Frequency Response Function Measurements of Disc and Drum Brake With its Verification by CAE

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Abstract - *Disc brake noise and vibration control in vehicle has received significant attention in the last years, The Noises are generated in Disc and Drum Brakes where there is a transition from static to dynamic condition or vice versa. The Eigen Value characteristics of a brake child parts is the important tool to detect brake noises. Frequency response measurement is frequently used counter-measures for eliminating or reducing squeal ,by getting high excitation frequencies, The Experimentation has been done on disc and drum brake child parts (i.e. caliper, rotor, pad, bracket for disc brakes and back plate, shoes, drum for drum brakes.) by FRF testing and by knowing Eigen values, results will be compared with the CAE results .To verify the Frequency Modes.*

Key Words: Disc & Drum Brake Child Parts, , FRF Measurement, FFT analyzer , Eigen Values, CAE, Abacus, Mode Shapes.

1. INTRODUCTION

Two key characteristics of a comfortable vehicle are good vehicle dynamics and low noise levels. Reduced noise levels in the cabin can be achieved through the tailoring of aerodynamics and drive train isolation. The success of these general noise reduction activities has made other vehicle noise sources, such as disc brake Noise, more apparent. In spite of significant engineering efforts, a generally accepted theory for brake Noise is not yet available, as most experimental, analytical and numerical investigations yield inconsistent results. Therefore, it is one of the most important issues that require a detailed and in-depth study for prediction as well as eliminating brake Noise.

Brake noise that generated in the disc brakes of the automobile & has been handled as a one of the major businesses in the automotive industry due to the persistent complaints that reduces Users satisfaction with their vehicle. Most of the scientist and engineers have agreed that Brake noise in the disk brake is initiated by instability due to friction forces, contributing to self-excited vibrations.

The Braking noise refers to the high-frequency sound emissions from a brake that are generated during the braking phase and characterized by a periodic or harmonic spectrum. This phenomenon is common to both drum and disc configurations and concerns with automotive brakes. Therefore, the geometry and the dimension of brakes can vary widely, thus leading to very different sets of squeal frequencies and associated modes.

The purpose of this report is to discuss frequency response functions. These functions are used in vibration analysis and modal testing. The purpose of modal testing is to identify the natural frequencies, damping ratios, and mode shapes of a structure. And validate those results By using CAE.

2. Frequency Response Function

A natural frequency is the frequency at which the structure would oscillate if it were disturbed from its rest position and then allowed to vibrate freely. All structures have at least one natural frequency. Nearly every structure has multiple natural frequencies. Resonance occurs when the applied force or base excitation frequency coincides with a structural natural frequency .

A frequency response function (FRF) is a transfer function, expressed in the frequency domain. Frequency response functions are complex functions, with real and imaginary components. They may also be represented in terms of magnitude and phase. A frequency response function can be formed from either measured data or analytical functions. A frequency response function expresses the structural response to an applied force as a function of frequency. The response may be given in terms of displacement, velocity, or acceleration.

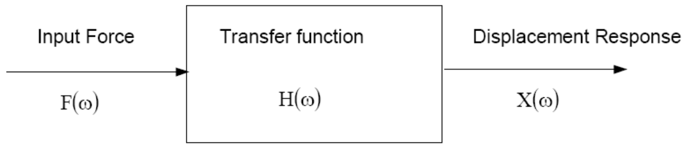

Fig-1: (Frequency Response Function Model)

F(w) is the input force as a function of the angular frequency w . H(w) is the transfer function. X(w) is the displacement response function. Each function is a complex function, which may also be represented in terms of magnitude and phase. Each function is thus a spectral function. There are numerous types of spectral functions. For simplicity, consider each to be a Fourier transform. The relationship in Figure 1 can be represented by the following equations.

$$X(\omega) = H(\omega).F(\omega)..... \quad (1)$$

$$H(\omega) = \frac{X(\omega)}{F(\omega)}..... \quad (2)$$

Usually brake squeal occurs in the frequency range between 1 to 20 kHz. Squeal is a complex phenomenon, partly because of its strong dependence on many parameters and, partly, because of the mechanical interactions in the brake system. Thus Frequency response in this case is considered between 1 to 16500Hz.

3. FRF Measurement Procedures:

1.Component Identification:
Components like Caliper ,Carrier, pads, disc for Disc Brake and Back plate, Leading Shoe ,Trailing Shoe, for Drum brake to be identified. Dissemble the components from each other ,Remove dirt and oil on the surfaces, remove the damping material if attached to the part. Emboss Component Name for easy identification.

2. Provide free hanging condition:
This Condition is to be provided for component to vibrate freely after the excitation.

3. Fix the accelerometer Location:
It is to be fix on the part whose frequency to be measured. The accelerometer location is based on the desirable results to be obtained. generally accelerometer is located at the corners of the component in X,Y,Z Direction to get the maximum frequency response in inplane and outplane modes.

Fig-2: (Accelerometer location on caliper with free hanging condition)

4.Connectivities:
Provide the Power supply to measurement LMS system, attach the LMS to Laptop(in which Software is installed) by LAN Cable .LMS is 5 channel front end, we attach accelerometer and hammer to the 2 channels.

5.System Configuration:
The Primary Settings are to be done in LMS software. like creating working Directory, setting up the two channels for accelerometer and hammer ,calibration of accelerometer ,input parameters like force(N) and acceleration(g) levels generally the force levels are vary in 46N to 250 N and Acceleration level is in between 197 to 2500 g.

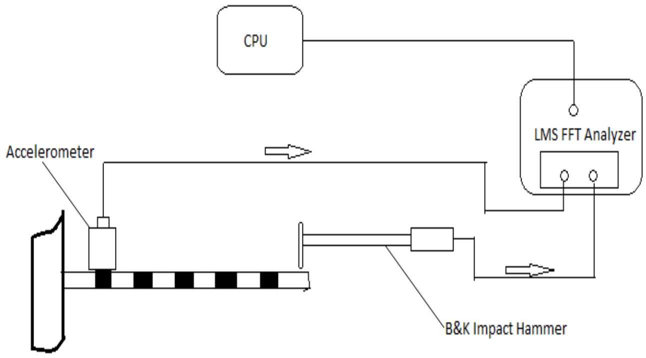

Fig-3: (Basic Equipment for modal analysis)

Fig-3: (LMS FFT Analyzer)

3.1. Hardware Specification:

LMS System:

1. 5 channel Data Acquisition system with maximum sampling frequency of 256khz
2. Hardware, LMS Scadas Mobile SCR01
3. Software, LMS Test Lab 9A
4. Make LMS Belgium.

Accelerometer:

1. Light Weight Modal Accelerometer
2. Weight <3gm
3. Frequency Range upto 17Khz
4. Make DJB France

Hammer:

1. Impulse Hammer/ force Transducer
2. Frequency Range upto 16.5Khz
3. Make Bruel & Kjaer, Denmark.

4.Eigen Values For Child Parts by FRF:

Disc Brake:

1.Caliper Without Piston:

Sr. No.	Frequency(Hz)	Sr. No.	Frequency(Hz)
1.	1173	13.	6822
2.	1253	14.	7441
3.	1319	15.	7707
4.	1411	16.	7862
5.	2442	17.	8115
6.	3354	18.	8791
7.	3639	19.	10639
8.	4165	20.	11733
9.	4380	21.	12283
10.	4795	22.	14559
11.	5906	23.	15815
12.	6423		

2.Disc Brake Rotor:

Sr. No.	Frequency(Hz)	Sr. No.	Frequency(Hz)
1.	1650	13.	9049
2.	3281	14.	9575
3.	3560	15.	9962
4.	3601	16.	10694
5.	3840	17.	11468
6.	4296	18.	11877
7.	6207	19.	12068
8.	7001	20.	12736
9.	7091	21.	12870
10.	8006	22.	13450
11.	8190	23.	14227
12.	8774		15655

3.Bracket:

Sr. No.	Frequency(Hz)	Sr. No.	Frequency(Hz)
1.	942	13.	9049
2.	985	14.	9575
3.	1775	15.	9962
4.	2005	16.	10694
5.	2664	17.	11468
6.	3003	18.	11877
7.	6207	19.	12068
8.	7001	20.	12736
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4.Pads:

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Drum Brakes

5.Backplate:

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5.Eigen Values By CAE:

The Eigen Frequency Values calculated By Modal analysis in abauqs .The input parameters like Material properties, elastic modulus are inserted in software .

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2. Disc Brake Rotor:

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6. Comparison Between FEA & FRF:

1. For Caliper Without Piston

Modes	FEA	FRF	FEA-FRF	% Variation
1	3006	3015	-9	-0.3
2	5236	5356	-120	-2.2
3	7648	7525	123	1.6
4	10944	10407	537	5.2
5	11468	12073	-605	-5.0
6	13271	13667	-396	-2.9

2. For Disc Brake Rotor

Modes	FEA	FRF	FEA-FRF	% Variation
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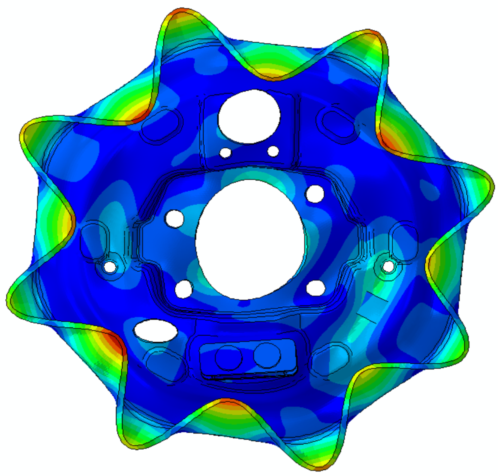
7. Mode Shapes



7. Discussion:

1.The main issues for accurately measuring brake Child Parts natural frequency and damping are Accelerometer location, attachment (cable/wire), contact excitation, and signal acquiring and processing.

2.The accelerometer mass effect on damping may be negligible when compared with the component

3.The frequency modes are selected by adjusting the cursors at highest amplitude peaks, peak may split in two in case of Double Hammer hitting. high frequencies, especially above 6 kHz. However, the effect may be case-by-case or mode-by-mode.

4.It should be noted that the study is based on a actual and CAE verification result for Common sized Components. The above experiment can Serve as a guideline. Further study may Include how the mass addition in component weight effects the frequency shift.

5. The LMS FFT analyzer is in Principle, the ideal method for measuring Natural frequency and damping. However, More channel FFT analyzer (pulse) can be used to measure natural frequencies of bigger component.

6.Every Damping Factor like rubber seals ,oil,etc. have the great influence on the frequency and amplitude.

5.To check wheather the frequencies Drawn are accurate or not ,10 Similar component frequencies are taken into consideration and percentage variation is calculated between them.like if we select caliper for finding Eigen Values(Frequencies) ,we take 10 calipers with same configuration and calculate percentage variation between them , generally percentage variation should be under

3%, if not there is something wrong while taking the frequencies.

6.The Squeal generation Tendency of the component can be Clearly observed in frequency response, those frequencies can be taken into consideration in further investigation on Dynamometer .And the Noise Problem can be Rectified .

7.The general observation states that noise generation is observed at lower frequencies like up to 6-7Khz.

8.The frequency Response of the complete Brake assembly is very Difficult to find as it include lot of Damping factors these damping factors gives nonuniform frequencies at same excitation.

9. The experiments realize done this work show that it is possible to Verify the Natural frequencies given by CAE can be compared With the experimental results to confirming the noise generation tendency of component at particular frequency.

8. Conclusion:

- The Process of Eigen Value analysis & Verification by FRF Testing Provide the Accurate cause of Noise generation in Disc and Drum Brakes.
- It is the system that covers most of the needs of different assessments strategies in NVH testing .
- The System is able to predict subjective rating for every noise event.
- The Mode Shapes we got in abaqus software are the simulation for the actual in plane and out plane modes of child parts.
- Eigen Value Determine whether the expected Frequency response violates the percentage variation criteria with the same part(with same manufactured batch)
- Though the FEA simulations can provide Eigen Values, it will rather be trial-and-error approach to arrive at an optimal configuration and also one may need to run many number of computationally intensive analyses to formulate the 'input-out' relationships for possible prediction. Thus this verification method by actual Experimentation Provide satisfactory solution.

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