THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Study of Engine Mountings: A Review

Salunkhe Karan Vishwas
Student, Department of Automotive Engineering, School of Mechanical Engineering, VIT University, Vellore, Tamil Nadu, India
Bramhekar Anand Arvind
Student, Department of Automotive Engineering, School of Mechanical Engineering, VIT University, Vellore, Tamil Nadu, India
Patil Milind Anil
Student, Department of Automotive Engineering, School of Mechanical Engineering, VIT University, Vellore, Tamil Nadu, India
Shinde Priyanka Sanjay
Student, Department of Automotive Engineering, School of Mechanical Engineering, VIT University, Vellore, Tamil Nadu, India
K. Ravi
Professor, Department of Automotive Engineering, School of Mechanical Engineering, VIT University, Vellore, Tamil Nadu, India

Abstract:
Comfort, vehicle stability and driving ability are the important factors in the terms of the performance of the vehicle. IC engine is the source of power to the vehicle and it produces vibrations which reduces performance of vehicle, so it is needed to control the vibrations up to some extent. IC engine is made up of rotary and reciprocating parts, which produces unbalanced forces and vibrations during their operation. These vibrations will be reduced by minimizing the unbalanced forces and by providing the mounts which absorbs the vibrations [3]. Engine mounts plays an important role in reducing the vehicle vibrations and noise. The function of the engine mounting is to properly hold the engine and transmission system on the chassis of the vehicle [4]. The development of engine mounting system is currently focusing on the improvement of frequency and vibrational amplitude [5]. This paper focuses mainly on study of various types of engine mount and its optimization methods for vibration isolation.

Keywords: *Internal combustion engine, engine mount, design, structural strength, unbalanced forces, vibrations*

1. Introduction

The internal combustion engine (IC Engine) is the bulky mass in the vehicle and if it is not designed and mounted properly, it will affect the vehicle comfort, stability and driving ability. Vibration generation in an IC Engine is depends on the unbalanced rotary and reciprocating parts, unbalanced forces, variable gas pressure in the combustion chamber and structure of mounts. The inertial force varies due to the combustion and compression difference of the engine. To reduce engine vibrations, proper mountings should be provided at the interface of the engine and vehicle chassis [3].

Internal combustion engine produces vibrations are of two types, torsional and longitudinal vibrations, Engine have some torsional vibrations due to their reciprocating parts [3]. Engine mounts plays an important role in supporting the weight of the power train, isolating vibrations produced by engine to body, segregating the transmission from road surface excitation to the power train [1]. The vehicle engine mounting system consists of an engine and several mounts connected to the vehicle body. The modern engine mounting system is developed with new technologies, but there is still a need to improve the performance of the engine mountings because of requirements of vibration control and noise control. Also modern cars are lighter in weight while engine is more power intensive, because of it engine performance is affected due to weight reduction and increased power requirements. Improvement in the performance of engine mounting system will improve the engine stability and vibration isolation [5].

An engine which is perfectly balanced will not have tendency to transmit vibrations to the frame, but there is no such an object which is perfectly balanced. Engine mounts are one who prevent fatigue failure and supports engine to reduce amplitude of vibrations produced by engine, hence design of engine mount should be done carefully [4].

Different types of engine mountings are developed such as active, passive, elastrometric, hydraulic [5]. In recent years' automotive sector shows a major interest in semi-active and active automotive engine mounting system. These systems are enabled to give more effective reduction of undesirable forces from engine to vehicle body than the passive mountings. Practically engine vibrations can't be completely eliminated, so that structural design of the engine mount is such that the position of the engine should be stabilized and dynamic components of forces should be minimized [2]. Engine mounts should have high stiffness and high damping in low frequency range, and low stiffness and low damping in the high frequency range [3].

2. Performance Requirements of Engine Mounting Systems

Basic function of the engine mounting system is to support the weight of the engine. Engine is mounted on the mountings coupled to the vehicle chassis, engine weight should be uniformly distributed among the load carrying mounts. This will ensure that engine is suitably situated in its specific designed position. Apart from supporting engine weight, the major function of engine mount is to isolate the unbalanced forces and vibrations. Internal combustion engine consists of two main dynamic disturbances, 1) the firing pulse due to the combustion of fuel in the cylinder; and 2) the inertia force and torque due to the rotating parts. The firing pulse will cause torque to act on engine, axis parallel to the crank. The direction of inertia force is parallel to the piston axis and perpendicular to the crank and pinion axis. These engine disturbances will excite the six degree of freedom vibration mode of the engine as shown in Figure 1

To isolate these engine-unbalanced disturbances, low damping and low elastic stiffness is needed as the force transmitted to the structure is proportional to the stiffness and damping value of the mounts. To obtain the low transmissibility of forces the engine mounts stiffness coefficient should very low. Lighter dampers are also gives low transmissibility at high frequency range.

Engine mounts should function in very adverse condition such as low and high temperature as well as oil, lubricating oil and gasoline. Also while designing the cost, reliability maintenance and life of mounts should also be considered [5].

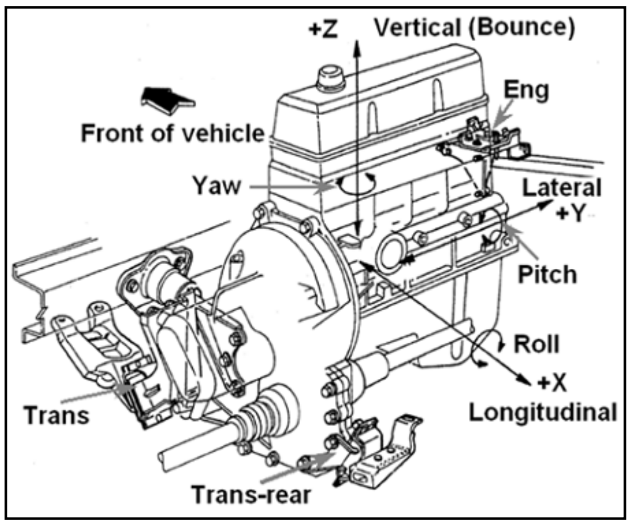

Figure 1: Engine six degree of freedom [5]

3. Engine Mount Structure

Figure 2 shows the structure of a conventional engine mount system. An engine mount consists of a bracket on engine side and to the body side and rubber insulator between the two brackets. This arrangement provides the connection between engine and vehicle frame. The large force acting due to engine acts in the direction, which bears the engine mass and engine torque, due to this the insulators are attached to the engine and vehicle frame in such a way that they are aligned with the axis in which the principle forces will act.

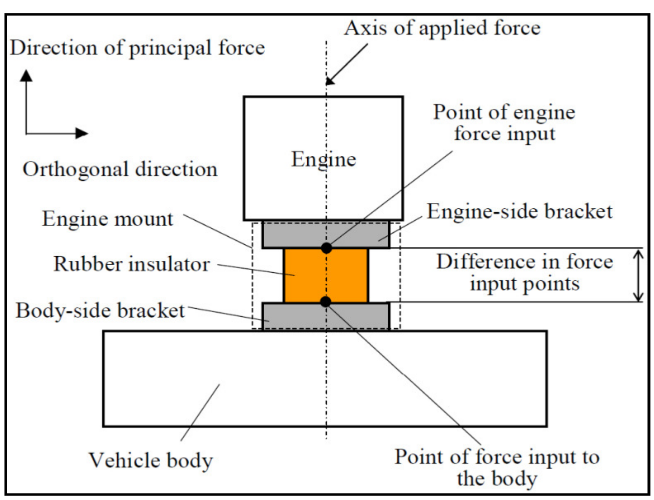

Figure 2: Elements of engine mount [6]

The noise transmission through the engine mounts is a very big issue, this can be effectively reduced by lowering the stiffness of insulators, but this will also affect the static stiffness of the insulators, which makes it difficult to balance the vehicle handling and stability of the vehicle. Because of these reasons, it is necessary to develop an engine mounting system which allows insulator stiffness to reduce only to medium to high frequencies and maintaining its static stiffness [6].

4. Design Flow for Engine Mount System

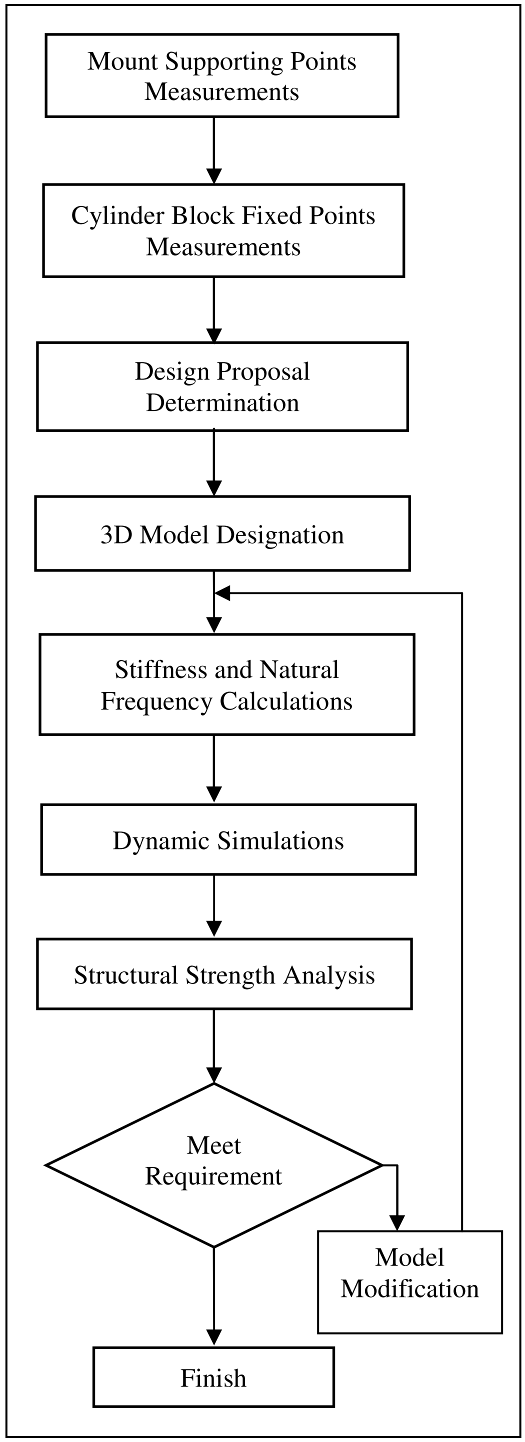

Figure 3: Design Flow for Mounts [1]

The above flow-chart describes the methodology to design the engine mount system. It includes the measurement of mount supporting points and engine mount points, design of actual 3D model of engine mounts, calculations of stiffness and natural frequency, dynamic analysis and static analysis.

5. Overview of Typical Engine Mounts

5.1. Elastomeric Mounts

This is the first type of engine mount that was used in automobiles since 1930's [28], compactness and cost effectiveness are its main properties. Elastomeric mounts have been subjected a lot of developments such as enhancing its temperature range and improvising its adhesive properties. These rubber mounts provide consistent performance and are maintenance free with long life [29,30,31]. Elastomeric mounts designed for the required elastic stiffness in all directions to get proper vibration isolations. There is variation in dynamic stiffness of an elastomeric mounts, this variation reduces its availability for maximum usage [27].

The elastomeric mount consists of spring and damper assembly shown in fig 4 [32].

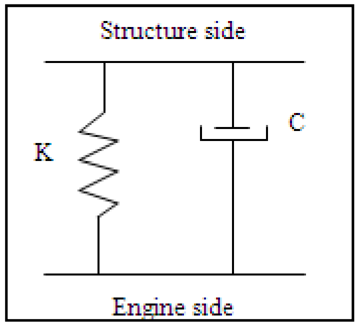

Figure 4: Mechanical Model for Elastomeric Mounts [27]

Low stiffness and low damping gives low noise but it results in high vibrations because of shock excitation. The dynamic stiffness from elastomeric mount will be greater at higher frequency while lower at lesser frequencies. Stiffness versus frequency graph is shown in fig 5. To deal with this problem, certain measures are suggested. It includes use of specific non-linear characteristics and high internal damping materials. These materials have high amplitude depending damping and stiffness [27].

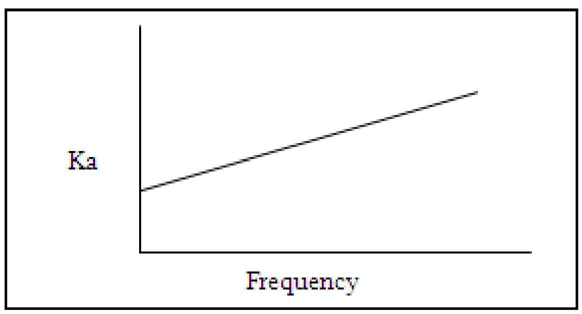

Figure 5: Dynamic Stiffness of Elastomeric Mounts

Elastomeric mounts have been in use in automobile from many years, but due to the recent vehicle development trends elastomeric mounts are becoming outdated. But still there is room for improvement in passive elastomeric mounts by using non-linear stiffness and damping characteristics of engine mount systems [27].

5.2. Passive hydraulic mounts

They are used to increase significantly ride comfort and reduce noise levels as compared to elastomeric mounts. It is modern use mount Inertia augmented damping is a considerable limitation of hydraulic mounts. These mounts increase low frequency damping but degrade vibration isolation performance at higher frequencies. Following Figure 6 represents passive hydraulic mount along with dampers [33].

There are three types of hydraulic mounts: hydraulic mount with simple orifice, hydraulic mount with inertia track, hydraulic mount with inertia track and decoupler. Hydraulic mounts with simple orifice or inertia track has greater dynamic stiffness [34]. These mounts increase damping at low frequencies but also degrade isolation performance at higher frequencies. Decoupler installation solves this problem. It makes hydraulic mount sensitive to low amplitude displacement. It increases low vibration isolation capacity of the mount [35]. But it is somewhat critical in installation. It requires following installments:

- Elastomeric mount that can support the load and act as a piston that can pump the liquid.
- Two separate chambers for fluid transfer.
- Orifice track to generate damping.
- Medium for fluid flow.
- Chamber provided with sealing and environment.
- Decoupler that permits low amplitude passage of highly damped vibrations [36].

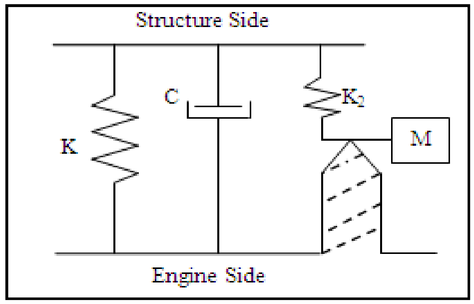

Figure 6: Mechanical Model for Hydraulic Mounts

5.3. Semi Active and Active engine mounts

Passive hydraulic mounts are unable to fulfill all the requirements during vehicle operation. Hydraulic mounts give frequency and amplitude dependent dynamic response and they are sensitive to structural parameters. To overcome the drawbacks of the passive hydraulic mount and to improve dynamic performance semi-active and active vibration controls are applied to engine mounting systems. In semi active control system, one or more system parameters are controlled to optimize dynamic response of the system. In most of the cases, vibration control is usually done by changing the dynamic properties of engine mounts. In case of active control, control force is created by using actuators to suppress the transmission of disturbances to the system.

5.3.1. Semi Active Engne Mounts

An engine mount with a semi active control mechanism is called a semi active engine mount. Semi active engine mounts can change the dynamic response of the system by controlling system parameters such as elastic stiffness and damping. All most all the semi active mounts are of hydraulic type. A semi active engine mount system consists of passive mounts with controllable elements and control mechanism. Fig. 7 shows the typical model of the hydraulic mount system. In this mass M can be changed to change the damping force.

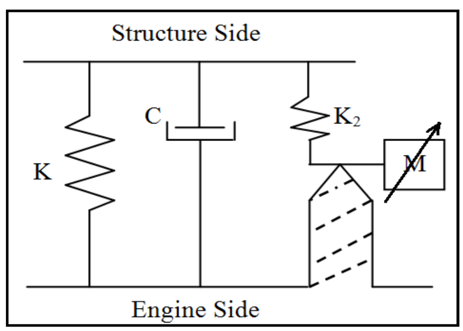

Figure 7: Mechanical Model for Semi-Active Hydraulic Mounts

Most of the semi active hydraulic engine mount are much sensitive to dynamic response to the system parameters. The semi active engine mounting systems are mostly used to improve system performance at low frequencies. Active controls are used for high frequency range.

5.3.2. Active Engine Mounts

A typical active mount consists of a passive mounts i.e. elastomeric or hydraulic, vibration sensor, force generating actuators and electronic controller. The main function of passive mounts is to support the engine in the case of actuator failure. The mechanical design of elastomeric and hydraulic active mounts is shown in fig. 8 in this design F represents the dynamic force generated by actuators.

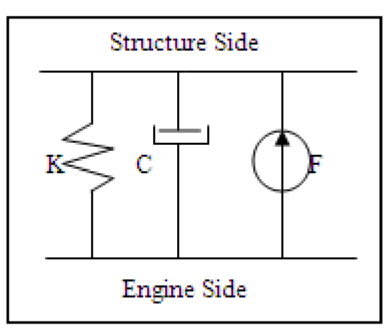

Figure 8: Mechanical Model for Active Elastomeric Mount [34]

According to the reference [28], an electromagnetic actuator generates dynamic force to reduce engine disturbances and the frame vibrations of at idle engine speed. The actuators are separated by conventional elastomeric engine mounts and fix on the front portion of the chassis. Recently active engine mounts with piezo actuators are developed to isolate vehicle vibrations [33]. Piezo actuators give very high speed response but very small displacement.

The stiffness of active mounts is equal to the stiffness of passive mounts at each and every frequency except at engine vibration frequency. The active mounts are alternative to passive mounts. It has high stiffness at low frequencies. Comparing with passive engine mounts, the active engine mounts will have increased weight, increased cost and energy consumption while reduced reliability of the system. Because of this active engine mounts are considered to be the next generation of engine mounting systems [34].

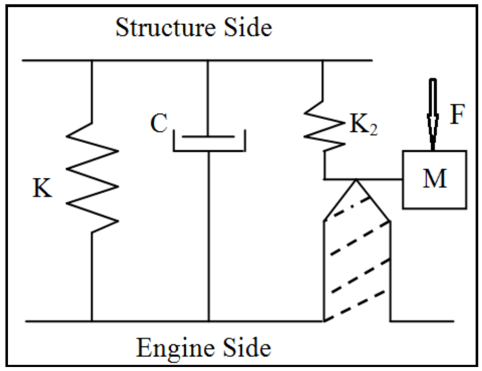

Figure 9: Mechanical Model for Active Hydraulic Mount [34]

6. Optimization of Engine Mount

As mentioned above engine mount system is subjected to real time vibration forces. They are transmitted from engine during real time running. Therefore, proper analysis of these forces is required. Using various analysis tools, final optimization of engine mount is mandatory. Following literature emphasizes on various analysis and optimization methods.

Design optimization of engine mount for passenger vehicle is proposed using EM TOOLS. It is MSC ADAMS based engine mount analysis software. It is useful to carry out vibration and static analysis of hydro mount. Frequency dependent modeling (FDM) is a part of it. In addition to EM TOOLS, vibration based optimization is carried out by design of experiment (DOE) program. It is basically a sensitivity analysis and optimization algorithm. It was concluded that MSC ADAMS is best option for vibration analysis of engine mount [7]. In accordance with the above paper here DOE method is used. Tuning the stiffness of engine mounts is more prevalent in today's time. Initially finite element method is used followed by multi-body dynamic modeling. HYPERMESH is used a meshing tool. MSC/NASTRAN is used with aim to model the sample and export to ADAMS/VIEWS. ADAMS is an engine analysis software. Certain parameters like stiffness, load bearing capacity were used and based on these results, permissible natural frequencies using RSM method was calculated. Finally results of CAE model were compared with extended model in ADAMS [22].

Vibration analysis of vehicle engine mount can be analyzed using DASY LAB software for passive engine mount. It is fundamental of all the three types of engine mounts. Time and frequency response curves are plotted and based on that improvement are proposed [8]. For pretention effect and service load HYPERMESH and ABACUS were used in these regard. Various materials like cast iron, wrought iron and mild steel are used. Static analysis for von misses stresses and natural frequencies were computed. By comparing the final results best possible material selection is the main objective [11]. Similarly design of engine mount bracket for a formula SAE car is further analyzed using finite element analysis. Along with modeling and modal analysis, mass optimization of bracket is also proposed. Experimental validation was carried out by installing the bracket. Various readings were taken and they were much in accordance with the software results [9].

Engine mount analysis methodology used by Piaggio vehicles has various parameters like yaw, pitch and vertical roll also lateral and longitudinal. Linear finite element software (raddias-linear) is used for the calibration of engine mount stiffness. Rubber models are used as input. Modulus of elasticity value (E) plays an important roll as a deciding factor for stiffness calculations. Results thus obtained from softwares are compared experimentally [15]. As it is well known that CAE models are very well analyzed without the need of any prototype, thus CAE tool is used for modeling. Finite element analysis is carried out in three stages. 1) Pre-processing phase, 2) solution phase, 3) post processing phase. Material properties, mesh size, loads and constraints are given as boundary conditions. It is followed by model acceptance criteria, design modification criteria, result interpretation and design failure criteria. Gray cast iron was the material chosen and results were calibrated [10].

Finite element analysis of engine mount for a multi-utility passenger vehicle is carried out in two parts. 1) Linear static analysis and non- linear hyper elastic analysis. 2) Vibration analysis for engine mount at natural frequency. Results of both the finite element analyses are found to be in close agreement with experimental results. Model response and vibration transmissibility of the mounts are determined [25]. The existing model was analyzed using finite element analysis followed by optimization of engine mount bracket. It was analyzed for static analysis, model analysis and harmonic response analysis. After computing the results, novel optimized model was proposed, main objective being the weight reduction check on noisy operation of the mount. As a result of optimization 12.5% weight was reduced along with permissible limit of yield stress and harmonic response [12]. With an account of designing engine mount layout for vibration isolation, FEA is used followed by modal assurance criterion (MAC). In this process, track mode shape that corresponds to exciting force creates maps. Maps are made of MAC value and natural frequency against design parameters. Finally using multi body dynamics model, model of engine was constructed and mount layout is optimized. As a consequence of the above tool, transfer force is reduced by 75% as compared to original design [21].

One of the main objectives of optimization is weight reduction. Aluminium and magnesium alloys were used as materials for analysis. Considerable weight reduction is achieved as compared to conventional mounting materials. Results thus obtained are maintaining the low cost and withstanding of high stresses [13]. Magneto rheological elastomers are simulated as engine mounts. A 4 parameter model is used and performance was compared with passive or rubber mounts for relative displacement and force transmissibility at high and low frequencies respectively. There is 50% vibration reduction at resonance and varying degree of isolation. This is done at varied frequencies. If magnetic flux input is tuned, MRE engine mounts are used for further vibration isolation. There is still more scope for research in this field [26]. Altair technology conference proposed by TATA HITACHI carried out static and vibration analysis of engine mounting bracket of TMX 20-2. It is a 2-ton class mini excavator. This excavator is developed by TATA HITACHI for digging, trenching, dozing, earth drilling, rock breaking etc. Opti-strut tool was used for checking the stress and deformation levels of engine mounts due to self-weight as well as due to the vibrations of engine. Vibrations were interpreted in the form of multi axial accelerations recorded by data logger. Finally, validation of the CAE model was cross checked with experimental data and was found to be in good acquaintance [14].

Anti-vibration active mount system can be significantly used for structure borne noise reduction from medium to high frequencies. Addition of mass to the insulator leads to resonance at lower frequencies. That provides double anti vibration performance. It significantly reduces noise transmission frequencies. Control force proportional to the vibrational velocity is used to suppress the increased vibration due to resonance of added mass. For the other remaining directions accept principal force direction, equations are developed. Resulting engine mount system is usable with fuel efficient engines for ensuring improvement in vehicle quietness [23].

Modeling followed by frequency response function curves are observed for vibration analysis of engine mount. Comparison is carried out between experimental and numerical tests. Overall results indicated that model is under permissible stress limit for both, steady state as well as dynamic loading. Thus to overcome high frequency shaking of engine, parallel associate rubber materials and some non-linear dynamic are to be altered. These views are suggested [16]. Driver seat of a passenger car is subjected to abnormal vibration forces. To evaluate this problem frame and seat rail was tested to identify vibration sources. Second order self-excitation of engine was the main cause and that was known from order tracking and spectrogram analysis. Bench test was used for performing dynamic analysis. Sample engine mount was tested for vibration of seat rail in multiple vehicle and engine working conditions. Finally, as a result abnormal vibrations were extremely reduced and engine was in the requirement of engine to dynamic stiffness under driving conditions [24].

Mahindra and Mahindra proposed optimization of design parameters of an engine mount. CAE tool is used for modeling. ADAMS is further used for simulation of the model. Simulation includes effect of eigen frequencies and vibrations transferred to the chassis. Optimum mount configurations using parametric model are selected and compared for best output. Main objective was stress analysis [17]. The following literature cites engine mounting system for a front wheel drive which is transversely mounted. It is a three-cylinder engine. Pendulum mounting system is used for modal analysis. Positions of front mounts were changed and conditions for zero preload on rear mount are studied. Modal analysis showed that in pendulum mounting system, roll made purity is improvised. Experimental results show that three-point engine mount system withstand higher loads then conventional two point [20].

In a work published, design of engine mount using finite element method followed by optimization is discussed. For the design of primary and secondary stiffness values and shapes, optimum shape design process and non-linear spring analysis are used respectively. Optimization using parametric model approach is suggested. Standard engine mount model of a passenger vehicle is used for validation. Three different models were compared by following the above procedure. Optimized among the three is selected [18]. As engine mounts are subjected to high temperature, transient thermal analysis of engine mount should be made. To estimate the life of an engine mount and evaluate its physical properties, a bench test is conducted. In this test engine mount is subjected to change in environment. In short it is subjected to dynamic temperature conditions. A time response curve is plotted and time constant is determined. Using time constant engine mount thermal model is prepared using a series of first order system response curves. Modeling results and experimental data are found in accordance with each other [19].

7. Conclusion

As studied in the above material, various references and articles one thing can be surely concluded that engine mount is one of the vibrant components of engine assembly. It is subjected to dynamic vibration transferred directly from the engine. Thus proper and accurate analysis of this component should be made. Various analysis tools are available in the market. Some of them are ADAMS, FEA and ABACUS. But the most prominent one is finite element method. Component is divided into numerous but finite elements and subjected to loading conditions.

After analysis comes optimization of the model. Prior to proposing a new model, validation of the analysis results must be made. Software results must be verified experimentally. Whether they are in accordance with each other is noteworthy. As stated in most of the above literatures, CAE models are experimentally verified and the results are compared.

Thus the above review basically states basic idea of engine mount and its analysis followed by optimization techniques.

8. Acknowledgements
This review is a team effort of all group members and our guide prof. K. Ravi Sir. This work is a combined interpretation of all the references that are used during this course of time. It is a result of all the researches that are made by respective scholars and researchers. We get immense pleasure to mention their works and initials in our review paper.
Last but not the least we are sincerely thankful to Automotive Department, VIT University.

9. References

i. Xiangming Qian,"Research on structural design of vehicle engine mount", Jinhua college of vocation and technology, jinhua, China.
ii. Bogdon supinski, marciej Rasol,Lukasz Jastrzebski, " Measurement-control system for an automotive vehicle engie mount", 2015 16th Intrenational carpathian control conference (ICCC).
iii. T.Ramachandran, K.P. Padmanaban, "Review on internal combustion engine vibratio and mountings", International journal of engineering sciences and emerging technologies. August 2012: 2231-6604.
iv. M.G. Sabarioaj, C.Senthilkumar, "Design and vibratio analysis of IC engine rubber mount", International journal of software and hardware research in engineering. May 2014: 2347-4890.
v. Yanhe Yu, Nagi G, Naganathan Rao, V.Dukkipatti, " A literature review of automotive vehicle engine mounting systems", Mechanism and machine theory, 36(2001) : 123-142.
vi. Yusuke Sato and Masahiko Kondo "New vibration control methodology in engine mount system for low fuel consumption engines", SAE International.
vii. Chang yong song, "Design optimization and development of vibration analysis program for engine mount system", technical division, seongam-si, Gyeonggi-do, Korea.
viii. The Swee Ing, "Vibration analysis of vehicle engine mounting", faculty of mechanical engineering, university of Malaysia.
ix. Jasvir singh dhllon, priyanka rao, V.P. Sawant, " Design of engine mount bracket for FSAE cae using finit element analysis", International journal of eginnering research and applications, ISSN: 2248-9622, vol 4, september 2014.
x. N.S. Vele, N.K.Kamble, Dr. S.V Joshi, " Finite element analysis of engine mounting bracket", D.Y.Patil college of engineering, pune.
xi. Sandeep Maski, yadavalli Basavaraj, "Finite element analysis of engine mounting bracket by considering pretension effect and service load", International journal of research in engineering and technology, eissn: 2319-1163.
xii. Monali Deshmukh, Prof. K.R.Sontakke, " Analysis and optimization of engine mounting bracket", International journal of scientific enginnering and research, ISSN:2347-3878.
xiii. P.D.Jadhav, Ramakrishna, " Finite element analysis of engine mount bracket", International journal of advancement in engineering technology, management and applied science vol-1, september 2014, ISSN: 2349-3224.
xiv. Koushik.S, assistant manager, TATA HITACHI construction machinery company ltd." Static and vibration analysis of engine mouting racket of TMX 20-2, using optistrut, Altair technology conference.
xv. S.S.sane, Vyankatesh Madane, Gaurav Upadhyay, "Engine mount analysis methodology", Piaggio vehicles pvt.ltd. HTC 2011.
xvi. Fernando M.D Ramos, "Vibration analyis of an engine mount", university of lisboa, Portugal.
xvii. Abhay A Bhivare, N.G.K. Gokhale, " Optimization of design parameters related to engine mounting using computer aided model", SAE International 990027.
xviii. Nak Kyu Lee, Myung Sik Lee, Heon Young Kim, Joong Jae Kim,"Design of engine mount using finite element method and optimization technique, SAE technical paper series 980379.
xix. Alaa El-Sharkawy and Ahmed Uddin, "Development of a transient thermal analysis model for engine mount", SAE technical series, 2016-01-0192.
xx. Shital P, Ghosh C, Talvar H. Gosain A.,et al, "Study of engine mount optimization of three cylinder engine through multi body dynamic simulation and its verification by vehicle measurement", SAE technical paper, 2015-26-0126, 2015.
xxi. Masahiro Akei, Kouichi Kouzato, Toshiyuki Uyama, "Study of engine mount layout for indutrial diesel", SAE technical paper, 2012-32-0108.
xxii. Arash Keshavarz and Mohsen Bayani Khaknejad, " Improving vehicle NVH behaviour via tuning the engine mount stiffness using DOE method", SAE technical papers, 2011-01-1510.
xxiii. Yusuke sato, masahiko kondo, "New vibration control methodology in engine mount system for low fuel consumption engines", SAE technical paper, 2013-01-1703.
xxiv. Wei Yang and Wenku Shi, "Research o vibration isolation of semi active control hydraulic engine mount wit air spring" , SAE intrenational 2014-01-0008.
xxv. Dhoble A.S, Sharma R.P, "Finite element analysis of engine mount for multi utility passenger vehicles", SAE technical papres 2001-01-0046.
xxvi. Ismail L. Ladipo, J.D Fadly, Waleed F. Faris, "Characterization of magneto rheological elastomers (MRE) engine mounts", advances in functional materials (conference 2015) AFM 2015
xxvii. Yunhe Yu, Saravanan M. Peelamedu, Nagnathan, Rao V. Dukkipati, "Automotive vehicle engine mounting system- a survey" , ASME 2001.
xxviii. Lord H.C ,1930, "Vibration Dampening Mounting" , US patent, 1,778,503, october 14.
xxix. Browne K.A ,and Taylor E.A 1939, "Engine mount", US patent, 2,175,825, october 10.

xxx. Clarke M, 1985, “Hydraulic engine mount isolation”, SAE paper, 851650.
xxxi. Miller L.R, and Ahmadian M. 1992, “ Active mounts a discussion of future technological trends”, Inter-noise conference, Toronto,Canada.
xxxii. Schmitt R.V, Leingang C.J.,1976 “ Design of elastomeric vibration isolation mounting systems for internal combustion engines”, SAE paper 760431.
xxxiii. T. Shibayama, K.Ito, T.Gami, T. Oku, “ Active engine mount for a large amplitude of idling vibration” , SAE paper, 951298.
xxxiv. D.A Swanson, “ Active engine mounts for vehicles”, SAE paper, 932432.