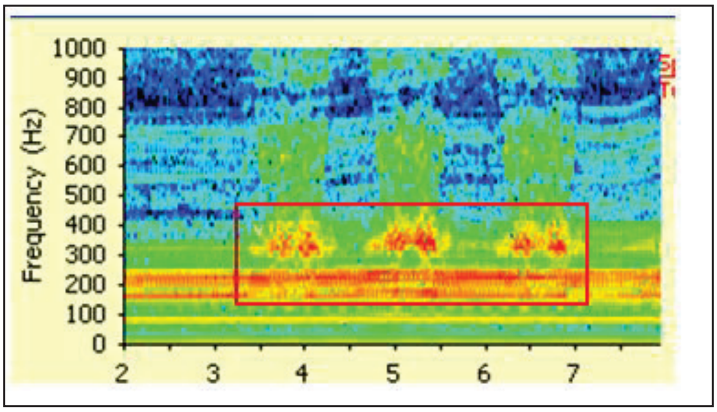

Figure 7 – Plastic pipe vibration

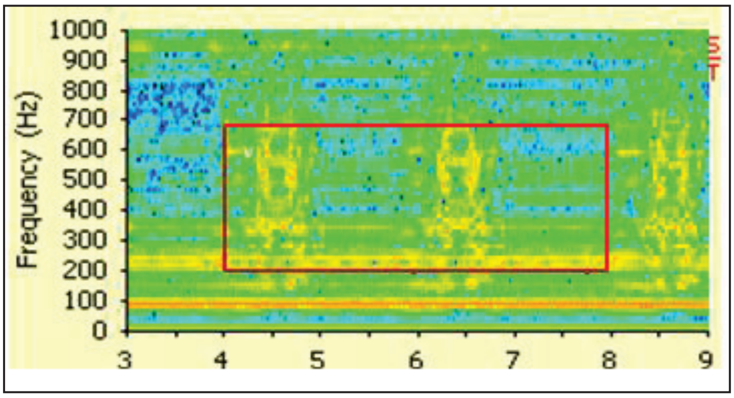

Figure 8 – Rubber pipe vibration

With rubber pipe below 400 Hz vibration level is less than plastic pipe but between 500-600 Hz vibration levels is slightly high. 500-600 Hz vibrations are not responsible for whoop noise.

Plastic pipe vibration is higher in 300-400 Hz band but peak was at 350 Hz in noise data taken near clutch pedal (passenger cabin), refer figure no.5. Peak observed in sound pressure level near clutch pedal may be because of amplification of vibration from clutch pedal. To identify the root cause of amplification from clutch pedal housing, FRF test was done.

3. FRF Test of Clutch Pedal Housing

Frequency response function is experimental modal analysis to find out resonance frequency, Damping and mode shapes. In experimental modal analysis many types of excitations can be provided. In our test, excitation was done by impact hammer. Since frequency of noise was less than 500 Hz. so plastic tip was used in impact hammer. Excitation was provided at point where clutch cable is attached to clutch pedal housing and response was measured at various position of clutch pedal housing and clutch pedal. test result has been shown in figure 9, in FRF test resonance was observed at 350 Hz in clutch pedal arm.

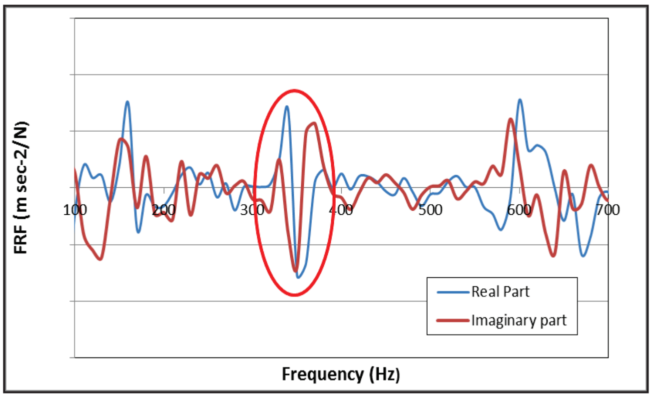

Figure 9 – FRF test result

3. Whoop Noise Test with weight on clutch pedal housing

To evaluate effect of clutch pedal resonance on whoop noise, 100 gram weights were added on clutch pedal at position where higher vibration was observed in FRF test and whoop noise test was done. Weight position has been shown in figure10.With weight whoop noise has been decreased by 6 dB inside passenger cabin near clutch pedal around 350 Hz.Noise level of std condition and with weight is shown in figure 11.

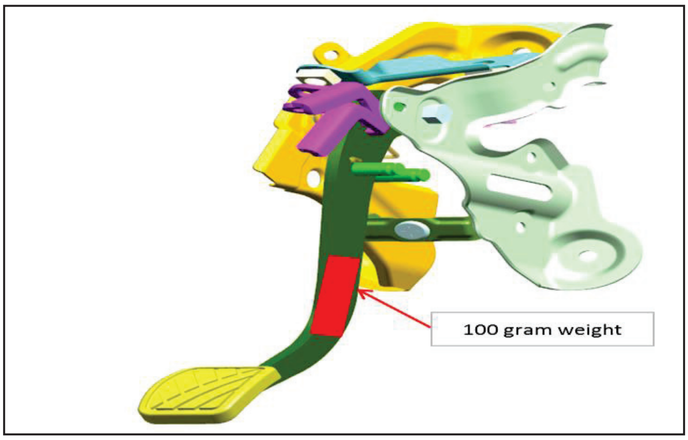

Figure 10 – weight position on clutch pedal

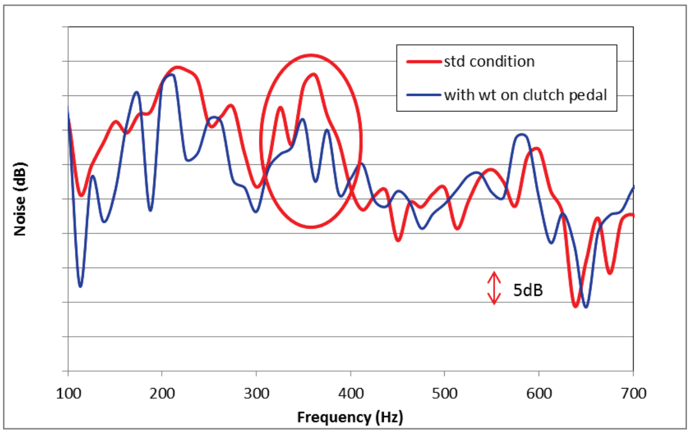

Figure 11 – Effect of weight on (on clutch pedal) whoop noise

4. Evaluation of Clutch pipe length and hardness on whoop noise

Other vehicles of same segment having plastic clutch fluid pipe were checked in idle condition and in driving condition by pressing clutch and it was found that whoop noise level is less than test vehicle. Main difference was found in clutch pipe length and pipe hardness. To evaluate effect of clutch pipe length, length of clutch pipe was increased by 23 percentages and hardness was reduced by increasing inner diameter by 60 percentages and outer diameter by 23 percentages.

Clutch fluid pipe vibration was measured near CMC with long and low hardness pipe and less vibration was observed in comparison to std condition. Vibration data of clutch pipe near CMC is shown in figure 12 and passenger cabin noise data of driver seat is shown in figure 13. Vibration data has been shown on dB scale by taking reference 0.000001 m/sec^2.

Peak vibration near CMC has been decreased by 7-8 dB while passenger cabin noise peak has been decreased by 2-4 dB in 300 to 500 Hz frequency band.

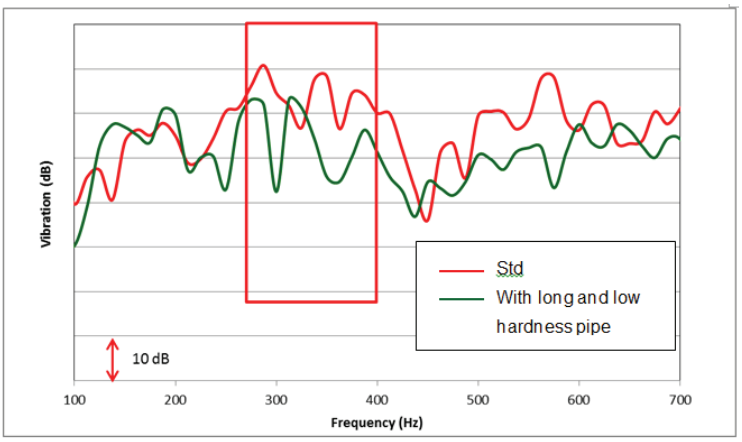

Figure 12 – Effect of pipe length on pipe vibration near CMC

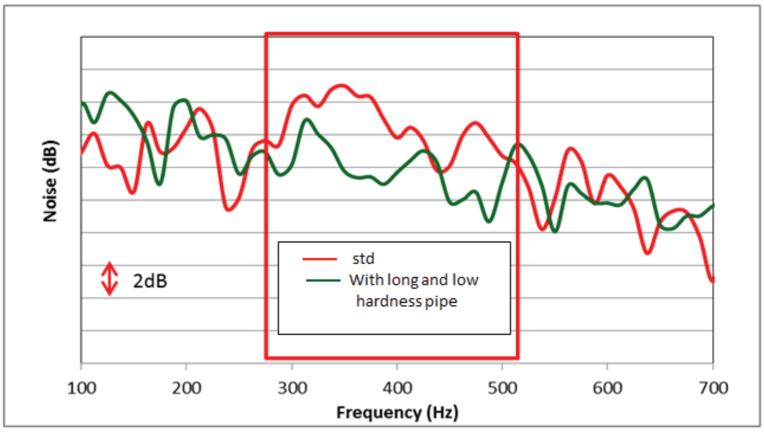

Figure 13 – Effect of pipe length on Passenger cabin noise

5. Evaluation of rubber mass damper effect on whoop noise

Rubber damper was prepared and it was installed near CMC of clutch pipe. Vehicle was parked inside semi-anechoic chamber having cut of frequency 100 Hz. E/G rpm was increased to 2000 rpm and clutch engagement-disengagement was done to generate whoop noise. With rubber damper near CMC, noise level reduction was very less subjectively.

In 2nd trial, Rubber damper was installed near CSC and clutch engagement-disengagement was done at 2000 rpm. With rubber damper near CSC, significant improvement was observed. Std condition data was measured again in semi anechoic chamber to ensure similar test condition and background level. Std condition data is shown in figure 14.

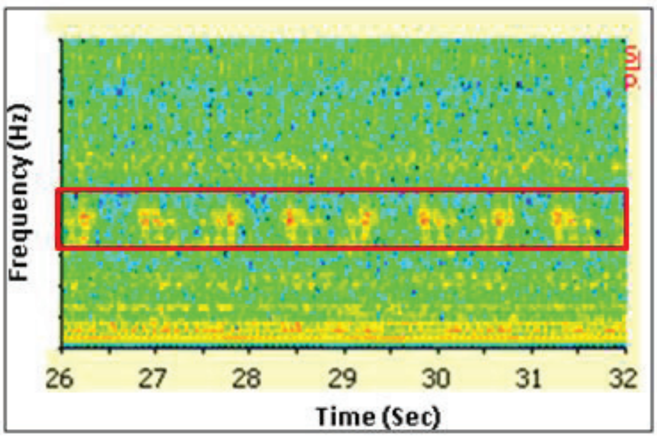

Figure 14 – STD condition noise data inside passenger cabin

With rubber damper near CSC also objective data was measured. Noise data measured near clutch pedal is shown in figure 15. With rubber damper passenger cabin noise near clutch pedal is reduced by 6dBA.

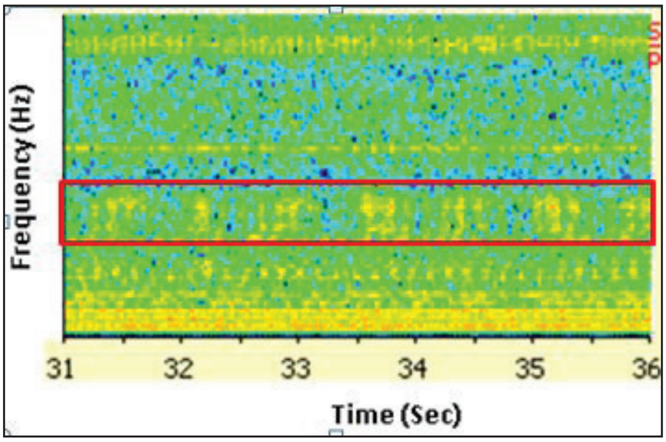

Figure 15 – With Rubber mount noise data inside passenger cabin

6. CONCLUSIONS

Experimental study of root cause analysis of whoop noise has been presented. Some experiments were carried out on vehicle to check effect of clutch pipe length, pipe hardness, pipe material and rubber damper on whoop noise. Correlations between clutch pedal housing resonance and whoop noise. has been established and countermeasure effectiveness is also shown.

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Definitions/Abbreviations

CSC	Clutch release cylinder
CMC	Clutch master cylinder
dBA	Decibel (A-weighted)
RPM	Rotation per minute
FRF	Frequency response function