Analytical Study of Engine Mount to Suit the Damping Requirements of Engine

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Abstract- An engine mount is a connecting link between vehicle chassis and engine. The engine excitation forces arising from firing pulse and unbalanced forces are widely considered among the main vibration sources for the road vehicles. The objectives of this work are to study the frequency-dependant stiffness of engine rubber mount. The ideal engine mount system should reduce engine vibration caused by engine vibratory force in engine and prevent engine bounce from shock excitation. This denotes that the dynamic stiffness and damping of the engine mount should be frequency and amplitude dependent. The development of engine mounting systems has mostly concentrated on improvement of frequency and amplitude dependent properties. The conventional elastomeric mounts do not meet all the requirements and can only offer a trade-of between static deflection and vibration isolation. The optimization of engine mounting systems is quite desirable.

Keywords – Rubber, Engine Mount, Stiffness

I. INTRODUCTION

The vehicle engine mounting system, generally, consists of an engine (vibration source) and several mounts connected to the vehicle structure. The modern engine mounting systems have been successfully used to isolate the driver and passenger from both noise and vibration generated by the engine. However, there is still a need to improve the performance of engine mounting systems for the following two reasons: One reason is that the requirements of vibration and noise level isolation for passenger cars. The second reason is that the modern car designs have a trend for lighter car bodies and more power-intensive engines. Such a weight reduction and increased power requirements often have adverse effects on vibratory behavior, greatly increasing the vibration and noise level. These two aspects are often conflicting. Substantial improvement in the performance of engine mounting systems definitely plays an important role in resolving such conflicting requirements. Different kinds of engine mounting systems, from elastomeric to hydraulic, and from passive to active, have been developed to improve the mount performance. Work on optimum tuning of engine mounting systems is also progressing.

Resources are becoming increasingly scarce, energy prices are rising and environmental pollution is increasing. Against this background, the subject of reducing consumption and emissions is becoming increasingly important in all areas of technology. Meeting the targets of the automotive industry in particular will require new drive concepts combined with the consistent implementation of lightweight construction. Weight-optimized plastic components are already being used in many vehicle subsystems and components, but steel and/or aluminum are normally used for load-bearing elements. In general, this goes for the engine suspension subsystem as well. In this area, plastic components were previously only used for sub-ordinate, moderately-loaded part components. The article deals with series development of mechanically high-load bearing plastic components for engine suspension of automobiles. The use of lightweight construction components contribute to reducing weight and a more favorable axle load distribution. The reduction of the front axle load positively affects driving dynamics and safety.

II. RUBBER IN ENGINEERING

Elastomers (natural and synthetic rubber) are amorphous polymers to which various ingredients are added, creating what the rubber chemist refers to as a compound. After heating and reaction (vulcanization), these materials become "rubber." Not only are they elastic and rubbery, but they also dissipate energy because of their viscoelastic nature. Their strength is high, especially under conditions of shear and compression. As with any mechanically loaded component, failure can occur as a result of fatigue. Thus, the long term durability of rubber has to be predictable. Simple design criteria should be made available. Computer-aided design and analysis is desirable.

Specifications are required to control product quality. Physical constants, as with any engineering material, should be readily available.

III. ELASTOMERS

Elastomers are essentially supercondensed gases because most precursor monomers are gases. Their density is greater by approximately 3 orders of magnitude, and viscosity by 14 orders, than the gaseous state. Through polymerization, a long-chain molecule is created (the primary structure of any polymeric material). The molecules can be arranged in an amorphous (rubbery), glassy or crystalline phase. Elastomers are typically categorized as amorphous (single-phase) polymers having a random-coil molecular arrangement. After it is properly compounded and molded into an engineered product, the material at some point is subject to an external force. When a solid body is deformed, an internal reactive force called stress, acting across a unit area, tends to resist this deformation. The measure of deformation is called strain.

IV. PROBLEM DEFINITION

The engine excitation forces arising from firing pulse and unbalanced forces are widely considered among the main vibration sources for the road vehicles. Dynamic forces, inertia forces could cause rapid fatigue of vehicle components and discomfort for the occupant. Even though the current engine mount designs are acceptable for vibration isolation, the performance improvement of the engine mounting system is still required for the tendency of light weight and higher power of the vehicle.

V. ENGINE SUSPENSION REQUIREMENTS

The development of an engine mount system is a complex process requiring close coordination of a range of departments. An interdisciplinary working group collaborates from the beginning of a development project. This team includes employees from the system simulation, design, analysis, noise & vibration and durability.

The engine mounts are the primary connecting link between the engine/drive unit and the chassis or body. Thus, it is subject to a variety of influences and interactions of a range of subsystems. The main tasks which must be performed by the mounting system include the following:

- Positioning of the engine/gearbox assembly.
- Support function (absorption of the weight forces).
- Structure-borne noise insulation.
- Support of the forces and moments which occur when driving (e.g. drive momentum, mass forces due to acceleration, deceleration or cornering).
- Limiting movements of the assembly (with the aim of guaranteed avoidance of contact with the body)
- Damping of shocks and vibrations caused by the road surface (e.g. shaking).
- Holding the engine in the event of a crash.

In addition to the requirements mentioned here, compliance with the component properties at the specified ambient conditions must be guaranteed. In the engine mount area, the standard temperatures are between -30°C to 120°C. Also, heavy soiling can impair the function of the mount.

VI. GENERAL DESIGN PRINCIPLES

Rubber is an engineering material: this is a fundamental issue. To design adequately, basic mechanical properties must be appreciated. Elastomers, as previously noted, are amorphous solids and behave isotropically (properties are independent of direction). The three elementary types of strain for isotropic materials are simple tension, simple shear, and uniform (hydrostatic) compression. The elastic behavior for these cases is defined by coefficients: Young's modulus E (tension), rigidity modulus G (shear), bulk modulus (compression), and Poisson's ratio. Poisson's ratio, defined as the ratio of relative lateral contraction to longitudinal extension under a simple tension stress, is 0.5 for a totally incompressible solid. For elastomers, v is 0.499 (for steel, v is approximately 0.3). For an isotropic incompressible material, $E=3G$. The essential incompressibility of rubber has many consequences in design, manufacturing, and application.

VII. ANALYTICAL CALCULATIONS FOR ENGINE MOUNT

We have to calculate optimum stiffness in z, y and x directions. We have an existing engine mount of elastomeric material having following parameters

1. Hardness = 57° A
2. Shear Modulus G = 0.88 N/mm^2
3. Height of Rubber , h = 30.7 mm
4. Width of rubber, b = 20 mm
5. Length of rubber, l = 58 mm
6. Static load, P_Σ = 125 kg

Specification

K_z = 316 N/mm ± 10% [312 to 328]

K_y = 108 N/mm ± 10% [97 to 119]

K_x = 69 N/mm ± 10% [62 to 76]

7.1 Shape Factor (Form Factor)

Shape factor is defined as the compression loaded cross sectional area of surface, A_c to the force free surface A_f

$$\text{Shape Factor, } k_f = \frac{A_c}{A_f}$$

$$= \frac{bonded\ area}{area\ free\ to\ bulge}$$

$$= 0.5530$$

7.2 Shear modulus conversion factor (k_m)

The shear modulus conversion factor km is dependent on the shear factor k_f.

At k_f = 0.5530

k_m = 6.25 [18]

7.3 Apparent young's modulus, E_a

The conversion actor km permits the determination of the apparent young's modulus from shear modulus G.

$$Ea = km * G$$

$$= 5.5 \text{ N/mm}^2$$

7.4 Inclined angle, α

The rubber axis is inclined to the vertical by an angle α. By taking stiffness ratio R.

$$R = \frac{k_y}{k_x}$$

$$= 1.565$$

$$R = \frac{\frac{2*A*G}{h}(cos^2\alpha + Ea\ sin^2\alpha)}{\frac{2*A*G}{h}}$$

$$\alpha = 20.75 \text{ or } 22\ °$$

7.5 Stiffness in z-direction (k_z)

Expression for stiffness in vertical direction is given by,

$$K_z = \frac{2*A*G}{h}(sin^2\alpha + Ea\ cos^2\alpha)$$

$$= 302.7 \text{ N/mm or}$$

$$K_z = 30.85 \text{ kg/mm}$$

7.6 Stiffness in y-direction (k_y)

Expression for stiffness in lateral direction is given by,

$$K_y = \frac{2*A*G}{h}(cos^2\alpha + Ea\ sin^2\alpha)$$

$$= 108.49 \text{ N/mm or}$$

$$K_y = 11.05 \text{ kg/mm}$$

7.7 Stiffness in x-direction (k_x)

Expression for stiffness in transverse direction is given by,

$$K_x = \frac{2*area*shear\ modulus}{h}$$

$$= 66.5 \text{ N/mm or}$$

$$K_x = 6.77 \text{ kg/mm}$$

VIII. RESULT AND DISCUSSION

The energy absorption characteristics of the engine mount are mainly influenced by two variables, the material and the design. In real world automotive manufacturing there is a fewer chances of the material changes for any subsystem as the material procurement is bulk order process. Hence the design of the engine mount becomes the critical aspect in terms of vehicle crashworthiness.[6]

By considering original dimensions and calculated results the CAD Model is drawn in CATIA V5 further FEA analysis is to be done with the help of ABAQUS and finally will be validated by experimentation.

IX. CONCLUSION

This paper covers the brief study of Rubber and Elastomer. And the basic requirements of Engine suspension system are elaborated. Natural rubber consists of suitable polymers of the organic compound isoprene, with minor impurities of other organic compounds plus water. The engine mount is being used to absorb and reduce the engine vibrations. Theoretical modeling of engine mount subjected to vertical, lateral and transverse loads are considered and the static stiffness of engine mount is calculated by using standard formulation. CAD models were prepared by using dimensions as per customer requirement by using CATIA V5.

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