Research on Vehicle Noise Vibration and Harshness

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Abstract. Vehicle noise, vibration and harshness (NVH) is usually the major attribute because of its priority in the design of vehicles. NVH affects the design and manufacture process of a vehicle as higher customer satisfaction are attributed by a good NVH behaviour. The research on NVH relies on a variety of computer software to improve and control NVH. In this paper, several vehicle components including rubber dampers and isolators which play an important role in controlling the NVH are presented. A description of source of NVH in a vehicle is shown.

1.  Introduction
Vehicles consist of space vehicles, airplanes, submarines, trains, road, off-road and others [1]. Vehicle noise, vibration, and harshness (NVH) is a major problem in the automobile manufacturing process and affects the customer satisfaction of automobile owners. The researches of vehicle noise, vibration, and harshness (NVH) are not only suitable for the design process of new automobiles, but contribute to improve the comfort and performance of current type of automobiles. Those researches are largely due to the increasing demands of vehicle manufacturers, Original Equipment Manufacturers (OEMs) and customers. The OEMs aim to look for the products that address issues of NVH, reduce vehicle weight, improve stiffness, and are easy to model, lower costs, and are environmentally friendly [2]. Automotive noise, vibration and harshness are the most important issues when the customers assess vehicle quality. On the other hand, some manufacturers refuse to corporate automation into vehicle design, as addressing the issues of NVH which makes vehicles too quiet may pose a threat to the safety of pedestrians [3]. The vehicular noise can act as a warning signal for pedestrians.

Some components in the vehicles play important roles in reducing NVH, namely rubber dampers, the power plants, chassis coupling, and elastomeric isolators. Rubber dampers insert between the fins and rubber dampers reduce the amplitude of vibration of fins which are used to speed up the heat transfer from the engine surfaces [4]. In vehicles, the engine mounts affect largely the noise, vibration, and harshness comfort. The mounts are used to provide supports for the power plant and to isolate the vibrations of the power plant from the rest of the vehicles.

A multiplicity of elastomeric isolators is needed, including engine mounts, suspension bushings, and frame and sub frame mounts [5]. Some functional requirements for isolators involve steering, braking, package, and durability, although these desired characteristics conflict frequently.

2.  The Effect of Rubber Dampers on NVH
The rubber damper is an important type of equipment to reduce noise, vibration, and harshness (NVH), widely being used in a number of machines, vehicles, trains and aircrafts. The popularity of rubber
dampers is due to the characteristics of rubber with high visco-elasticity and high elasticity. Compared with steel, elastic deformation of rubber is large and elasticity modulus of rubber is small. As well, rubber is considered as incompressible material. The function of rubber dampers between the fins is to make a compromise between vibration amplitude increases and fin base temperature decreases. Through the research on the effect of rubber dampers on the radiated noise from engine, it is concluded that the effect of the rubber dampers is to reduce engine high frequency noise level, which means the problem of vehicle noise vibration and harshness can be partly handled by using the rubber dampers. Engineers continue to work on the issues of high vehicle noise vibration and harshness when an engine does not rubber dampers with two methods. These two approaches are related to structural noise problems.

The first method is to find ways of reducing the sound power by passive means and the other method is to use active control approaches. Compared with active control solutions which may be suitable in the future, passive control should not be ignored as it is useful for high frequency noise [6]. Rubber dampers are not the only equipment using rubber in vehicles and some rubber connections are widely employed for structural parts. A change in rubber joint material properties can help evaluate the sensitivity of the full-scale system vehicle noise vibration and harshness (NVH) [7]. A three level modeling approach with a material, a component, and a system level has been introduced to evaluate the sensitivity of the NVH.

3. Powerplant Mounting System NVH

The basic function of engine mount is to support the weight of power train and to isolate the vibration and harshness transmission from engine to body, to segregate the transmission from road surface excitation to power train [8]. As well, in order to lighten the car body, increase power-intensive engine and require vibration, noise, and harshness isolation for passenger cars, the performance of the powerplant mount system need to be improved. Many factors, such as the engine layout state, the supporting positions of chassis mount, the fixed positions on the cylinder of the mount and the layout of surrounding parts, should be considered before the designation of engine mount [9].

The responses of the powerplant mounting system to low frequency vibrations are important for improving the NVH in terms of rigidity and damping. Some designs of powerplant mounting system try to handle the issues of NVH by concentrating on the positioning and design of resilient supports. However they fail to consider chassis and suspension system interactions as these designs are based on decoupling rigid body modes from a grounded powerplant mode.

![Figure 1. Powerplant Mounting System.](image)

The traditional engine mount design strategies consider only the rigid body modes of a grounded engine and arrangements of powerplant rigid body mode. When considered as a rigid body, three translational modes and three rotational modes of frame represent the vibration, noise, and harshness (NVH) of powerplant using dynamic decoupling method. In detail, three translational modes are bounce, lateral, and longitudinal vibrations and three rotational modes are called by rotations about
pitch, roll and yaw. It is believed that the vibration, noise and harshness (NVH) transferred to the car body structure can be reduced by conditioning the powerplant mounting system such that the powerplant oscillates about the torque axis [10]. The torque roll axis decoupling strategy controls the displacement of the uncoupled blocked powerplant. With less displacement of the powerplant, the level of NVH is reduced.

The traditional design strategies sometimes may not put the issues of vehicle vibration noise and harshness (NVH) into consideration. With the development of technology and increasing demands of customers for comfort, the manufacturers and automobile companies begin to pay attention to design new powerplant mounting system. The current powerplant mounting strategies examine the rigid-body modes of the power train as it would sit on the mounts attached to the ground and neglect the effect of the chassis. The current engine mount system has achieved the goal that makes sure the driver and the passengers isolate from vibration noise and harshness (NVH) generated by the engine.

4. Isolator on NVH

Elastomeric isolator and hydraulic isolator are widely used in automotive vehicle including shock absorbers, engine mounts and body mounts. Isolators can reduce vibrations and improve the ride performance experienced by drivers and passengers. Noise, vibration and harshness (NVH) are important to the consumers’ acceptance of a vehicle. Isolators’ type, sizing and placement are critical to NVH design [11]. The difference between elastomeric isolator and hydraulic isolator is that hydraulic isolators are frequency dependent and elastomeric isolators are independent of frequency. It is largely because they use different mediums to dissipate mechanical energy.

A hydraulic isolator connects a vibrating body and an isolated body in a vehicle and consists of a cylinder with two chambers and a piston. An electronic control system is required to cooperate with hydraulic isolator to supply an alternating current of appropriate amplitude and phase to several magnetic coils disposed adjacent to the tuning slug [12]. Matching the isolation frequency with the vibration frequency and adding energy to the vibration isolator to compensate for damping losses is the basic theory how no vibration is transferred from the vibrating body to the isolated body with the help of hydraulic isolator.

![Figure 2. Hydraulic Isolator.](image)

The elastomeric isolators in the vehicles are separated into two kinds, namely rubber isolator and metal-net isolator. They are used for engines, especially for large power diesel engine. The metal-net isolator with the characters of nonlinear stiffness, large damping and power circumstance adaptability has advantages over rubber isolator and can be used as diesel engine’s mount component.

Rubber isolators have been used in NVH control for years. Rubber is hyper elastic material and its suitability as isolator is due to good flexibility and resilience characteristics [13, 14]. Rubber isolators cannot be used in low, high temperature, erode and tough circumstance, e.g. in low temperature, rubber isolators have no isolating effect causing the aggravation of NVH and also can only isolate a
single frequency vibration in any circumstance. It is due to the traditional design depending on experience and repeat experiment. Modern rubber isolator is designed with finite element method [14]. A modern rubber isolator is composed of steel and rubber. What differentiate modern isolator rubbers from traditional rubbers is that there are several holes. Those holes can effectively change the static and dynamic characteristics of rubber isolators. As a result, it manages to improve NVH with the improvement of performance of rubber isolators.

![Figure 3. Rubber Isolator.](image)

A metal-net isolator consists of the stainless steel web and the metal wire. When the force is on the stainless steel web, the metal wire slides and results in dry friction damping that absorbs and consumes the energy of system to approach isolating and cushion aims. The isolator’s elastic character is nonlinear, which has higher carrying capacity. Active isolation and passive isolation are two kinds of ways to isolate vibration with the use of metal-net isolator. Active isolation reduces vibration by isolating machine from vibration source and passive isolation relaxes the effect of external vibration.

![Figure 4. Metal-net Isolator.](image)

Compared rubber isolator with metal-net isolator, the transfer rate of metal isolator is smaller than that of rubber isolator, which means metal-net isolator has more ability to control NVH and absorb energy.
5. Conclusion

Vehicle vibration, noise and harshness (NVH) has been receiving considerable attention for many years. The main sources of usual NVH are power engine, brake, suspension system, the steering system as well as other hardware of the vehicle. Also, the road NVH and wind NVH has become important issues as they dominate the medium and high speed ranges. In order to improve NVH, the performance of rubber dampers and isolator should be taken measured to improve.

The paper gives a brief description of the current research of NVH, several modern methods such as finite element method and blade element momentum have already put into use. These methods greatly increase the accuracy and efficiency when addressing the issues of NVH. Two major components in a vehicle used to control NVH are introduced in the paper, namely rubber damper and isolator. The effect of rubber dampers is to isolate the engine NVH. Isolators are widely used in a vehicle and can be separated as elastomeric isolator and hydraulic isolator. The metal-net isolator has more advantage than rubber dampers. Engine and engine mount are the main sources of NVH. Some traditional engine mounting systems have shortages in design and manufacture.

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