Design and Optimization of the Mounting System for a Low Horse Power (20 kVA) Genset

Kulkarni S S, Jadhav T A, Thakur R, Jain A

[1]

***Abstract*— Generator set (or Genset) is a device that comprises of an engine and an alternator coupled to each other and mounted on a common base frame along with other accessories. In all the places where electricity is required, gensets can be used. A 20 kVA genset is considered here to explore possible options of optimization of its mounting system. Currently very soft mounting system is used to provide isolation to genset from its base. The drawback of current mounting system is that the start and stop motions of the engine are high.**

This study focuses on reduction of these roll mode vibrations during start and stop and maintaining the desired isolation of the Genset. Total of four different configurations are proposed using Creo and its simulation is performed using ANSYS, MATLAB, and MINITAB etc. The results from this simulation show that the effect of the change in location of AVM along height, width and length of engine and alternator has different effect on the roll frequency of the mounting system. The configuration that increases the roll frequency reduces the amplitude of vibrations.

***Index Terms*— AVM, Elastomeric rubber mounts, Isolation, Mounting system, Vibrations**

I. Introduction

Today gensets have become a wide necessity everywhere. Gensets use mechanical power of engines and convert it into the electrical energy at output. Genset comprises of an engine, alternator and other accessories. What comes with an engine is the inevitable vibrations. Gensets are not an exception to this. In all these cases an object has to be isolated from the source of vibrations. The idea of suppressing unwanted vibrations with the use of vibration isolators has been around for five decades. Isolation devices are currently used in a wide range of applications: automobiles, buildings, aerospace structures such as helicopters and satellites, and machinery. When analyzing isolation systems, a question that arises is "What are the criteria that define isolation?" A general answer to this question would be that vibration isolation is the means to mitigate unwanted oscillating disturbances or forces. This can result in reducing forces or vibrations emanating from a foundation to a piece of equipment or it can result in reducing forces or vibrations emanating from the equipment to its foundation.

This work is sponsored by Cummins India Ltd., Pune, India.

Kulkarni S S, *Department of Mechanical Engineering, Sinhgad College of Engineering Pune (email: supriyaskulkarni123@gmail.com)*

Jadhav T A, Department of Mechanical Engineering, Sinhgad College of Engineering Pune (email: tajadhav.scoe@sinhgad.edu).

Thakur R, Power systems, Cummins India Ltd., Pune, India (email:rohit.thakur@cummins.com)

Jain A, Power Systems, Cummins India Ltd., Pune, India (email:amol.jain@cummins.com)

II. Literature Review

Many researchers have worked upon reducing the vibrations of an engine. Various type of mounting systems are developed and a lot of work is being carried out on each of the system [1, 6]. Most widely used mountings are of elastomeric rubber type. These are passive AVMs (anti vibration mountings) but study shows change in their properties with dynamic loadings.

Active and semi active mounting systems provide better isolation properties and also more accurate control but with the drawback of increased cost and space required [1, 3, 4]. Many new methods and different configurations are being experimented around the world with the aim to reduce the vibrations, such as: negative stiffness mechanism etc.[5, 4, 8].

An AVM or any mounting system should not only reduce the amplitude of vibrations but also the transmissibility of the system should be maintained within the criteria.

III. Structure of Gensets

A genset comprises of mainly an engine, an alternator, radiator, mounting system, fuel tank, skid and other accessories. The genset considered here for study is a low HP (20kVA) genset.

Components of the considered genset:

Engine: 2 cylinder inline engine

Alternator: 25 kVA, 4 poles

Existing mounting system: Elastomeric rubber AVMs, 4 nos. – 2 below the engine and 2 below the alternator.

Stiffness of rubber AVMs – 30 kg/ mm

Fig. 1. Low HP Genset (20 kVA)

Fig. 1 represents a genset with all the mentioned parts. The existing mounting system is classified as soft mounting system as the stiffness of the rubber mounts is very less.

Two cylinder inline engine of the considered genset constantly runs at 1500 RPM during operation. Therefore the excitation frequency of the system can be taken as:

$$f = \frac{1500\,rpm}{60\,sec} = 25\,Hz \qquad \text{------ (1)}$$

Now, as the excitation frequency is 25 Hz, we know that our natural frequency of the mounting system should be well below or away from this frequency. Also the transmissibility of the genset mounting system can be less than one, if the natural frequency of the mounting system is:

$$f_n = \frac{1}{\sqrt{2}}\, f = \frac{25}{\sqrt{2}} = 17.5\,Hz \qquad \text{---- (2)}$$

So, this provides us with the information that, if any of the six modes of vibration has a frequency near to 17.5 Hz, which can excite excessive vibrations. So using a built in program in MATLAB, following analysis was performed for the existing system:

Existing AVMs with Existing Model										
INPUTS										
From rear face of block		All								
2	0									
Engine	181	5.6162	4.183	5.8213	0.00388	0.0981	0.205			
Alternator	132	3.440	3.384	1.690	0	0	-0.213			
4	1.4									
Eng_left_mnt	147150	294300	147150	0.207	-0.152	0.325	0	0	0	0
Eng_right_mnt	147150	294300	147150	-0.207	-0.152	0.325	0	0	0	0
Alt_left_mnt	147150	294300	147150	0.1395	-0.18	-0.238	0	0	0	0
Alt_right_mnt	147150	294300	147150	-0.1395	-0.18	-0.238	0	0	0	0
0	9.81	0								
OUTPUT										
Mode	Frequency, Hz	Horizontal	Vertical	Fore-aft	Pitch	Yaw	Roll	Remarks	Acceptance criteria	
1	**5.77**	-0.41	0	0	0	0.03	0.91	ROLL	MEETS	
2	**6.76**	0	0.02	0.58	0.82	-0.01	0	PITCH	MEETS	
3	**10.39**	0.03	0	0	-0.01	-0.99	0.14	YAW	MEETS	
4	**11.53**	-0.01	-0.96	0.06	-0.26	-0.02	-0.03	VERTICAL	MEETS	
5	**14.49**	0	0.03	0.1	-0.99	0.01	0.02	PITCH	MEETS	
6	**18.52**	0.05	0	0	0.01	0.22	0.97	ROLL	DOES NOT MEET	

Fig.2 MATLAB output of existing mounting system

As can be seen from fig.2, the roll mode of vibration does not meet the criteria of frequency to be less than 17.5 Hz. Though it is away from the excitation frequency of the engine, it results into higher vibrations of roll mode during starting and stopping of the genset.

IV. Various Configurations of Rubber Mountings

Various constraints such as space availability, allowable changes in the design of the existing model and cost are the governing factors that affect the design of the new configurations. Total of four configurations are generated, as follows:

1. *Configuration I: Locating the AVMs in the plane of CG of engine and alternator*

The existing model has the AVMs located at the foot of the engine and alternator. As seen from the fig 2, the vibrations of roll mode are more than any other mode. Hence the task mainly concentrates on reduction of these Roll mode vibrations. It is obvious that if the force acts on the center of gravity no moment is produced. Thus to reduce the roll torque, the AVMs can be taken as close to the center of gravity of the engine and alternator as possible.
Hence, the AVMs are placed in the plane of CG of engine and alternator.

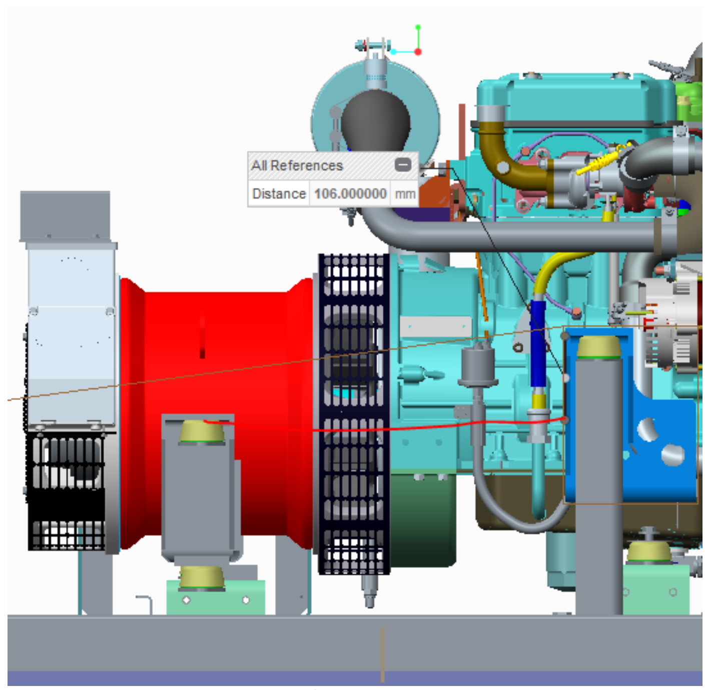

Fig. 3. Configuration I model

For this configuration, the brackets attaching the engine to the AVMs and AVM supports are modified in CREO, as shown in following fig. 4.

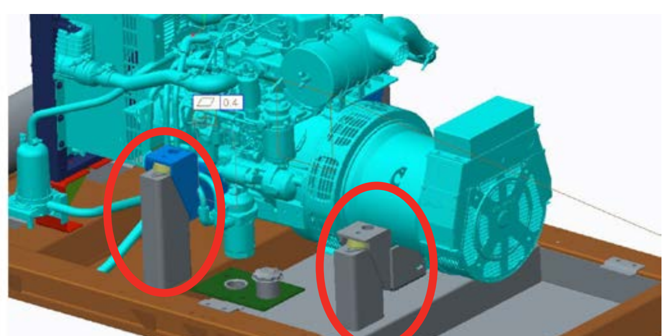

Fig. 4. Configuration I: CREO Model

2. Configurations II & III: Use of a cross channel below engine and alternator and Use of two AVMs in parallel

Instead of mounting engine and alternator AVMs on separate brackets, a single cross channel is provided below engine and alternator and AVMs are fitted below it. Following snaps represent the model:

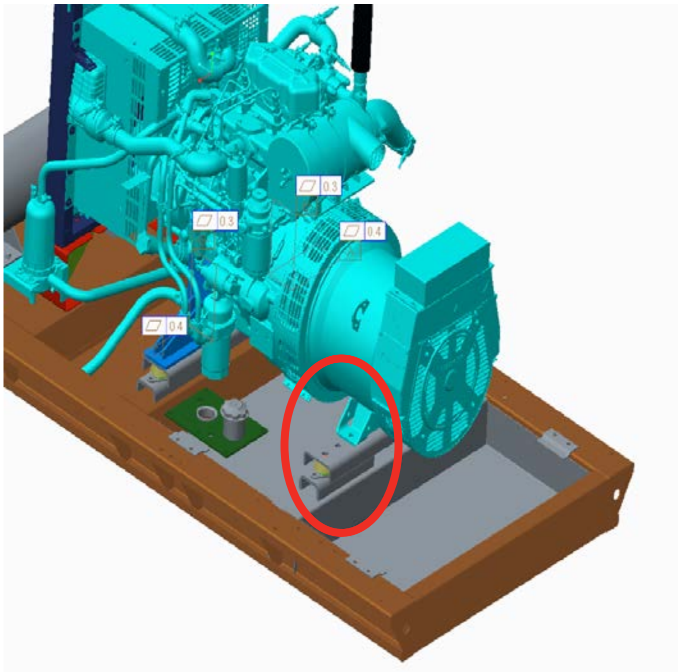

Fig. 5. Configurations II and III

The cross channel will facilitate positioning of the AVMs at wider locations thus ensuring that the roll frequency is slightly increased. With increased frequency, the amplitude of vibration would reduce. Analysis of this configuration using software does not take into account the effect of rigidity of the cross channel provided below engine and alternator.

Configuration III is a better option if the roll frequency is not supposed to be increased. This configuration engages the existing mounting system for the entire operation thus by maintaining the existing transmissibility of soft mounting system, but it also restricts the vibrations after certain deflection by using hard mounting system. The amplitude of vibrations is high during the starting and stopping, but very negligible during constant rpm running of the engine. Thus, design of this configuration engages the soft mounts for entire operation. A gap of 2-3 mm is maintained between the heights of soft and hard mounts, thus hard mounts are engaged only during starting and stopping vibrations of the genset. Thus the vibrations amplitude are restricted after 2-3mm and the gap is again maintained during the constant rpm running of genset.

3. Configuration IV: Use of Mechanical lock AVM

An already existing solution in the market, with exceptionally no modifications required in the existing model is the Mechanical lock AVMs. These AVMs come with a metal cup inside the rubber bush that restricts the motion of the central bolt connecting engine brackets with the AVMs, thus acting like a mechanical lock.

Following fig. 6 shows the section of the CREO model of mechanical lock AVM.

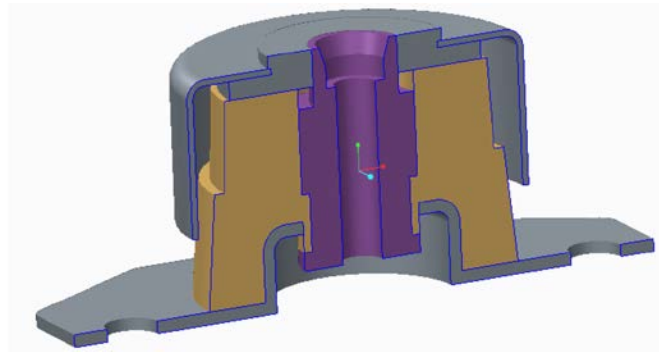

Fig.6. Configuration IV: Mechanical lock AVM

There is certain gap between central screw and the metal cup on each side, thus the roll mode vibrations will be restricted after a deflection of the screw equal to the gap on each side by this AVM.

V. SIMULATION OF RUBBER MOUNTS

The performance of these configurations is judged upon the frequency output of the analysis. MATLAB uses a coded program that accepts inputs such as: engine and alternator mass and CG locations, stiffness of AVMs and their locations from a reference point. The output obtained from this is the 6 natural frequencies of the mounting system and its detailed description into 6 modes of vibration.

Thus from this analysis we can state the exact factors affecting the roll mode frequency of the mounting system.

Total 32 iterations were performed in the MATLAB to understand the effect of six different factors such as: Location of AVMs on each alternator and engine side along:

i) Width iii) Height

ii) Length

Table 1
Factors affecting roll frequency of mounting system

	Engine Mounts location(mm) along			Alternator mounts location(mm) along		
	Length	Width	Height	Length	Width	Height
High	325	377	98.1	-238	307	0
Low	75	207	-152	-238	139.5	-180

Maximum and minimum possible value of each factor is taken for analysis and its effect is then studied.

As is seen from the following analysis the roll frequency is excessively high that is 25.37 Hz which is not acceptable. This is because of the space restrictions in the design.

Simulation of first configuration shows following results:

INPUTS

rom rear face of block		All											
2	0												
Engine	181	5.6162	4.183	5.8213	0.00388	0.0981	0.205						
Alternator	132	3.440	3.384	1.690	0	0	-0.213						
4	14												
Eng_left_mnt	147150	294300	147150	0.377	0.0981	0.325	0	0	0	0	0	0	
Eng_right_mnt	147150	294300	147150	-0.377	0.0981	0.325	0	0	0	0	0	0	
Alt_left_mnt	147150	294300	147150	0.307	0	-0.238	0	0	0	0	0	0	
Alt_right_mnt	147150	294300	147150	-0.307	0	-0.238	0	0	0	0	0	0	
0	9.81	0											

OUTPUT

Mode	Frequency, Hz	Horizontal	Vertical	Fore-aft	Pitch	Yaw	Roll	Remarks	Acceptance criteria
1	**8.16**	0.97	0	0.19	-0.02	0.11	0.04		
2	**8.16**	-0.19	0	0.98	0.09	0.01	0.01		
3	**11.4**	0	-0.51	0.01	-0.86	0	-0.01		
4	**12.21**	0	-0.12	-0.01	0.99	0	-0.01		
5	**14**	0.01	0	0	0	1	0.1		
6	**25.37**	0	0	0	-0.01	-0.18	-0.98	ROLL	

Fig. 7. Result for configuration I

VI. Results

Results similar to shown in fig. 7 are obtained for all the 32 iterations and these are plotted using MINITAB to analyze the effects.

The graphs obtained from MINITAB are shown below:

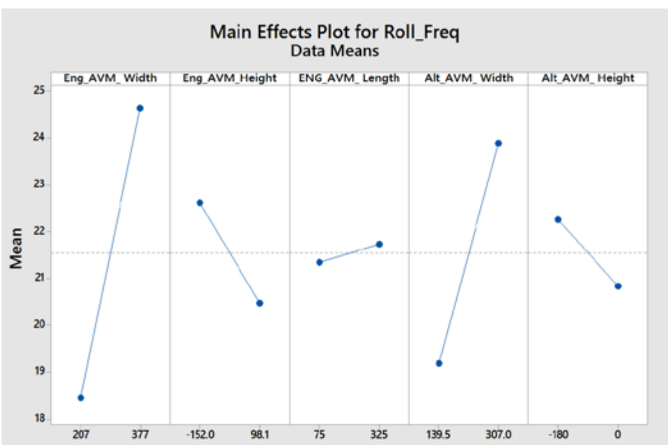

Fig. 8 Main effects plot for roll frequency

Fig. 8 shows the effect of various factors on the roll frequency, as can be seen the location of AVM along width of engine and alternator has the maximum effect on the roll frequency. Increasing the location along the height of alternator and engine reverses the effect but it is not as effective as the changes due to along width.

VII. Conclusions

Following conclusions are drawn from the design and simulation of four configurations:

1) Location of AVMs is increased along width of engine and alternator in configurations 1 and 2, which result into increased roll mode frequency of the mounting system and thus lesser amplitude of vibrations.
2) Due to increased roll mode frequency, the transmissibility of the mounting system may increase.
3) Configurations 3 and 4 use the same stiffness of mounting system and thus, roll mode frequency is same as existing model, but these configurations also restrict the deflection and thus amplitude of roll mode vibrations is reduced.
4) Thus, configurations 3 and 4 reduce the amplitude of roll mode vibrations by 25-40% during start and stop of genset and also maintain the desired transmissibility.

VII. Future Scope

Due to constraints in software, simulation of all the models is not possible here. Thus the future scope includes possible validation of these configurations experimentally.

References

1. Yunhe Yu, Nagi G. Naganathan, Rao V. Dukkipati, "A literature review of automotive vehicle engine mounting systems", Elsevier, Mechanism and machine theory,36, 2001.
2. Mattias Sjoberg, "On dynamic properties of rubber isolators" Department of vehicle engineering, The Marcus Wallenberg Laboratory for Sound and Vibration Research 2002.
3. Thanh Quoc Troung, Kyoung Kwan Ahn, "A new type of semi-active hydraulic engine mount using controllable area of inertia track" Elsevier, Journal of Sound and Vibration,329, 2010.
4. P. L. Walsh and J. S. Lamancusa., "A Variable Stiffness Vibration Absorber for Minimization of Transient Vibrations". Elsevier, Journal of Sound and Vibration, 158, 1992.
5. David L. Platus, "Negative Stiffness mechanism vibration isolation systems", Vibration Control in Microelectronics, Optics, and Metrology, 1991.
6. A. S. Sathawane and A. V. Patil, "Analytical Study of Engine mount to suit the damping requirements of engine", International Journal of Latest trends in engineering and technology, 3 January, 2014.
7. Robert Simmons, "Vibration Isolation", ASHRAE journal, August 2007.
8. Priyanka P. Pawaskar, et. al., "Hydraulic Engine Mount – in automotive application", International Journal of Scientific Research and Management, 2015.
9. Singiresu S. Rao, "Mechanical Vibration", Fifth edition, Pearson, 2010, pp. 801-842.
10. J. P. Den Hartog, "Mechanical Vibrations", 1985 Dover Publications, Inc., pp.87-117, 258-262.