AUTOMOTIVE BUZZ, SQUEAK AND RATTLE (BSR) DETECTION AND PREVENTION

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Abstract: The Buzz, Squeak and Rattle evaluation is a common problem faced by automotive OEM’s. With increased importance to driving comfort and quality perception buzz, squeak and rattle detection and elimination in modern automotive systems has become much more important in recent years. Many techniques involving time frequency analysis, acoustics, digital signal processing etc. are used to understand and control this unpredictable and desirable vibro acoustics phenomenon. An extensive literature survey was performed to gain understanding of the current state of the art. The high profile nature of squeak and rattle has motivated the manufacturers to pay attention during early phase of vehicle development program. Traditional methods of prevention and elimination of squeak and rattle have been found to be no longer sufficient to develop acceptable products in shortened product development cycle. The automotive industry the designers, the analyst and the rest engineer is still in want of a cost effective the product quality and cycle as well as to reduce the testing cost at the same time. This paper is an attempt to study the elimination methods to reduce the BSR noise.

Keywords – BSR (Buzz, Squeak and Rattle).

I. INTRODUCTION:

Squeak is a friction-induced noise caused by relative motion resulting from a slip-stick phenomenon between interfacing surfaces. The elastic deformation of the contact surfaces stores energy that is released when the static friction exceeds the kinetic friction, producing the audible squeak noise. The slip-stick cycle usually occurs at lower frequencies induced by suspension inputs but the release of energy produces a vibration of the surfaces that causes audible squeaks in the 200-10,000 Hz range [1]. Generally, there are two squeaks per cycle. For a suspension-hop-induced squeak, the frequency of the sound bursts would be twice that of the hop frequency. The amplitude and frequency of the squeak depend on a host of complex factors such as material constituents, coefficient of friction, normal load and load history, sliding velocity, inertia and thermal effects, wear characteristics, temperature and humidity conditions, etc. Rattle is an impact-induced phenomenon that occurs when there is a relative motion between components with a short loss of contact. It is generally caused by loose or overly flexible elements under forced excitation. Impacts are caused when surfaces close to each other move perpendicular to each other due to insufficient attachments or insufficient structural strength forcing repeated separation and reestablishment of contact. As with squeaks, the exciting force is predominantly road surface induced, which forces components to vibrate internally. This motion results in impacts if the tolerances are inadequate, vibration is excessive and/or the subassemblies are very close. Of course, the impacts will only be perceived as noise if surface areas of components adjacent to the impacts are large enough to radiate audible sound-power levels [2]. The frequency range of audible rattles is between 200-2000 Hz. Higher frequency rattles are often perceived as Buzz. Generally, there is one rattle per cycle. For a suspension-hop-induced rattle, the frequency of the individual sound bursts would be the same as the hop frequency.
II. THEORY:

BUZZ: Highly frequency rattle is usually called as buzz. It is generally caused due to the self-resonance or if adjustment of surfaces in proximity.

![Fig. 1(a) Buzz]

2.1 squeak: It is a friction-induced noise caused by relative motion resulting from slip stick phenomenon between interfacing surfaces. An essential condition for occurrence of slip stick phenomenon is a decrease of frictional force between two parts and increase in sliding speed.

![Fig.1 (b): Squeak]

2.2 Rattle: It is an impact induced phenomenon that occurs when there is a relative motion between components /parts with a short loss of contact. It is genially caused by loose and overlay elements under forced excitation.

![Fig.1(c): Rattle]
2.3 Sources of BSR

2.3.1 Design related:

- Higher design clearances causing impacts, friction causing slip-stick.
- Not enough damping in the system.
- Lower stiffness of the panels, parts.
- Improper routing of cables, harnesses, connectors and links.
- Improper clamping of parts.
- Durability of assembled parts.

2.3.2 Process related

- Dimensional Variations.
- Assembly Variations e.g. improper torque while tighten.
- Assembly with wrong parts such as assembly of plastic trims with broken clips.
- Alignment of doors, seat mountings.
- Fits and Finishes.

3 Mechanisms:

The following assumption are taken in consideration is that BSR sounds come from very different mechanisms in terms of the actual acoustic disturbance generator. This investigation begins with an assumption set of the sourcing mechanisms. Physical realizations of these sound generators are built, stimulated and the sounds are recorded. The sounds are then mixed at the threshold of audibility with a luxury vehicle interior they differ, however, in the non-linear mechanism that disturbs the air. For this investigation, the classifications of Hum, Buzz, Buzz/Rattle, Rattle, and Squeak will be modeled as spring/mass/damper resonant system

3.1 Hum Mechanism:-

![Hum Mechanism](image)
This is mechanism as shown in fig 3(a) linear spring mass damper system with minimum damping. Given a stimulus, this system will vibrate at its natural frequency and generate sound by disturbing air with some amount of its surface area. This type of noise is generated in panels, and brackets that are rather linearly constrained.

3.2 Buzz/Rattle Mechanism:

![Fig.3(b): Rattle Mechanism](image)

This mechanism as shown in fig 3 (b). Buzz could be characterized by the same spring mass dampers system of hum with the exception that at one end of the mass travel, there is an obstruction or stiffness discontinuity. The behavior of this mechanism is like the hum mechanism at low amplitudes but as the amplitude of response increases to the point of contact with the stiffness discontinuity an impact sound is generated that may have a repetition rate of the natural frequency of the base resonator but will have burst of sound comprised of the local resonances stimulated by the impact and their respective radiating areas. This lead to more metallic impact that would be characteristic of rattle. The Rattle sound may likely be sourced from the same sort of mechanism as buzz with the exception that the impacting element is more characteristic of a metal-to metal contact leading to a sharper higher bandwidth burst of energy at impact.

3.3 Squeak Mechanism:

![Fig.3(c): Squeak Mechanism](image)

The Squeak phenomenon is shown in fig 3(c) is characterized by the stick/slip transition of static/dynamic friction between two surfaces that are forced to slide against each other. This stick-slip behavior stimulates local resonant behavior that disturbs the air and produces sound. The relative movement of the surfaces may be resonant or non-resonan
4. Evaluation techniques for BSR

4.1 Testing on track:
On testing tracks the vehicle is driven such as random, pave track, Iron angle track, Belgium pave, square pot have by containing vehicle motion either \([x, y, z]\) in longitudinal, lateral or vertical direction of vehicle. This input faces geometric the BSR problems the vehicle. These problems are generated at different road vehicle speeds in different gears. This method is useful in identifying noise location. It is mainly not possible to reproduce the same BSR problem at same frequency and amplitude every time for this grained jury is required. Trained jury while sealed in vehicle on testing tracks identifies different vehicle subsystems for BSR noises. This method helps in indentifying BSR noises in door systems, power train, and dashboard system.

4.2 Lab Tests:

In this technique the vehicle is tested on BSR rig under controlled environment. By these simulation techniques we can determine of subsystems and prototype vehicle degradation upstream in the development process. Simulation technique is used to map the progression of BSR performance with respect to vehicle life. This technology simulates multiple vibration inputs to the vehicle and its components, in both magnitude and phase. This gives the reproduction of realistic loads perceived by components for various events like driving on rough roads and city roads. In these lab testing we can evaluate BSR that are performed at system component and vehicle level. Vehicle level BSR assessment gives valuable information about the performance of all the systems and components which can be correlated to customer expectations to the vehicle manufacturer. BSR performance depends on the component that generates the noise and interaction and behavior of all the systems and components together. Due to bad design of steering column assembly which carries a lot of vibration to the dashboard, dashboard mounted assemblies and components designed and processed to combat BSR doesn’t work, which causes rattling of components on i
4.3 Evaluation of BSR noise level

For BSR evaluation the vehicle which has to be tested is mounted on BSR rig in BSR environmental facility a trained jury has to sit inside the vehicle and at low flow of servo valves, which limits the actuator velocity about 1m/s with frequency 1-40 Hz, amplitude 1-5 mm with full stroke operation.

Fig. 4(b): Road lab Inputs to BSR rig

4.3.1 Methodology: The method adopted for vehicle BSR testing is summarized below

- Test vehicle is placed on four poster rig.
- In Sinusoidal sweep at each wheel rate the BSR problem
- Replay the inputs to the vehicle to generate vehicle roll, pitch and twist modes.
- The random noises are also observed with all wheels actuated.
- Root cause analysis of all BSR problems.

Fig. 4(c): Road lab Inputs for amplitude and frequency

35
- Replay the frequency and amplitude for set track.
- Individual wheel can be actuated with different frequencies and amplitudes.

- TABLE1: Subjective rating system

<table>
<thead>
<tr>
<th>Parameters</th>
<th>BSR Rating Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Score</td>
<td>4</td>
</tr>
<tr>
<td>Sound intensity/</td>
<td>Very</td>
</tr>
<tr>
<td>Irritating</td>
<td></td>
</tr>
<tr>
<td>Frequency of</td>
<td>4 times and</td>
</tr>
<tr>
<td>4 more</td>
<td></td>
</tr>
<tr>
<td>Detection</td>
<td>All customers</td>
</tr>
<tr>
<td>Vehicle System</td>
<td>Very poor</td>
</tr>
</tbody>
</table>

4.4 BSR noise rating System:

BSR noise problem rating mainly depends on three factors.

- Sound intensity ,
- Frequency of occurrence,
- Detection.

The subjective rating of BSR problems is done higher the score poor is the performance of vehicle. The different vehicle systems (e.g. Seating system, body door systems, body trims and ornaments etc) and the final score is evaluated more the score poor the BSR performance of vehicle. Further to calculate the final score is calculated by

\[ \text{Final Score} = (S \times O \times D) \times \text{weightage factor}. \]

Keywords: S-Severity O-Occurrence, D- Detection
5 BSR PREVENTION

BSR can be controlled efficiently by minimizing relative motions. It can also be reduced by using smarter structural design. Reduced BSR warranty bills can easily offset the initial cost of method development and implementation. By utilizing good design principles, relative motions can be minimized, but not eliminated. Using the resonant frequency of a vehicle structure or component as a parameter to measure NVH quality of a vehicle has proven to be valuable in many structural NVH issues, including BSR. The objective is to isolate modal frequencies and minimize interaction and excitation. The target setting procedure follows the benchmarking process. The resonant frequency and modal shape derived from a modal analysis results in incomplete comparisons because of differences in classical behavior. Modal mass, modal stiffness, modal damping, static stiffness and other derived parameters must be incorporated into the target setting process in addition to the resonant frequency.

5.1.1 Manufacturing control: All BSR problems occur due to poor manufacturing control or large process variations. Tighter control in manufacturing reduces BSR but at a higher cost. Providing adequate tolerances and knowledge of effective manufacturing assembly feasibility at the design level can be very beneficial for BSR prevention.

5.1.2 Design considerations: Good design considerations consist of several incremental factors that can provide effective solutions to niggling BSR problems. Attention to small details gives high return in the BSR performance. It has been observed that more attention is given to aesthetic than BSR performance. Certain shape used in door system and IP trim gives effective acoustic amplification. Other material gives hard acoustic reflection surfaces. Major structural members must be adequately supported. Component masses should be attached to major structural members.

5.1.3 Material properties of adjacent components: stiffening body structures doesn’t eliminate the relative motion in totality. The BSR performance of these components depends upon frictional properties of the components which are in contact. Selection of material of component will reduce the BSR problems. Various kinds of slip coatings an anti squeak coats are available but applications are limited due to problems with wear and environment durability. Selection of material depends upon the strength, durability and cost. The BSR problems can be minimized by the selection of materials having properties like frictional, thermal properties and its suitability with the material of the adjacent parts.

5.1.4 Effect of BSR on mileage: Laboratory simulation techniques allow determination of subsystems and prototype vehicle degradation upstream in the development process. The vehicle BSR performance is mapped at regular intervals, in parallel to structural durability using the four poster road load simulator as described in flow chart. The deterioration in vehicle BSR performance is observed for 12 to 18 months of customer usage, till it gets stabilized. BSR performance is mapped more frequently in the early stages of the service usage to capture the premature deterioration.
5.2 Detection of BSR: In these detection techniques, microphones are mounted inside the vehicle or next to the component. The BSR occurrence can be detected by using processed data derived from the noise measured with the microphones. For this detection, a binaural head is positioned in the driver’s seat of a sport utility vehicle. The binaural head is used to represent that the human ears perceive noise which is based on fact that there is a relation between measured signals and subjective perception. The sound which is used for playback is of the highest realistic. Two or more microphones can be used to gather the information on the direction the noise is coming from which helps in correlating the subjective evaluations to results of off-line jury tests. It is anticipated that for the measurement of the signals for component level tests and for end of line inspection stations, single microphone are adequate and therefore it is required to compare the data resulting from noise measurement carried out with different transducers systems. The detection technique involves the following data derived from test conditions:

1. Hop: Front and rear excitation- the front wheels are excited 180 degrees out of phase from the rear wheels
2. Tramp: Twist excitation: the driver side front wheel and passenger side rear wheel are excited 180 degrees out of phase from the passenger side front wheel and driver side rear wheel
3. In phase: Vertical excitation: all wheels are 0 degrees out of phase
4. Wobble: Side to side excitation: the driver side wheels are excited 180 degrees out of phase from the passenger side wheels

The noise signals are then analyzed by using a combination of MTS Sound Quality and MTS I-DEAS Test software. The signals acquired with a sine sweep excitation which is used as phase reference are filtered to remove the lower harmonics of the excitation frequency

III. RESULTS AND DISCUSSIONS:

After modifications the BSR noise level inside the cab is subjectively measured and evaluated, and the results for one of vehicle subsystems are as shown in graph.

6.1 Tailgate System:
Target setting: From measurement of BSR noise level of Tailgate subsystem on Test vehicle and modified test vehicle the noise level at passenger ear level on test rig as well as test track is reduced.

**TABLE 2: RESULTS TAILGATE RATTING**

<table>
<thead>
<tr>
<th></th>
<th>Test vehicle</th>
<th>Modified Test Vehicle</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Rig</td>
<td>69.53</td>
<td>65.31</td>
<td>38.56%</td>
</tr>
<tr>
<td>Test Track</td>
<td>75.7</td>
<td>73.28</td>
<td>23.96%</td>
</tr>
</tbody>
</table>

**IV. CONCLUSIONS:**

The methodology for identification and prevention of BSR events and the process change is to be made for elimination of BSR event in vehicle development. The process for mapping the progression of BSR performance with the vehicle service usage has to be developed and successful implementation and monitoring for prevention of the BSR deterioration with usage and durability with cost effective analysis and solution for the BSR problem.

**V. ACKNOWLEDGEMENT**

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**VI. REFERENCES**

[5] “Noise Pollution and Control” By S.P.Singal Narosa Publication