Ramachandran et al. 2018. *Int. J. Vehicle Structures & Systems*, 10(3), 215-219
ISSN: 0975-3060 (Print), 0975-3540 (Online)
doi: 10.4273/ijvss.10.3.12

International Journal of
Vehicle Structures & Systems
Available online at www.maftree.org/eja

Vibration Characteristics of Al6061-SiC Metal Matrix Composite based Rubber Mount for I.C Engine Chassis

T. Ramachandran[a,b], S. Sudhakara Reddy[a,c] and S. Jeyakumar[d]

[a]*Dept. of Mech. Engg., Malla Reddy Engg., College, Secunderabad, Telangana, India*
[b]*Corresponding Author, Email: ramji.kkp1973@yahoo.com*
[c]*Email: saripallisudhakar@gmail.com*
[d]*Dept. of Mech. Engg., PSNA College of Engg., & Tech., Dindigul, Tamilnadu, India*
Email: kmk_jai@yahoo.com

ABSTRACT:

Vibrations are found to be dangerous and reduce the life and reliability of the vehicle. The studies were carried out by many researchers to stiff the structures by increasing the wall thickness of the plates, rubber and to minimize the vibration by increasing the damping coefficient of the rubber materials. The conventional materials indicate an improvement in stiffness, but not satisfying the requirements of the engine vibration at different speed and load standards and also increased the mass of the structure. This research on the engine mount vibration isolation aims at developing an alternative material for the structures which exhibit good damping and stiffness characteristics. In terms of properties such as chemical resistance, ease of production, high strength to weight ratio and damping, composite materials are increasingly used in many engineering application where the vibration is predominant. In this paper, the steel plates are replaced by Al6061-SiC Metal Matrix Composites (MMC) and studies are carried out on the engine mount made of Al6061 MMC structural material and integrated with rubber. The static and dynamic properties of the Al6061MMC-rubber mounts are determined using experimental investigations. The harmonic analysis is also carried out to test the damping characteristics of the mounts.

KEYWORDS:

Al6061-SiC rubber mount; Damping; Mechanical properties; Vibration displacement;, Vibration acceleration

CITATION:

T. Ramachandran, S.S. Reddy and S.J .Kumar. 2018. Vibration Characteristics of Al6061-SiC Metal Matrix Composite based Rubber Mount for I.C Engine Chassis, *Int. J. Vehicle Structures & Systems*, 10(3), 215-219. doi: 10.4273/ijvss.10.3.12.

1. Introduction

Automotive industry requires manufacturers with huge concentration on better comfort and good riding quality [1, 7]. This made to their attention for the invention of good quality engine mounting devices, with traditional physical prototyping and testing. An engine which is perfectly balanced for forces and moments will have no tendency to move or to transmit vibration [5] to the frame or foundation to which it is attached for the vibration modeling and characterization, the engine and vehicle are assumed to be rigid body. The engine need to be balanced (8) as there is no vehicle with perfectly balanced engine. As a consequence, flexible mounts are needed for supporting an automobile engine and its peripheral components [13]. The flexible mounts [3] are used to prevent the fatigue failure of the engine and gearbox support points and to reduce the amplitude of engine vibration which is transmitted to the vehicle chassis to minimize the human discomfort and fatigue by partially isolating the engine vibrations from the engine to chassis [6]. Hence, the material selection of engine mounts also needs to be performed in order to ensure the engine mount strength and damping capacity.

To isolate the vibration caused by the engine unbalanced forces, the least values of vibration transmissibility, elastic stiffness and good damping ability are needed [9]. Hence high elastic stiffness and damping are required to minimize the engine vibration and take over engine shake [10]. Aluminium alloys are preferred engineering material for automobile, aerospace and mineral processing industries for various high performing components that are being used for varieties of application [4]. Al6061 metal matrix composites particularly Al6061-SiC (silicon carbide) composite have a lot of advantages over monolithic metals including high specific modulus, high specific strengths, better properties at elevated temperatures, low coefficient of thermal expansion, good impact and erosion resistance, good fatigue fracture properties, excellent corrosive resistance, high structural integrity [7], good resistance to aggressive environments, improved wear resistance and damping characteristics. Owing to these enhanced properties, metal matrix composites are under consideration for a wide range of applications in automotive industries.

The composites formed out of aluminium alloys are of wide interest owing to their high strength, fracture toughness, wear resistance and stiffness. These composites are superior in nature for elevated temperature applications when reinforced with ceramic particle. In this work, generally used steel structural supporting material for the engine mount engine damper is replaced by the Al6061-SiC metal matrix composite and tested for the mechanical properties and vibration behaviour. For that the Al6061-SiC metal matrix composite is manufactured using stir casting method and is tested for the mechanical and damping characteristics. The engine mounts that are prepared using MMC composite and steel mount are used in four cylinder four stroke diesel engine and compared for vibration characteristics.

2. Preparation of Al6061-SiC MMC mounts for engine

Aluminium Matrix Composites (AMCs) refer to the category of light weight high performance aluminium centric material systems. In AMCs, one of the constituents is aluminium/aluminium alloy, which forms a continuous phase and is termed as matrix. The other constituent is embedded in this aluminium/aluminium alloy matrix and serves as reinforcement, which is usually a non-metallic material (common ceramics are SiC and Al_2O_3). Major advantages of AMCs, compared with the unreinforced materials are greater strength, improved stiffness, reduced density, better temperature properties, enhanced abrasion and wear resistance as well as improved damping capabilities. On account of the excellent physical and mechanical properties of AMCs, they are applied widely in aircraft technology, electronic engineering and automotive industries. Of all the commercial aluminium alloys, 6061 is an efficient choice to prepare metal matrix composites.

There are numerous techniques available for fabrication to manufacture MMC materials. The fabrication techniques can vary depending on the selection of matrix and reinforcement material. The solid state processes are generally used to obtain the greatest mechanical properties from among the various methods in MMCs, particularly in discontinuous MMCs. This is because segregation effects and inter-metallic phase formations are less for these processes, when compared with liquid state processes [11]. The most widely applied methods for the production of composites are based on casting techniques such as squeeze casting of porous ceramic performs with liquid metal alloys, stir casting and powder metallurgy methods [12]. Several research works have been carried out for the production of composites. Various methods have been chosen to fabricate the composites. Among these methods, stir casting method has been found to be best suited for fabricating aluminium composites because this method is highly versatile, most economical and easy to handle.

Aluminium (Al6061) alloy composite is produced from stir casting method for that the aluminium alloy (Al6061) is melted at 750°C in a furnace and is held for 40 minutes until the alloy melts completely. In the furnace, aluminium dross floats above the molten metal surface and it is fully removed. Before the inclusion of the SiC, it is heated at 400°C temperature about 1 hour to remove the moisture particles. A blender is used to stir the Al6061 molten metal at 600 rpm and simultaneously the SiC particle is added to the molten Al6061. A small amount of magnesium powder is also added to increase the solidification of matrix metal and reinforcement particles during the stirring. The molten alloy is stirred for 10 minutes and the crucible is removed from the furnace. The molten alloy (matrix and reinforced particulates) then is poured into a coated, dried and preheated rectangular mould cavity of size 105 x 105 x 30mm (Fig. 1). The pouring temperature of 600°C is sustained and is allowed to cool to the room temperature to obtain the casted composite. The cast composite manufactured, machined and tested for the mechanical properties and then resized to according to the required dimension of 50 x 100 x 5mm plate. The prepared Al6061-SiC MMC is now used to fabricate the mount for the engine. To fabricate the engine mount, the elastomeric rubber and the Al6061-SiC are bonded together such that the top and bottom plates are the composite and the elastomer at the middle Fig. 2.

Fig. 1: Al6061-SiC MMC specimen for mount plate

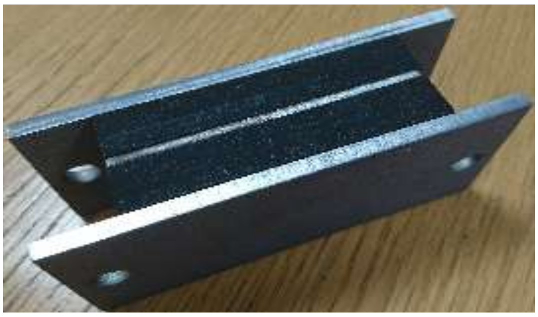

Fig. 2: Engine Mount made of Al6061-SiC MMC

3. Micro-structural analysis & mechanical characteristic of Al6061-SiC MMC

Using the scanning electron microscopic (SEM) examinations the microstructure of Al6061 and cast Al6061-SiC composite material are carried out to identify the distribution of particles. The distribution of silicon carbide particles are found to be uniform which enhances the mechanical properties of the composite. The hardness and toughness of composite is found to be more and better than that of Al6061. From the microstructures of Al6061 and Al6061-SiC as shown in Figs. 3(a) and (b), the reinforcement particles of Silicon carbide are uniformly distributed in Al6061 matrix material. This uniform distribution of SiC in Al6061 provides an improved strength to the composite by increasing the grain boundary and by hardness.

The steel and Al6061-SiC plates are tested for the mechanical properties to evaluate the requirement and for the engine mount supporting structure qualities that are shown in Table.1. The properties are found to be good enough than the steel when applied for the engine mount requirement functionalities. The response function analysis for frequency for the steel and Al6061-SiC specimens are also measured and the damping coefficient ζ is determined using the method of half power band width. For the determined stiffness of the mount, there is much improvement in the damping factor and also there is a reduction in mass of the composite plate structure when compared to steel plate. The MMC composite material well minimizes the vibrations in proper way compared steel plate (2). The hard nature of the Silicon carbide particles attributed to the brittle nature imparted by the aggregates present in the Al6061 matrix structure. This quality of Al6061-SiC made fit for absorbing or damping out the vibration initiated in the structures. The engine mounts produced using the steel and Al6061-SiC material with the integration the natural rubber, which is most widely used as the mounts where the vibration is predominant, and are used as the damping mediators between the engine and the chassis. The fabricated mount consists of top and bottom plates of steel and Al6061-SiC and the rubber of stiffness 150N/mm. The plates prepared in the size of 100 x 50 x 5mm and the rubber is bonded between the plates of top and bottom plates. The prepared three mounts are fitted to the engine and analysed for the vibration.

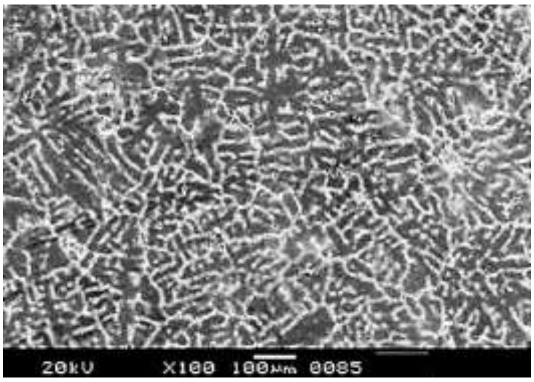

Fig. 3(a): SEM image of A16061

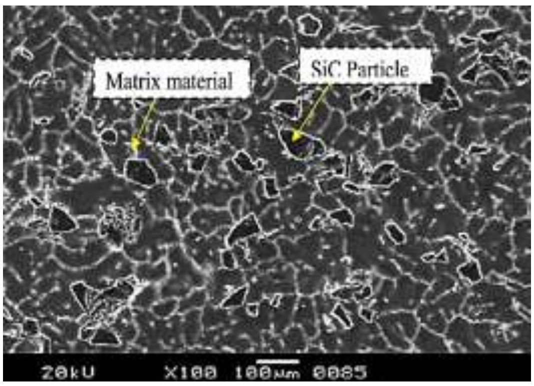

Fig. 3(b): SEM image of A16061-SiC composite

Table.1: Mechanical properties of steel and Al6061-SiC

Mount material property	Steel	Al6061-MMC
Material density (ρ) kg/m^3	7850	2600
Young's Modulus (E) GPa	210	82
Poisson ratio (υ)	0.25	0.35
Stiffness (N/mm)	0.097	0.1
Deflection (mm)	103	98
Mass (kg)	0.508	0.235
Damping factor (ζ)	0.007	0.0319

4. Results and discussion

The three mounts are prepared in each Al6061-SiC-rubber and steel-rubber combinations and are fitted to the I.C engine for the testing of vibration behaviour. The dynamic analysis is carried out on the steel-rubber and Al6061-SiC-rubber mounts using an experimental setup. The setup consists of an accelerometer fitted on the table, dynamic analyser, impact hammer and all are interring connected with each other. To test the dynamic behaviour of the mounts, the mounts are rigidly fixed to the accelerometer table and the harmonic excitations are applied on the mounts. To determine the frequency response of the mounts, a steady-state dynamic analysis is performed. This analysis carried out to find the steady-state amplitude and displacement the response of the system by the harmonic excitations at given frequency. Two base vertical loads considered in this analysis are the load caused by the engine weight and an additional load of 2000N by the engine excitations. The impact load of 2000N is applied to the engine mount to determine the displacement caused at both the mounts and are measured using the accelerometer.

The acceleration results obtained from the sensors are transferred to the software and the obtained displacement results for the both mounts are shown in Figs. 4(a) and (b). The displacement caused in the steel-rubber mount reached the peak of 6e-3mm and slowly damped out for the time period of 1.6s. When the Al6061-SiC mount is excited, the maximum displacement obtained is 4.5e-3mm and the excitation displacement is damped out within the 1s. The Al6061-SiC mounts have good damping factor and are capable of minimizing the vibration caused in the engine. This ability of the mount is more than enough to reduce the transfer of vibration forces from the engine to the chassis by executing more reaction forces towards the engine.

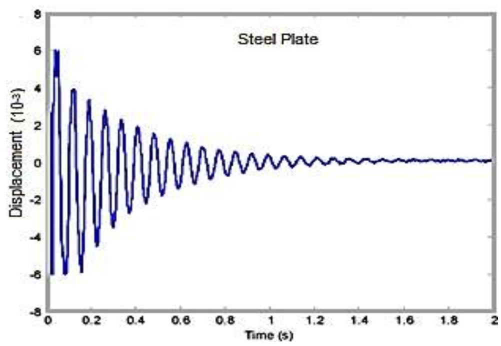

Fig. 4(a): Vibration displacement at the Steel mounts

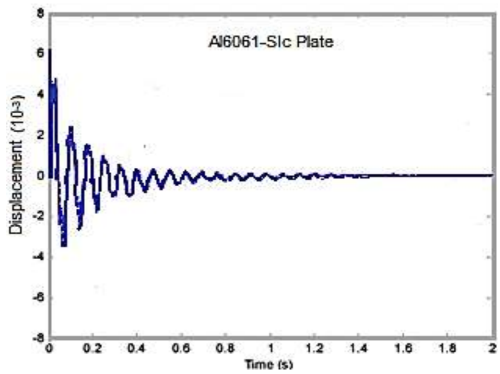

Fig. 4(b): Vibration displacement at the A16061-SiC mounts

The excitation of the applied force is simulated in the range 1-1000 Hz and the reaction forces exerted by the mount are measured with respect to the frequency range for the steel and Al6061-SiC mount. The variation in the mount natural frequencies due to the variation in the material properties of the mounts is reflected clearly in the mount displacement response curves. From Fig. 5, it is identified that the mount fabricated with Al6061-SiC possessed a great anti-resonance valley and exerted least reaction forces against the excitation. In case of the steel based mount has less ant resonance valley and exerted more reaction forces against the excitation. It indicates that the mount is still accomplishing required mission of minimizing the vibration transmission. The phase angle of the reaction force with respect to frequency distribution for the epoxy mount is appreciably increased and also clearly damp out the excitations. For steel mount, the phase angle variations for the frequency distribution are comparatively less and found to be constant. The frequency decrease of the anti-resonance valleys for the mount reactions in the opposition to the effect helps to reduce the overall system transmissibility in the frequency range of interest.

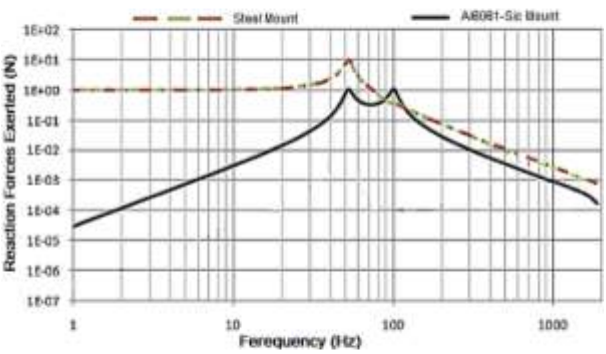

Fig. 5: Reaction forces exerted by steel and Al6061-SiC Mounts

The mounts are fitted to the four cylinder four stroke diesel engine and tested for the vibration accelerations at the max. load conditions with a speed of 1500rpm. The mounts are connected with the acceleration sensors and the experiments are carried out to determine the dynamic vibration behaviours. The obtained vibration accelerations (Figs. 6 & 7) for the Al6061-SiC and steel mounts are analysed for the comparison. The plot of the Al6061-SiC mount shows that the time domain variation of the acceleration is maximum at the peak cycle-cycle variation and is minimum with an average of 0.7g during the remaining cycles.

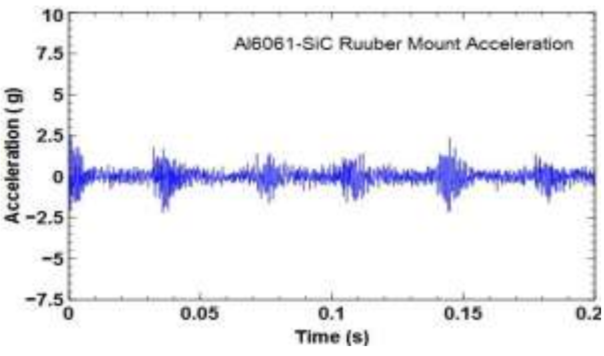

Fig. 6: Measured vibration accelerations of steel mount

In case of steel mount (Fig. 7), the time domain accelerations reach the maximum of 3g and the average of the remaining cycles is nearly 1g which is more than that of the Al6061-SiC mounts. It shows clearly the vibration damped out in the Al6061-SiC mount is more and effectively reduced the vibration transmissibility of the engine to the chassis.

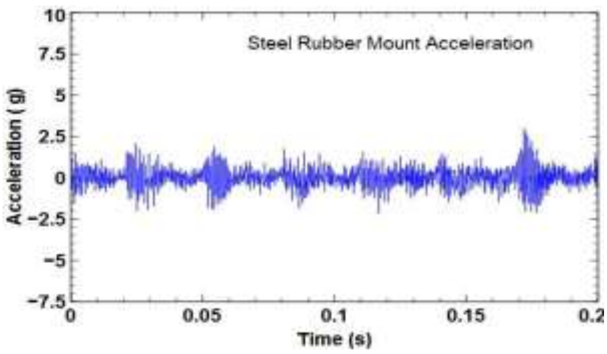

Fig. 7: Measured vibration accelerations of Al6061-SiC mount

5. Conclusion

In this work, Al6061-SiC plates are prepared for the suitability of the engine mount supporting structure. Generally the elastomeric mounts are manufactured using the steel supported structure which is minimizing the vibration caused engine to some extent. To minimise furthermore vibration transformation to the chassis a better material is identified and tested for the mechanical characteristics. Such kind of material is Al6061 having good strength and weight to strength ratio and is improved in vibration characteristics by attributing the SiC material as composite. In this regard, the stir casting technique is used to prepare the Al6061-SiC composite and is prepared in the form of plates. The mechanical properties of the steel and Al6061-SiC plate is tested and compared for the stiffness and damping characteristics. From the results, it is identified that the Al6061-SiC composite have improved strength and damping properties than the steel.

To test the vibration behaviour of the both mounts, the mounts fabricated by integrating with rubber with natural rubber and prepared as per requirement of the engine in which the experiments are carried out. The mounts tested experimentally for the steady-state response subjected to impact excitation of 2000N to determine the vibration displacement and the reaction forces exerted. The results show that the vibration displacement measured for the Al6061-SiC mounts are minimum when compared to the steel mounts. This shows the ability of the improved vibration damping ability of the composite mount and inferred that composite mounts are well damp out the vibration forces transferred. The frequency response function of the mounts showed that the effectiveness mounts in the isolation is well justified in the frequency range of interest. The mounts are also tested with engine at maximum load with 1500rpm to analyse the dynamic response of the vibration characteristics. The vibration accelerations are measured with respect to time domain and are found to minimum for the Al6061-SiC mounts and found to be more efficient than the steel based rubber mounts. Hence forth the Al6061-SiC elastomer mounts would be replaced in place of steel based elastomer mounts as they are having good strength to weight ratio and damping properties.

REFERENCES:

[1] L.E. Ooi and Z.M. Ripin. 2014. Optimization of an engine mounting system with consideration of frequency-dependent stiffness and loss factor, *J. Vibration and Control*, 22(10), 2406-2419. https://doi.org/10.1177/1077546314547532.

[2] S. Palli, R.C. Sharma and P.P.D. Rao. 2017. Dynamic behaviour of a 7 DoF passenger car model, *Int. J. Vehicle Structures & Systems*, 9(1), 57-63. https://doi.org/10.4273/ijvss.9.1.12.

[3] F. Wang and S. Duan. 2011. Fault diagnosis of diesel engine using vibration signals. in: Chen R. (eds) Intelligent computing and information science, *Communications in Comp. and Information Sci.*, 135.

[4] J.S. Taog, R. Liuk and Y. Lam. 2000. Design optimization of marine engine-mount system, *J. Sound and Vibration*, 235 (3), 477-494. https://doi.org/10.1006/jsvi.2000.2945.

[5] K.K. Chokshi and H.H. Ghoneim. 2017. A flexible-matrix-composite hydraulic engine mounts, *Proc. Int. Mech. Engg., Congress and Exposition*, V04AT05A028. https://doi.org/10.1115/IMECE2017-70189.

[6] T. Ramachandran and K.P. Padmanaban. 2015. Multibody modelling of engine and minimization of engine mount vibration using ant colony algorithm optimization, *Int. J. Vehicle Structures & Systems,* 7(1), 10-15. https://doi.org/10.4273/ijvss.7.1.02.

[7] S.K. Sharma, R.C. Sharma, A. Kumar and S. Palli. 2015. Challenges in rail vehicle-track modeling and simulation, *Int. J. Vehicle Structures & Systems*, 7(1), 1-9. https://doi.org/10.4273/ijvss.7.1.01.

[8] R. Kumar, M.P. Garg and R.C. Sharma. 2012. Vibration analysis of radial drilling machine structure using finite element method, *Adv. Materials Res.*, 472, 2717-2721. http://dx.doi.org/10.4028/www.scientific.net/AMR.472-475.2717.

[9] L.R. Wang, Z.H. Lu and I. Hagiwara 2010. Analytical analysis approach to non-linear dynamic characteristics of hydraulically damped rubber mount of vehicle engine, *J. Non-Linear Dynamics*, 61, 251-264.

[10] S. Jeyakumar, K. Marimuthu and T. Ramachandran. 2013. Prediction of cutting force, tool wear and surface roughness of Al6061/SiC composite for end milling operations using RSM, *J. Mech., Sci., & Tech.*, 27 (9), 2813-2822. https://doi.org/10.1007/s12206-013-0729-z.

[11] S. Naher, D. Brabazon and L. Looney. 2004. Development and assessment of a new quick quench stir caster design for the production of metal matrix composites, *J. Materials Proc. Tech.*, 166, 430-439. https://doi.org/10.1016/j.jmatprotec.2004.09.043.

[12] J.W. Kaezmar, K. Piebrzak and W. Wlosinski. 2000. The production and application of metal matrix composite materials, *J. Materials Proc. Tech.*, 106, 58-67. https://doi.org/10.1016/S0924-0136(00)00639-7.

[13] T. Ramachandran and K.P. Padmanaban. 2015. Experimental investigation of static and dynamic properties of steel-rubber, cast iron-rubber and epoxy granite-rubber as I.C engine mount, *Trans. Indian Institute of Metals* 68 (1), 83-86. https://doi.org/10.1007/s12666-015-0612-y