EFFECT OF RUBBER DAMPERS ON ENGINE'S NVH & TEMERATURE

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ABSTRACT

NVH is the study and optimization of the noise and vibration characteristics of vehicles for improving the system performance and comfort. NVH is the measure of vehicle feel and is a combined measure of noise, vibration and harshness .Fins as extended surfaces are attached to the internal combustion engine surfaces for enhancing the heat transfer. However, these fins produce undesirable radiated noise. For overcome this effect, automobile industry inserts rubber dampers between these fins. These rubber dampers reduce the fin's amplitude of vibration and thus reduce the radiated noise from the fin surfaces. This paper presents the effect of rubber dampers on the engine's NVH (Noise–Vibration–Harshness) and thermal performance using numerical (FEM and CFD. Experiments were conducted in the semi-anechoic chamber on an engine with and without rubber dampers. To investigate the thermal performance, computational fluid dynamics (CFD) simulations were performed on engine with and without rubber dampers. Many research was done on rubber damper, from that it concluded that rubber dampers increase engine temperature by about 10%. Effect of rubbers dampers on the cost and environmental impact has also been discussed.

Keyword: - *NVH, Vibration, Noise, FEM, CFD, Rubber damper*

1. INTRODUCTION

US Energy Information Administration said that transportation sector uses 20% of the world's total delivered energy. From 2007 to 2035, growth in transportation energy use would account for 87% of the total increase in world liquids consumption. Besides limited resources and high energy needs, rise in the input raw materials cost has forced automobile sector to optimize their product so that the use of associated components/materials can be minimized or completely eliminated. In this paper, an investigation is reported that could bring about huge resources and energy saving; reduce pollution and increase productivity of the automobile industry.

Fig. 1 shows photographs of air-cooled engines of two-wheeler vehicles taken from various motorcycle brands. It can be seen that rubber dampers have been inserted between the fins. Fins are extended surfaces. Fins are used to enhance the heat transfer from the engine surfaces. It reduces the temperature. Fig.1a and b shows 2-stroke (2S) engine cylinder head and Fig.1c and d of 4-stroke (4S) engine cylinder head. Use of rubber dampers is a common practice among automotive industry. Fins on the 2S engines are generally longer and wider than 4S engines as thermal loads on engine is theoretically two times more in the former case. Rubber dampers are provided between the fins to reduce the amplitude of fin vibration. The reduced vibration would lead to lower radiated noise for the fins surfaces. Also, these dampers add to the vehicle cost and pollutes environment. Scientific literatures on the effect of these rubber dampers on engine's NVH (noise, vibration and harshness) and thermal performance are sparse. NVH is the study and improving of the noise and vibration characteristics of vehicles. This paper provides a systematic study of NVH and thermal effects of rubber dampers. Furthermore, a design study of the cylinder head has been provided so that the rubber dampers can be eliminated altogether while maintaining the same NVH and better thermal behavior of the engine.

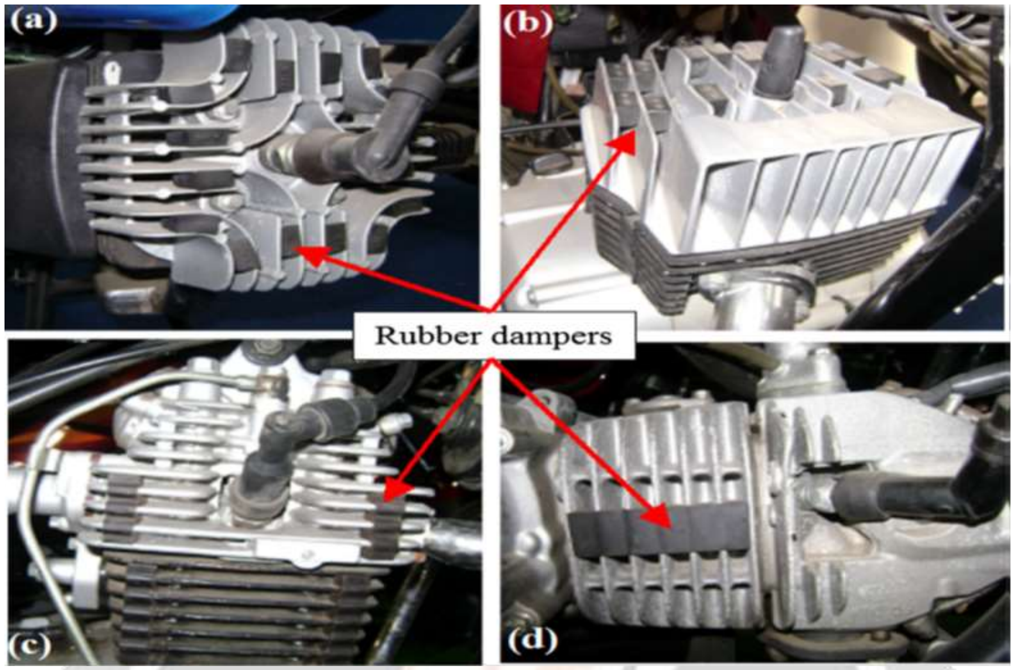

Fig.-1 Engines with rubber dampers between the fins from four different bike.

2. REVIEW OF LITERATURE

O.P. Singh and T. Sreenivasulud done research work provides a systematic methodology to investigate the effect of rubber dampers on engines NVH and thermal performance using numerical simulations and experimental measurements. Experiments conducted in the semi-anechoic chamber on the engine with and without rubber dampers reveal that frequency band of the radiated noise increases at higher engine speeds without dampers. An increase in 3–4 dB noise levels was observed on the engine without dampers. Finite element analyses were carried out on the base design to understand the fin modes of vibration. It was observed that local fin modes at lower frequencies were the dominant modes of vibration. Further design concepts were investigated. It was found that with the increase in natural frequency of vibration, amplitude of vibration also reduces. Prototypes of the final design of the cylinder head was made and tested in the semi-anechoic chamber. The noise radiated by the new design without dampers were comparable with that of base design with dampers. Hence, it is demonstrated that an engine without rubber dampers can be designed with the same NVH performance.

Li-Rong, Jia-Cai, Wangb and Ichiro Hagiwara present that a graphic modeling and simulation method of HDM is presented, which provides a convenient approach for characteristic analysis and prediction of HDM. The graphic model can be set up on effort–flow structure by attaching element units according to a systematic modeling procedure for multi-domain system, and automatic simulation can be carried out by the block based numerical computation of Simulink. Moreover, parameter identifications using FE method for hyper elastic material, FE method for hydrostatic fluid–structure interaction and experimental analysis are carried out, which are integrated into the proposed graphic model of HDM. Investigations into static elasticity, dynamic characteristic and frequency response analysis of a typical HDM with fixed de-coupler verify the effectiveness and practicability of the proposed method. This elementary characteristic simulation method of HDM is a practical and time saving method to computer-aided engineering system of HDM and PMS. In the future research, parameter identification methods of rubber viscoelasticity, dynamic FE analysis of rubber spring and identification method of chamber volumetric elasticity considering frequency- and amplitude dependent characteristics should be investigated to improve accuracy of parameter identification for performance simulation of HDM in high frequency range.

A.Stenti, D.Moens and W.Desmet presents a non-deterministic methodology has been presented based on a three-level approach which aims at evaluating directly in the frequency domain the influence of the rubber joints on the NVH response of a full-scale system model, when rubber nonlinear visco-elastic behavior is considered. It was observed that the specific strain amplitude of the vibration a rubber joint experience in real-life conditions is generally not known by the design engineer, and this lack of knowledge often does not justify the computational burden and the modeling effort of including detailed nonlinear models of the joint in a full-scale system model.

3. EXPERIMENTAL ANALYSIS

Effect of rubber dampers on the radiated noise from the engine was studied in a semi-anechoic chamber (Fig. 2). The length and width of chamber was approximately four and three times of vehicle width respectively. Two microphones were placed at half meter distance from the engine. Using data acquisition system and data analysis software LMS-Pimento, noise levels are measured during vehicles gradual acceleration. Accelerometer mounted on the engine was used to measure the engine acceleration levels. Quantification of noise levels with and without rubber dampers on the cylinder head was done systematically. 4 dampers are removed each time and the engine was run at various speeds from 0 to 6000 RPM. Hence the radiated noise was measured with 16, 12, 8, 4 and 0 (no dampers) dampers. It is noticed that noise radiated by the engine fins is lowest when all the dampers are present on the cylinder head throughout the engine speed range. As the numbers of rubber dampers are reduced, noise level increases. Fins radiate an average of 3–4 dB higher noise level when no dampers are used.

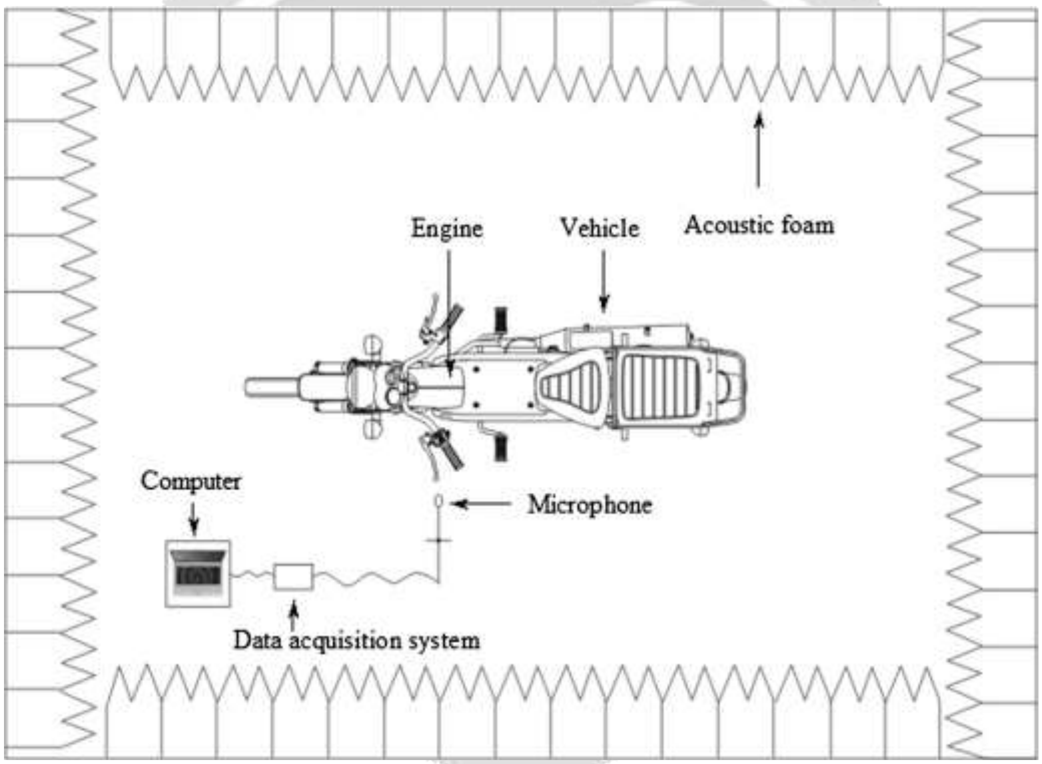

Fig.-2 Semi-anechoic chamber

Engineers have followed essentially two major approaches to solve structural noise problems namely: (i) find ways of reducing the sound power by passive means such as re-design or modification of the structure and (ii) use active control approaches. Although active control solutions have a strong potential in the future, especially for low-frequency noise, passive control still has to be considered because it addresses the problem at the source generally with a low cost and is especially successful for high-frequency noise. Furthermore, according to previous observations, reduction in ability of the structure to respond to excitation is the only possible way of obtaining any significant reduction at source. It is observed that fins get excited when rubber dampers are removed. Hence, the following section looks into the structural modifications of engine cylinder head and its effect on the radiated noise. To make the effect of rubber dampers more clearly, the radiated noise during gradual acceleration with all and no rubber dampers is shown in Fig. 3.

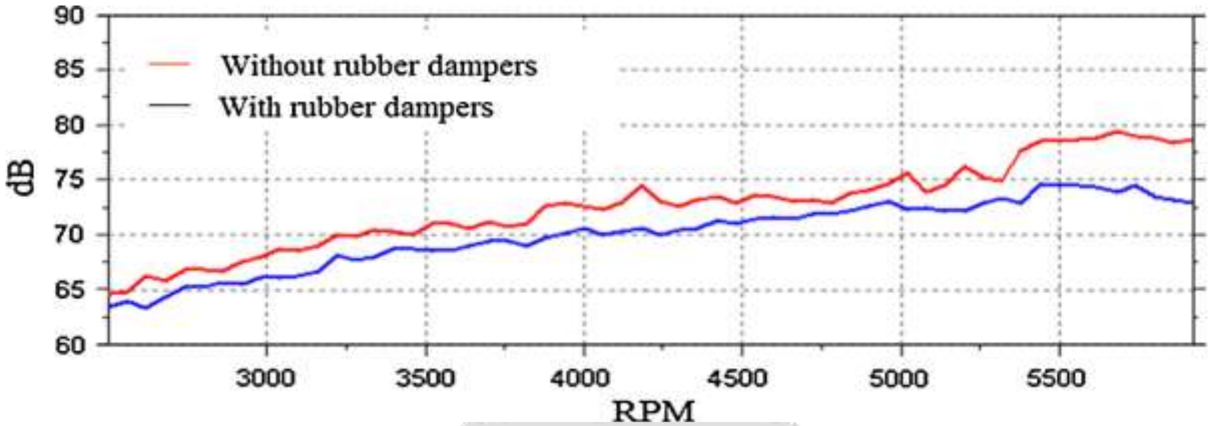

Fig.-3 Radiated noise during gradual acceleration with all and no rubber dampers

4. COMPUTATIONAL FLUID DYNAMICS ANALYSIS

Rubber dampers affect the free flow of ambient air around the engine surfaces and this in turn can increase the engine temperature. Data on the effect of these dampers on engine thermal performance is rare or not available in the scientific literature. The effect of dampers on the engine temperatures using CFD simulation is investigated. A conjugate heat transfer model was developed to study both the fluid and solid domain. The engine assembly with head–block with rubber dampers between the fins is placed in a wind tunnel for the external aerodynamics study. The base mesh size for head and block was 5 mm with minimum size was kept at 10% of the base size after the grid independence study. A fine mesh is generated near the fluid and sold interfaces to keep the wall y+ within 5. The differential equations governing the flow, turbulence and heat transfer under the assumptions of steady, incompressible flow were solved using finite volume method. Velocity of vehicle was specified as 40 km/hr. at the inlet whereas static pressure (ambient value) was specified at the outlet of the wind tunnel. Constant heat flux boundary condition was applied in the engine liner and combustion chamber. This heat flux was taken as 50% of the maximum engine BHP as thermal load. For validation of these boundary conditions, a full vehicle CFD model was built though the purpose of this exercise was different and not to study the effect of rubber dampers. Experiments were performed and temperatures were measured at the specified locations on the engine

5. RESULTS AND DISCUSSION

Quantification of noise levels with and without rubber dampers on the cylinder head was done systematically. 4 dampers are removed each time and the engine was run at various speeds from 0 to 6000 RPM. Hence the radiated noise was measured with 16, 12, 8, 4 and 0 (no dampers) dampers. Values of the first & fifth natural frequencies and their percentage increase from the base design (design 1) are mentioned on the left and on the right side of the figure. First 5 natural frequencies are extracted for each design (see Table 1). The first natural frequency of design 1 is 1470 Hz. Since the first mode frequency is too low, the first mode frequency of the subsequent design is targeted to increase it above 4000 Hz. Human ear is less sensitive to frequencies above 4000 Hz. From the vibration pattern at this frequency it is seen that the fins located at the center exhibits the local modes of bending motion. These local modes of vibration could radiate higher noise levels at resonance. Noise also gets reduced by 3-4 db after using rubber damper.

Table-1 First 5 natural frequencies are extracted for each design

Mode no.	Design1(Hz)	Design2(Hz)	Design3(Hz)	Design4(Hz)
1	1470	2968	3481	4134
2	1652	3123	3973	4203
3	1654	3128	4008	4297
4	1992	3130	4012	4302
5	2086	3632	4304	5317

6. CONCLUSIONS

A systematic methodology to investigate the effect of rubber dampers on engines NVH and thermal performance using numerical simulations and experimental measurements. Experiments conducted in the semi-anechoic chamber on the engine with and without rubber dampers reveal that frequency band of the radiated noise increases at higher engine speeds without dampers. An increase in 3–4 dB noise levels was observed on the engine without dampers. Finite element analyses were carried out on the base design to understand the fin modes of vibration. It was observed that local fin modes at lower frequencies were the dominant modes of vibration. Further design concepts were investigated. It was found that with the increase in natural frequency of vibration, amplitude of vibration also reduces.

7. REFERENCES

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