Roadmap to Control and Analyse Brake Squeal Warranty Problems

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Abstract

Modern motor vehicles have become increasingly refined and comfortable for the occupants. Interior noise levels continue to become lower, and any noise concerns are picked up more readily by the customer. Brake noise complaints especially brake squeal noise forms a major warranty costs to vehicle and brake manufactures. It affects the brand image of the brake manufacturer. Till date automotive industry is struggling to completely eliminate brake noise. It is partly due to the sheer complexity of the mechanisms that cause brake squeal at both the micro and macroscopic levels, and partly due to the transient and elusive nature of brake squeal that often limit the direct probing of a squealing brake. Hence as of now brake squeal warranty is unavoidable but with effective quality control it is possible to minimise such warranty problems.

Introduction

Brake squeal countermeasures like pad chamfer, slot,..etc and addition of shim are defined based on experimental testing and using FEA analysis. But it must be understood that this countermeasure is defined based on validation on few number of brake assemblies and limited driving conditions. Any significant change in one parameter or cumulative minor changes in child parts may drastically detoriate brake squeal performance. And hence it becomes increasingly important to monitor all the parameters related to brake squeal right from development stage to regular production.

Parameters contributing to brake squeal can be best explained with the help of fish bone diagram. We can get an overview of all the parameters and make an effective quality control system to monitor these parameters which can certainly help to curb warranty cost as well as to analyze if there is any warranty problem.

Fish-bone diagram – Brake squeal

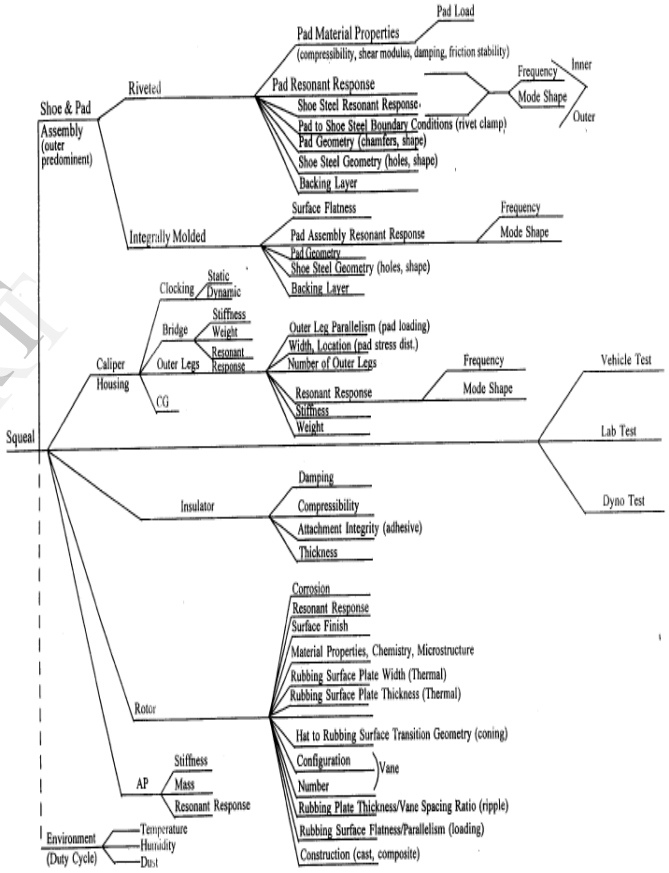

Figure 1 Fish bone diagram – Brake squeal

Brake squeal sensitivity

Following are some of major parameters for which brake squeal is very sensitive:

1. Dynamic characteristics of brake parts

2. Brake kinematics

3. Friction behaviour

4. Brake pad shim bonding

5.Abuse of brake like higher drag, thermal cycles,…etc.

Dynamic characterization of brake parts (FRF test)

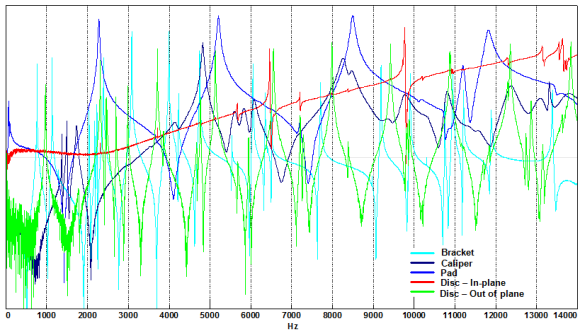

Figure 2 : FRF test data for brake parts

FRF test data of NVH test parts based on which squeal countermeasure is validated and finalised should be the reference for all future changes like

a) change in manufacturing process,
b) change in material
c) dimensional deviation
d) manufacturing location
e) design change…etc

Regular FRF tests of production brake parts will act as a preventive measure to control squeal problems.

FRF test can identify if there is any significant change in dynamic characteristics of brake child parts.

Brake kinematics

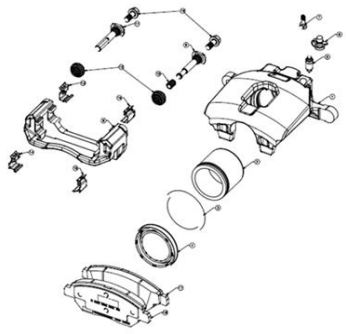

Figure 3 : Exploded view of disc brake assembly

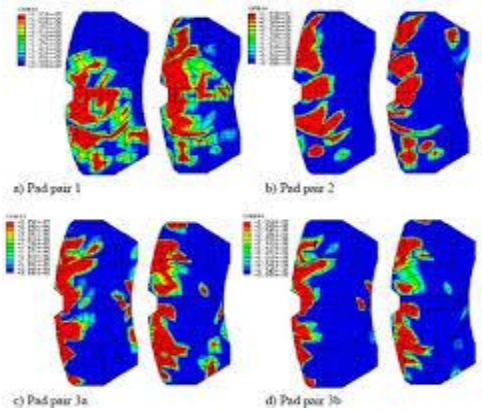

Figure 4 : Brake pad pressure distribution

Brake squeal is very sensitive to brake pressure distribution. And brake kinematics to a greater extent control the brake pressure distribution.

Any deviations in child part may change the brake kinematic behaviour and result in change in pressure distribution which can adversely affect brake squeal performance.

In some of the cases it is observed that only because of change in brake pressure distribution on account of dimensional variation brake squeal noise has tremendously increased and after correcting the dimensional deviation brake squeal noise has almost completely suppressed. This is an impact dimensional deviation can do to brake squeal performance. This is proved with the help of a case study as discussed later in this paper.

The effect of dimensional deviation is difficult to get captured in FRF test and hence it becomes increasingly important to control the dimensions related to brake kinematics.

So it is necessary to identify the brake part dimensions which are significant to brake kinematics and control these dimensions in drawing and ultimately in manufacturing as well.

If during mass production such deviation happens and field complaints for brake squeal increases it obviously raises the question for squeal countermeasure. And since it is very difficult to pin point the effect of brake

kinematics, it may mislead the complete development activity.

For example, if there is a field complaint for squeal noise, then as a preliminary check functional tests like residual drag, sliding forces,..etc are done and if all these functional tests are OK then it is concluded that all brake child parts are OK which may not be the case. This is proved in a case study discussed later in this paper.

So ensuring brake kinematics is the key to control brake squeal noise.

Friction behaviour

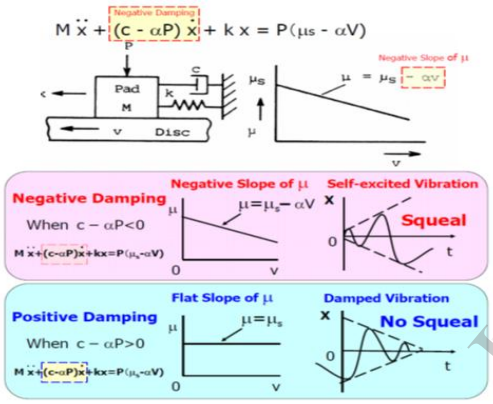

Figure 5 : Brake squeal due to negative slope of mu

A negative slope characteristic of dynamic friction coefficient against the sliding velocity in the contact interface is one of the major reasons for producing brake squeal noise.

So any change in friction material can significantly affect squeal performance.

It is necessary to monitor friction behaviour during mass production by various periodic tests like

a) Brake pad FRF,
b) Pad compressibility,
c) Physical properties,
d) Dynamometer test.

Brake pad shim bonding

Brake pad shim helps to damp pad out of plane (bending) vibrations.

If the bonding of shim with brake pad is not done correctly it will detoriate the bonding and hence reduces the damping effect provided by shim. This will increase propensity for brake squeal noise.

Abuse of brakes

Sometimes it is observed that brake is highly abused by the user and hence squeal noise may be increased. But this is a very specific case and need to be evaluated based on condition of brake parts.

Case study_1 : To check the effect of dimensional variation in disc brake caliper on brake squeal performance.

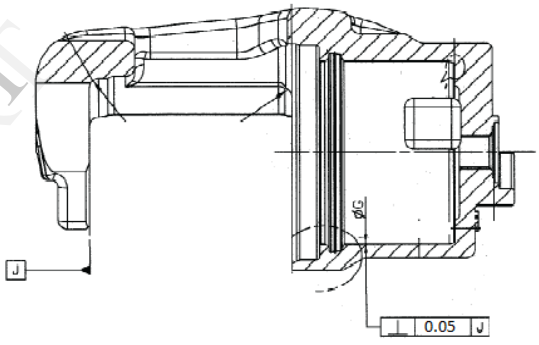

Figure 6 : Caplier piston bore squareness wrt J face

In this case study brake squeal performance is measured with two different calipers. In caliper 1 squareness of piston bore wrt J face as shown in figure is within drawing specification and for caliper 2 squareness values is significantly deviated wrt drawing specification i.e. 0.189mm. Following are brake squeal results for disc brake with tested these calipers:

Caliper 1:

Total cycles : 1902

Total noise events – 46 (Global occurrence – **2.4%)**

Major squeal frequency – 6.45kHz

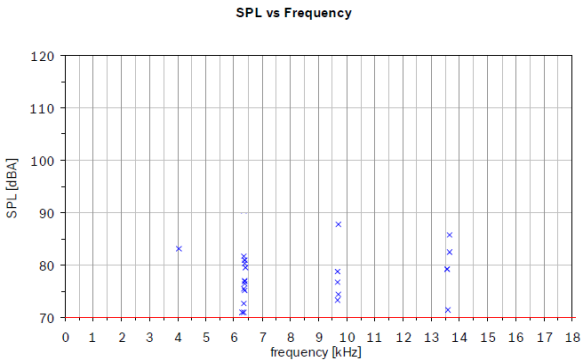

Figure 7 : Squeal performance with Caliper1

Caliper 2:

Total cycles : 500 (test stopped after 500 cycles due to higher noise)

Total noise events – 270 (Global occurrence > **50%**)

Major squeal frequency –3.3kHz

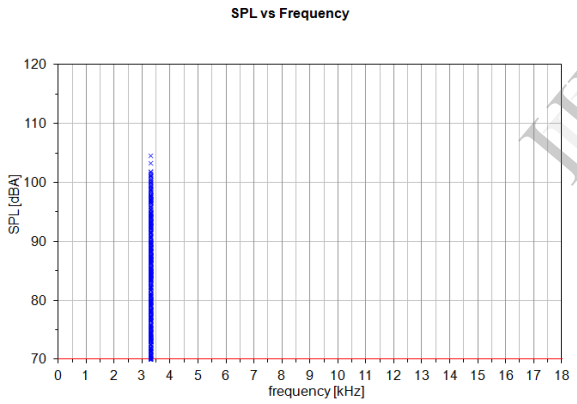

Figure 8 : Squeal performance with Caliper2

Also it must be noted that there is no major difference in FRF between these two calipers and all the functional tests meet the acceptance criterion with these two caliper. However noise behaviour is significantly different for these two calipers and this is mainly due to change in pressure distribution.

Case study 2 : To check the effect of FRF variation of brake drum on brake squeal performance.

In two brake drums having different FRF test data are tested with same drum brake assembly and it is found that there is significant difference in squeal performance between these two drums. Following are the comparative test results.

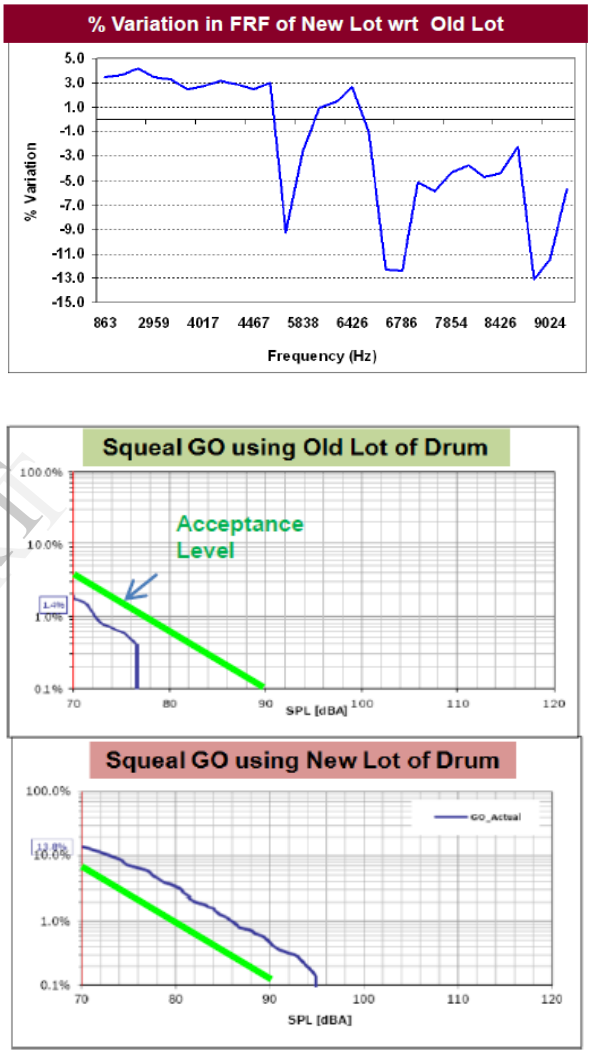

Figure 9 : Effect of brake drum FRF variation on brake squeal performance

Above test results clearly depict the importance of dynamic characterisation of brake parts on squeal performance.

***Case study 3*: To check the effect of poor shim bonding on brake squeal performance.**

Case (1): Noise global occurrence is 5% with OK shim bonding

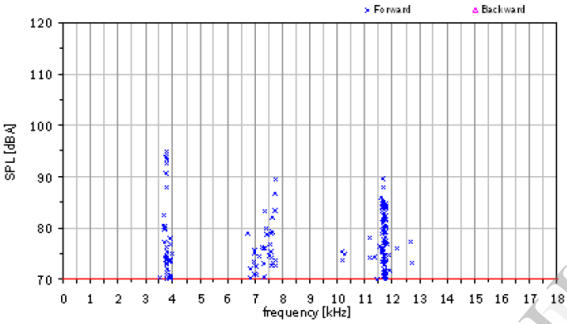

Figure 10 : Squeal performance with OK shim bonding

Case (2) Noise global occurrence – 20% with NG shim bonding

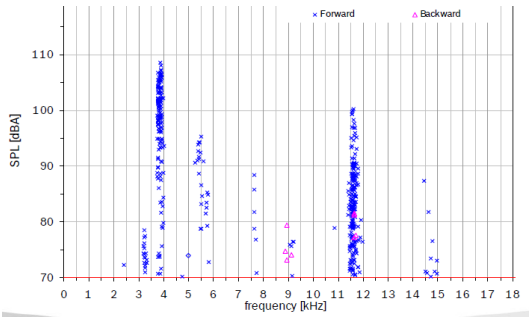

Figure 11 : Squeal performance with NG shim bonding

Conclusion :

1) It is possible to effectively control as well as to analyse brake squeal warranty problems with the help of tighter quality control in following areas:
   - Dynamic characterisation of brake parts
   - Brake kinematics
   - Friction
   - Brake pad shim bonding

2) As NVH performance is a value added feature as everybody in automotive industry is struggling to deal with it, more awareness need to be generated about the product overall quality right from development phase to regular production.

   This link between development parts and regular production parts must be understood i.e. **any deviation in regular production parts wrt development parts increases the risk for brake noise.**

Future work

The way forward would be to implement this road map for the live projects and generate more data base to prove the effectiveness.

References

[1] SAE Paper 1999-01-0142 "An Investigative Overview of Automotive Disc Brake Noise" K. Brent Dunlap, Michael A. Riehle and Richard E. Longhouse, Delphi Chassis Systems

[2] "New Fundamental Challenge for Brake Squeal Reduction- Dynamic Instability System and Disturbance – Paper by Dr. Dr. Masaaki Nishiwaki