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Research Paper

Dynamic Analysis of Electric Vibration Motor to Reduce the Vibration Transfer Path Using Finite Element Method

Engineering

KEYWORDS : Modal Analysis, FEA, OLI Motor, TPA, Frequency Response

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ABSTRACT

Electric Vibration motor is mostly used in the cement industry. Increasing the life of motor is the prime concern in the industry. Increasing the life of motor is important such that the motor doesn't go under maintenance frequently. There are various aspects to increase the life of motor such as lubrication, electrical winding and mechanical vibration. From the vibration perspective increasing the life of motor will be interesting part. In this study a dynamic simulation is conducted on an OLI MVE 300/3 motor. Finite element analysis is performed to obtain the mode shape behavior and response on the motor for the applied loading. Simulation inputs were taken from the motor catalogue, based on that, load and boundary conditions were decided. This load is applied to the FE model in NASTRAN, and boundary conditions were applied according to the motor mounting conditions. The simulation is carried on original design to know the mode shape behavior and response of the motor. Design modification is created on motor such that the vibration through the transfer path reduces without shifting the motor frequency to the higher side as this motor is meant to generate vibration..

INTRODUCTION

The dynamic analysis of 3 Phase and 2 poles OLI vibrator Motor (MVE 300/3) is performed to determine the Eigen frequencies and know the possibility of high vibration. After knowing the global mode of the motor, amplitude at the base of motor is reduced by doing the modification in the structure.

This modification will reduce the vibration at the imparting structure by transfer path analysis (TPA). TPA is performed on the motor by frequency response analysis. In this work result of original model is compared with the modified model and effect on vibration transfer path is studied.

OLI motor MVE 300/3 (Three Phases 2 Poles 3000 RPM) configuration is available which is used for the cement industry. The detail configuration of the motor is shown in the Table 1. Complete assembly of OLI motor is composed of Motor housing, Shaft, Flange, Counterweight, Armature and Side Cover. 3D model is created based on the physical model The CAD model for the motor is generated in CAD software (unigraphics). Detail of individual component of the Motor is shown in Figure1.

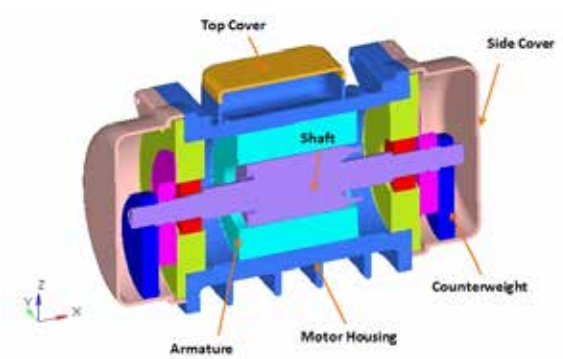


Figure 1: OLI Motor – 3D Sectional View

TABLE – 1
Mechanical Feature of OLI - MVE 300/3

Mechanical Feature – MVE 300/3	
Weight [kg]	9.8
Working Moment [kg-cm]	4.5
Motor RPM -60Hz	3000 - 3600

SCOPE OF WORK

This paper can be used to understand the methodology used to create FE model for dynamic simulation using NASTRAN as solver, Hypermesh

V11.0 is used to build FE model, HyperView v11.0 and HyperGraph v11.0 is used for post-processing.

FE methodology covers Geometry import, geometry clean up, procedure to create meshed model, time step calculation, material application, mass application, boundary conditions application, post processing results, interpretation of results and comparing the result of original design with the modified design.

MODELLING APPROACH

Material properties

The material chosen for this analysis is chosen from the catalogue (@Industrial Vibrator., OLI-Catalogue). Structural aluminium is considered for the Motor housing and end cover which is the major weight contributor. Flange and eccentric weight considered as Gray cast iron.

Shaft is considered as structural steel material. The entire component relevantly assigned density. The relevant material properties are summarized below in Table 2.

TABLE – 2
Material Properties

Component	End Cover, Motor Housing	Flange, Eccentric Weight	Cover, Shaft
Material	Aluminium	Gray Cast Iron	Steel
Specification	6061-T6	ASTM -40	AISI 304
E-modulus [MPa]	68,000	1,24,000	1,93,000
Poisson Ration	0.33	0.26	0.3
Density [kg/m^3]	2.7e-9	7.2e-9	7.9e-9
Yield limit [MPa]	276	276	240
Ultimate Limit	310	400	585

Meshing and Method

All individual motor components (Housing, Shaft, Counterweight, End Cover and Armature) are meshed with 3D solid (Tet10) element using meshing software Hypermesh v11.0. Following steps are followed for meshing the frame.

1. Import thee CAD model in hypermesh.
2. Defeaturing the geometry by removing small holes, fillet and trimming.

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3. Different material is created, based on material of different component provided in material catalogue.
4. Bolted joints are considered as rigid and hence modeled using a beam and RBE2 spider connection. Bolts are modeled using combination of rigid element and beam elements. The diameter of beam element is equal to that of bolt with high material stiffness.
5. Bearing are modeled as bush element and assigned stiffness of NSK 6202Z.

Mass and FE modelling strategy is described in detail in Table 3

TABLE – 3
Mass and FE details

Components	Total Mass [kg]	FE detail
Motor Housing	2.8	FE mesh
Armature	1.2	FE mesh
Shaft	1.32	FE Mesh
Counterweight (Total no. -04)	1.46	FE mesh
Side Cover	0.52	FE mesh
Flange (Total no. -02)	2.5	FE Mesh
Bearing	-	Modelled as 1d Bush Element
Total	9.8	

No load and boundary condition in case of dynamic analysis as it is free-free modal analysis. The bolt hole location is not constrained as motor is mounted on the AVM which make it as two state system. Total torque of magnitude 441.45 N-mm is applied on the shaft. This torque is transferred at varying frequency. In case of frequency response analysis to avoid the singularity the model needs to be constrained at some location. As the load is transferred through the AVM it is assumed that the motor firmly rest on AVM and corresponding holes constrained in translational DOF

RESULT AND DISCUSSION

Modal analysis is performed to evaluate the natural frequencies and mode shapes of the OLI MVE 300/3 motor. By performing the modal analysis eigenvalues and eigenvector are precisely extracted.

Using this method local and global modes has been identified which are presented in Table 8 and highlighted as dark color.

From the result following observation can be drawn.

•First 22 modes are the local modes of the motor in which shaft or side cover are participating maximum modal mass. As these are the local modes of the structure, motor will not generate the peak response in these modes. the local mode don't contribute large modal mass and hence this mode not capable to excite the other structure or other way we can say that the effect is very local and limited to the component.

•Global modes in the structure are the dominant modes and able to vibrate the whole structure which lead to high amplitude or response in the structure. These modes called as critical mode as it has ability to vibrate the other structure. Large modal mass contributes at these global modes. Global modes and their and corresponding mode shape are observed at following frequencies

@3527 Hz; Torsional mode of motor
@4322 Hz; Lateral bending of motor and End cover bulging more dominant
@4347 Hz; Longitudinal bending of motor
@4898 Hz; End cover bulging dominant and motor tilting one side

Details of the motor global mode is shown in Figure 2, Figure 3 and Figure 4.

In Table 4 all the extracted modes are tabulated in which first critical local modes and global modes are highlighted.

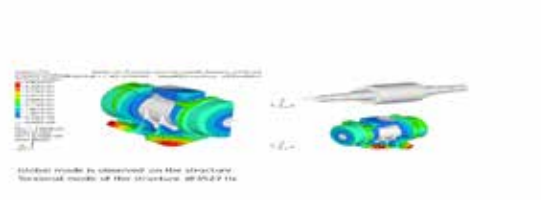


Figure 2: Global mode @ 3527 Hz; Torsional mode of structure

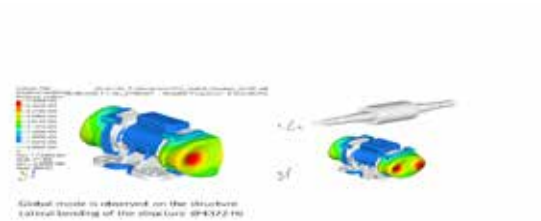


Figure 3: Global mode @ 4322 Hz; lateral bending of structure

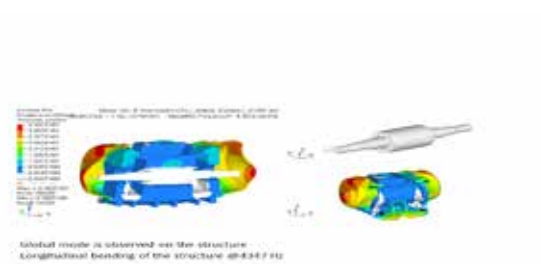


Figure 4: Global mode @ 4347 Hz; longitudinal bending of structure

TABLE – 4
Mass and FE details

Mode	Frequency [Hz]	Mode shape
1	3527	Torsional mode
2	4322	Lateral Bending mode
3	4347	Longitudinal Bending mode

To reduce the vibration from the motor to another structure, modification in motor base has been done. The modified CAD model for the OLI- MVE 300/3 is shown in the Figure 5. Dimension for the bush is shown in Figure 6.

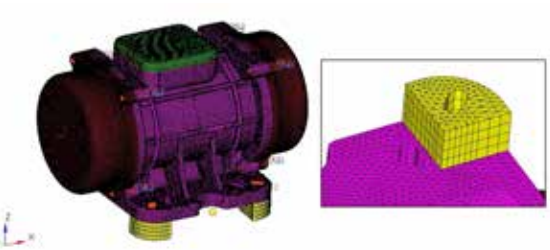


Figure 5: Modified Model for OLI- MVE 300/3

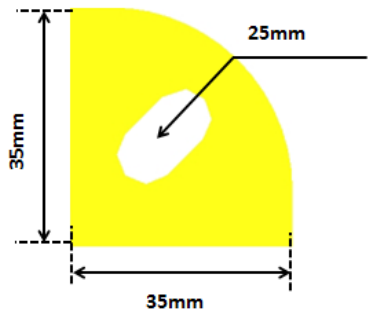


Figure 6: Bush Dimension

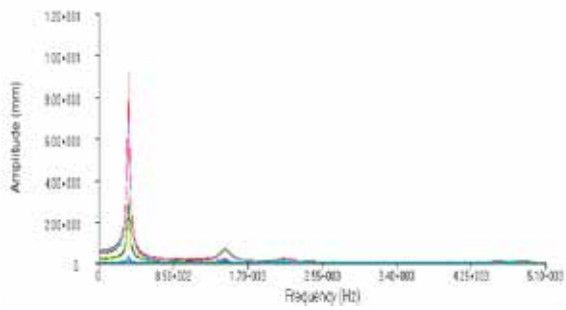


Figure 7: Vibration amplitude (mm): Original Design

After calculation of amplitude for the original design, frequency response analysis with the same set-up is performed on the modified design. Transfer path analysis (TPA) is performed by FRF method on the both the designs and purpose of the modified design is to reduce the vibration amplitude on another structure without shifting the frequency obtain from the modal analysis.

The detail of amplitude obtained for the modified model is shown in Figure 8. From the graph we observed that maximum amplitude of 4.5 mm is observed for the modified design. All the vibration amplitude is measured at the bush of the motor base.

From the result obtained we can say that the vibration amplitude at the base is reduced by 50% as compared to the original design. This indicates improvement in the vibration transfer path.

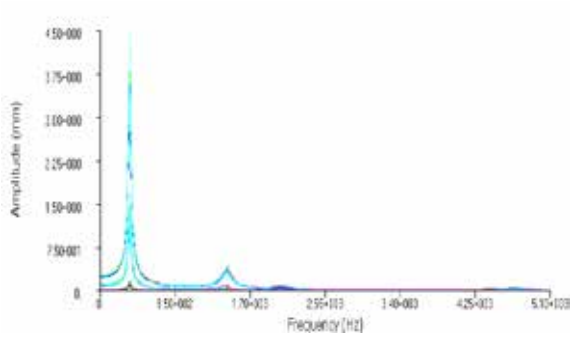


Figure 8: Vibration amplitude (mm): Modified Design

Mode shape comparison

Modal analysis has been performed on modified model. From the modal analysis it has been observed that due to modification in the base of the structure the first global mode of the motor is appeared at 2900 Hz which is 17% less than the first global mode of original design.

Reduction in the frequency is also observed for other global modes but the variation is less than 1%. As the first global mode is shifted to the lower frequency, the motor will readily excite at lower frequency as compared to the original design.

Hence the purpose of motor for which it is mean to induce vibration on another structure is still valid.

First global mode is torsional mode. Mode shape for both the design at first global mode is shown in Figure 9.

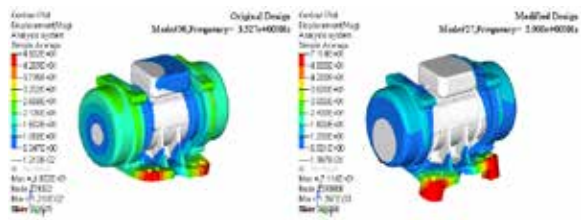


Figure 9: Torsional mode

Second global mode is lateral bending mode. Mode shape for both the design at first global mode is shown in Figure 10.

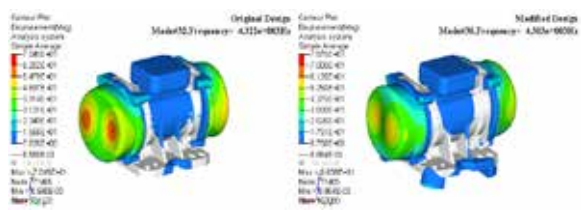


Figure 10 Lateral Bending mode

Second global mode is longitudinal bending mode. Mode shape for both the design at first global mode is shown in Figure 11.

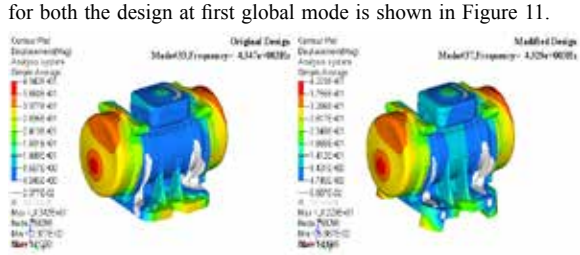


Figure 11: Longitudinal Bending mode

TABLE – 5

Mode shape and Eigen value for Original and modified design

Frequency – Original Design [Hz]	Frequency – Modified Design [Hz]	Variation (%)
3527	Torsional mode	-18
4322	Lateral Bending mode	-0.4
4347	Longitudinal Bending mode	-0.4

CONCLUSIONS

In the original model the first global mode is achieved at 3527 Hz whereas in the modified model first global is achieved at 2900 Hz which is lower than the original model. Hence we can say the proposed modification of motor is not shifting the frequency to higher side i.e. the motor will readily excite at even lower frequency than the original model for the purpose it meant.

As the modal behavior is not sufficient the frequency response analysis of motor is required to evaluate the response of the structure. To longer the life of the motor the vibration at the imparting structure need to reduce. From the frequency response

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analysis after the modification the response at the base of the structure is reduced by 50% than the original model.

Testing of the motor for the both the design will provide for data for the validation of the FEA result and accordingly the analysis can be modified. More parameter can be study to increase the life of motor and that parameter can be included in Finite element analysis.

Modification at the shaft will also be of great interest. Addition of bush near the shaft can be explore such that it will improve the vibration transfer path.

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