Design and Development of Control Panel Box for Diesel Generator using Finite Element Method

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ABSTRACT

Now a days Diesel generator set have become basic need of the modern world for constant electric supply or for power back up solutions. A Diesel Generator set consists of a diesel generator, an alternator and a control panel box. The speed of a diesel engine in a generator may have speed ranging within different limits but alternator have to maintain a constant electrical supply of frequency 50 Hz. Many vibration issues are related with the Diesel Generator set. The vibration level becomes severe when the engine runs at highest speed. Control Panel is one of the key elements of Diesel Generator set. The control panel covers some of the intricate components and electrical circuits which is hard to replace frequently. The main objective of this paper is to discuss the design and development of a control panel for given generator to minimize its vibrations in order to avoid resonance.

Keyword: *Control panel, Diesel Generator Set, Resonance.*

1. INTRODUCTION

A control panel is a set of displays that indicate the measurement of various parameters like voltage, current and frequency, through gauges and meters. These meters and gauges are set in a metallic body, usually corrosion proof, to protect from the effect of rain or snow. The panel may be set up on the body of the generator itself, so they are subjected to severe shocks and vibrations. Some of the common things today's control panels offer include; continuous digital readouts, large character LCD screens, displays with running time, oil pressure and water temperature sensors, set points and custom message options, wiring harnesses, remote and local start/stop capabilities, and of course shut-down capabilities. The control panel should be able to sustain the vibrations generated by the Generator. The control panel box should be designed to avoid the resonance. The present paper focuses on the increase in natural frequency of the control panel box beyond the frequency of engine vibrations. There are many methods to do this. In this paper we are dealing with FEM.

The analysis approach is different based on whether the control panel is rigid or relatively flexible. For the given maximum speed of 3600 rpm, the frequency of vibration is maximum Hence 60 Hz is designated as threshold frequency. If the lowest natural frequency of the system is more than the threshold frequency, the system is considered as rigid. The model was created using SOLID WORKS. Then the model was imported to ANSYS 16.0 and then it was analyzed.

2. PROBLEM STATEMENT

A Diesel generator set includes diesel engine, alternator and control panel mounted on a common base frame. The control panel is less rigid in comparison with generator and alternator. As the engine speed increases, frequency of engine vibration also increases. The frequency of vibration is maximum at highest speed of engine. The objective of the study is to design the control panel box to withstand the external vibrations at maximum engine speed without resonance.

3. MATERIAL AND DIMENSIONS OF CONTROL PANEL BOX.

The Finite Element analysis of the control panel box has been carried for three different models of the control panel box. Base Model and both iterations are made from same material and have identical shape and size. The dimensional details of control panel box are given below.

Table 3.1 Control Panel dimensions

Structure Parameter	Value
Control Panels width (mm)	300
Control Panels height (mm)	450
Control Panels thickness (mm)	101
Thickness of the sheet (mm)	1

The materials used for manufacturing of control panel box and its properties are mentioned in a Table shown below.

Table 3.2 Material Specifications

Material Specification	Structural Steel
Density	7850 kg m^{-3}
Young's Modulus	2.0 x 10^{11}
Poisson's Ratio	0.3
Yield Strength	2.5 x 10^{08}
Specific Heat	434 J kg^{-1} C^{-1}

4. FINTE ELEMENT ANALYSIS OF CONTROL PANEL

The Finite Element analysis of the control panel box has been carried for three different models of the control panel box namely Base Model, Iteration 1 Model and Iteration 2 Model. All three models are mainly analyzed for modal analysis in ANSYS. The all three models of the control panel assemblies are created using Solid Work. The model was then analyzed in ANSYS 16.0 software.

4.1 Modal Analysis of Base Model

Modal Analysis includes study of dynamic properties of a structure under vibration. The Dynamic response of a structure which is under vibration is measured and analyzed by Modal Analysis. In modal analysis pre-stressed static structural environment is considered. Modal analysis was carried out to determine the natural frequencies and mode shapes of a structure.

The base model is a primary control panel box which was previously used in the diesel generator set. A 3D diagram of Base model is shown in the following fig.1

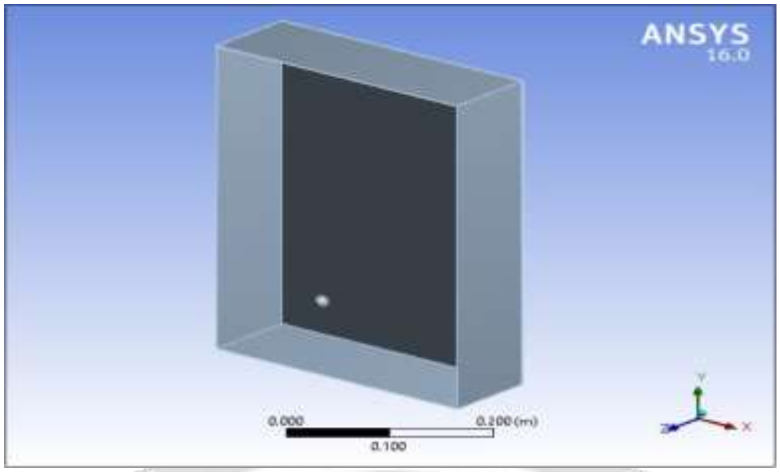

Fig 1 : Base Model

The natural frequencies of vibration for first six modes of vibration are obtained using ANSYS software which is shown in the following Fig 2

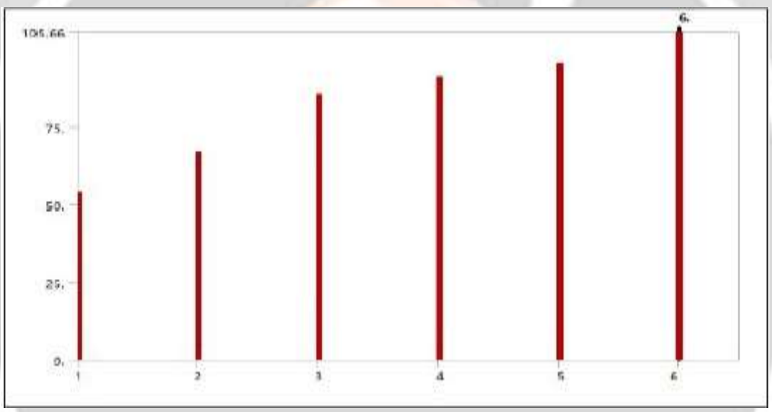

Fig 2: Natural frequency of base model

The results of natural frequencies of base model for first six modes of vibration are given in the following table.

Table 4.1 Natural Frequencies of Base Model

Mode	Frequency (Hz) (ANSYS)
1	53.662
2	66.625
3	85.673
4	91.228
5	95.689
6	105.66

The diesel engine used in the generator runs at a maximum speed of 3600 rpm. So the frequency of vibration of engine at maximum speed is 60 Hz. The design frequency of vibration for control panel box is 60 Hz. In case of base model, the first mode of natural frequency is at 53.662 Hz, which is less than the design frequency. It means, as the speed of engine increases there is a point where natural frequency of control panel becomes equal to the external excitation frequency and this leads to resonance. In order to avoid resonance and to make design more rigid, some changes have to made in the base design of control panel.

4.2 Modal Analysis of Iteration 1 by FEA

Iteration 1 is modified design of base model of control panel box. The change in base model is that two common supports are provided to horizontal and vertical surfaces as shown in Fig.3

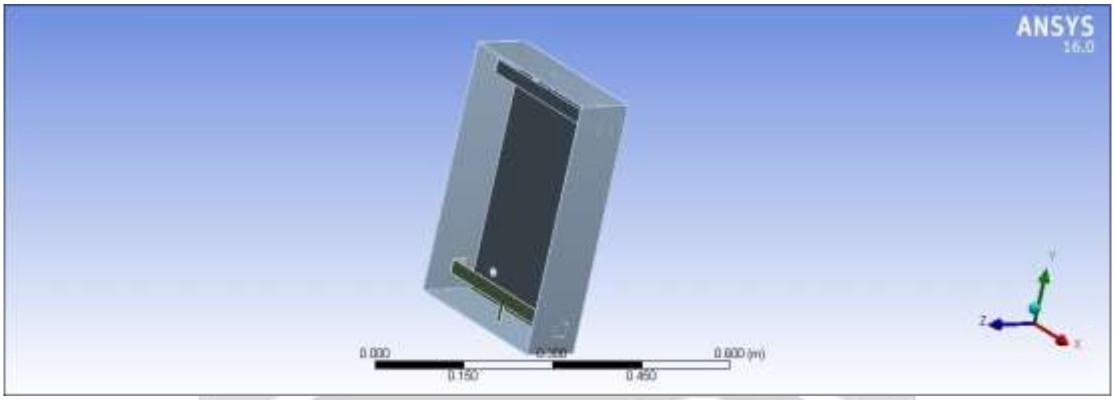

Fig 3 Iteration 1 Model

The results of modal analysis of iteration 1 are represented using following Fig.4

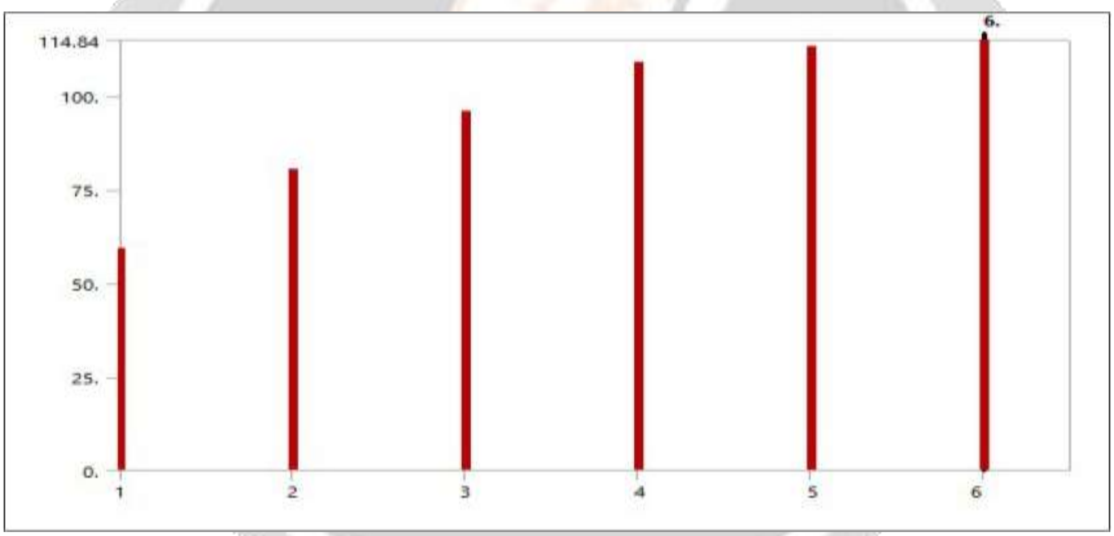

Fig 4 Natural frequency of Iteration 1

The results of natural frequencies of base model for first six modes of vibration are given in the following Table 4.2

Table 4.2 Natural Frequencies of Iteration 1

Mode	Frequency (Hz) (ANSYS)
1	59.168
2	80.149
3	95.984
4	108.92
5	113.1
6	114.84

As discussed earlier the diesel engine used in the generator runs at a maximum speed of 3600 rpm. So the frequency of vibration of engine at maximum speed is 60 Hz. The design frequency of vibration for control panel box is 60 Hz. In case of Iteration 1 the first mode of natural frequency is at 59.168 Hz, which is less than the design frequency.

4.3 Modal Analysis of Iteration 2 by FEA

Iteration 2 is a modified design of Iteration 1 of control panel box. In Iteration 2 entire focus is made to increase the rigidity of the control panel box. For doing so, additional mass is added away from the center of the control panel box.

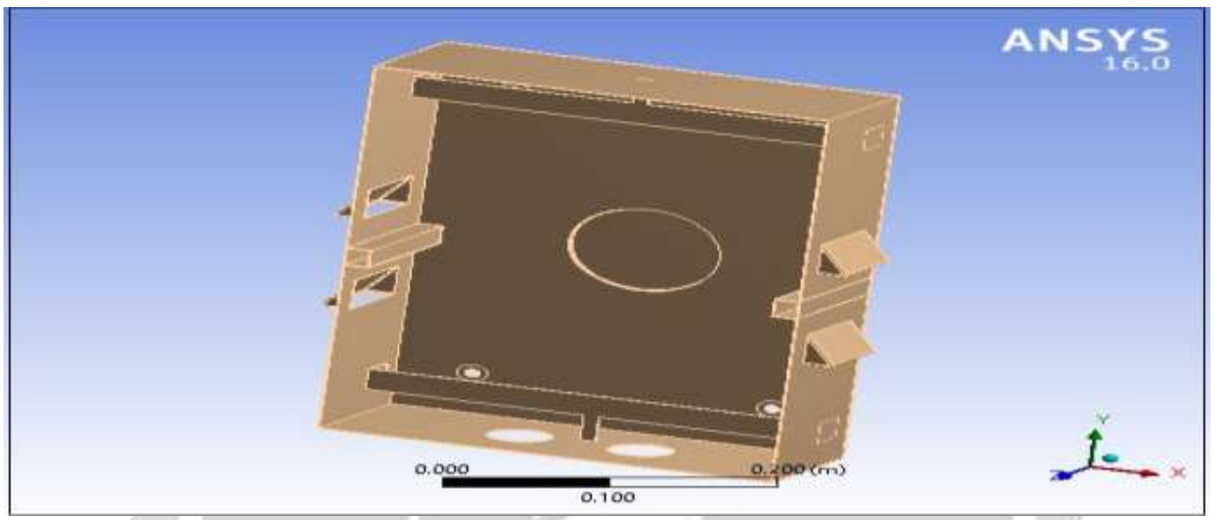

Fig 5 Iteration 2 Model

The modal analysis of iteration 2 is carried to evaluate natural frequencies of first six modes of vibration. The main objective is to check whether the natural frequency of vibrations of iteration 2 at various modes of vibration. The natural frequency at first mode of vibration must be greater than the frequency of external excitation at maximum speed of engine.

The results of modal analysis of iteration 2 are represented using following Fig.6

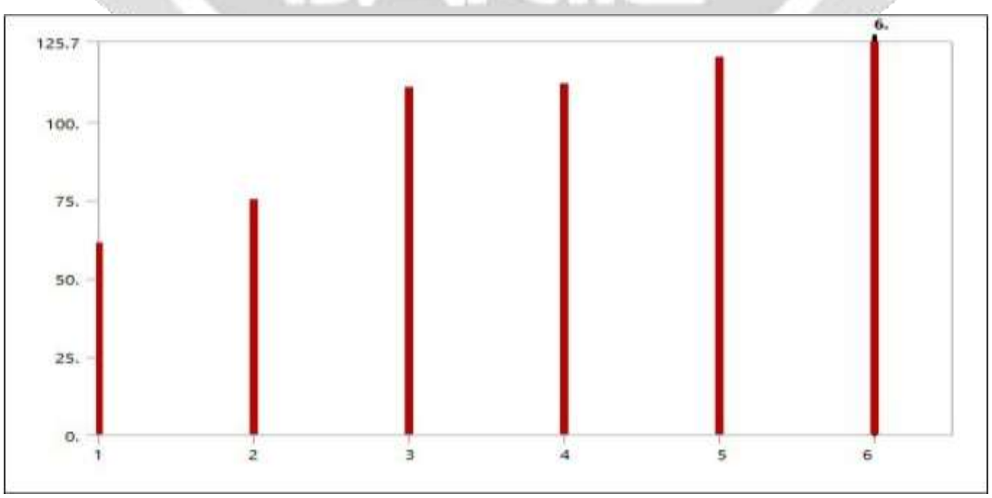

Fig 7 Natural frequency of iteration 2

The results of natural frequencies of base model for first six modes of vibration are given in the following Table 4.3.

Table 4.3 Natural Frequencies of Iteration 2

Mode	Frequency (Hz) (ANSYS)
1	61.324
2	75.329
3	111.12
4	112.4
5	120.57
6	125.7

As discussed earlier the diesel engine used in the generator runs at a maximum speed of 3600 rpm. So the frequency of vibration of engine at maximum speed is 60 Hz. The design frequency of vibration for control panel box is 60 Hz.

The natural frequency at first mode of vibration is found to be 61.324 Hz. It means natural frequency of vibration at first mode is greater than the external excitation frequency at maximum speed of engine. So the design of Iteration 2 is safe for the given working environment.

5. RESULT AND DISCUSSION

With the use of finite element method, we have obtained significant results of natural frequencies of Base model, Iteration 1 and Iteration 2. First six modes of vibration have been considered as significant considering working conditions of the system. The comparison of obtained results will prove the usefulness of the suggested model i.e. Iteration 2 of the Control Panel Box. The Table 5 shows the comparison of obtained values of natural frequencies using finite element method.

Table 5 Natural Frequencies for Control Panel Boxes Using FEA in Hz

Mode	Base Model	Iteration 1 Model	Iteration 2 Model
1	53.662	59.168	61.324
2	66.625	80.149	75.329
3	85.673	95.984	111.12
4	91.228	108.92	112.4
5	95.689	113.1	120.57
6	105.66	114.84	125.7

From Table 5 we found natural frequencies have been increased steadily and for Iteration 2 it is beyond the frequency of external excitation at maximum speed of engine. The maximum speed of engine is 3600 rpm and hence frequency of excitation at maximum speed is 60 Hz.

6. CONCLUSION

The minimum natural frequency obtained from finite element analysis of control panel box is found to be greater than the system frequency of vibration due to external excitation. This avoids the resonance of control panel which leads to the satisfactory design of the control panel box.

7. REFERENCES

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