Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

Investigative Study of Vibration Induced Stress Analysis on Motor Mounting Lugs

Chandrashekhar Bhore,
Department of Mechanical Engineering,
Pimpri Chinchwad College of Engineering,
Pune, India

Prof. L.V. Awadhani,
Department of Mechanical Engineering,
Pimpri Chinchwad College of Engineering,
Pune, India

***Abstract* – The Alternate Current Pump Motor (ACMP) is components used in aircraft and it is operating in heavy mechanical vibratory loading environment that are either harmonic or random in nature . In all these situations, the structure or machine component subjected to vibration may fail because of material fatigue resulting from the cyclic variation of the induced stress. In case of resonance, large deflections and failure may occur. The effect of these vibrations is to increase the stress levels in the components. Due to this, the fatigue failure of the components may occur. This paper presents investigative study of vibration induced stress analysis on motor mounting lugs where vibration loading requirements as per aerospace standards (DO-160, MIL-STD 810E) and the numerical FEA allowing verifying those loads through modal analysis and nodal solution especially to FEA preprocessing, solutions and Post processing. Modal analysis results Alternating Current Motor Pump gets resonance for complete assembly and Nodal analysis gives the critical stresses on motor mounting lugs. The experimental test setup as per aerospace standard follows vibration test procedures guides for testing step by step vibration testing. Simultaneously shaker tables feeds forced vibration loads to shakes the ACMP components and Strain gauge measurement system gives stain measurement which is converted into vibration induced stress at stain gauge location. The vibration induced stress outcomes from numerically and experimentally co-relates. This projects beneficial to understand and takes through complete numerical and experimental cycle.**

Keywords— Vibration Induced Fatigue, Modal Analysis, Vibration Fixture, Power Spectral Density, Finite Element Method ANSYS, Strain Gauges,Stress etc.

I. INTRODUCTION

The effect of aerospace industry components are heavily under vibrations is to increase the stress levels in the components. Due to this the fatigue failure of the components may occur. In order to safeguard the component, the vibrations and the stresses induced in the components needs to be studied thoroughly. In this work an investigation is carried out on a motor mounting lug used in the aerospace industry which is located at mid fuselage. The investigation is based on numerical analysis using FEA and experimental analysis for the validation using the appropriate standards.

In this work an Alternate current motor pump (ACMP) lugs support is chosen for the vibration studies Function of ACMP: Auxiliary power is provided by a 20-35 N/mm2, 12-gpm, 8000 rpm fluid - cooled motor pump. This protects the electrical wiring from being exposed to caustic hydraulic fluid environment. Please refer Figure 1.

Figure 1: ACMP CAD Model

Location of the motor in aircraft : The Alternate Current Motor Pump (ACMP) is located in mid fuselage and adjacent wheel wells (wing/body) fairings, both centre system. It is shown in Figure 2.

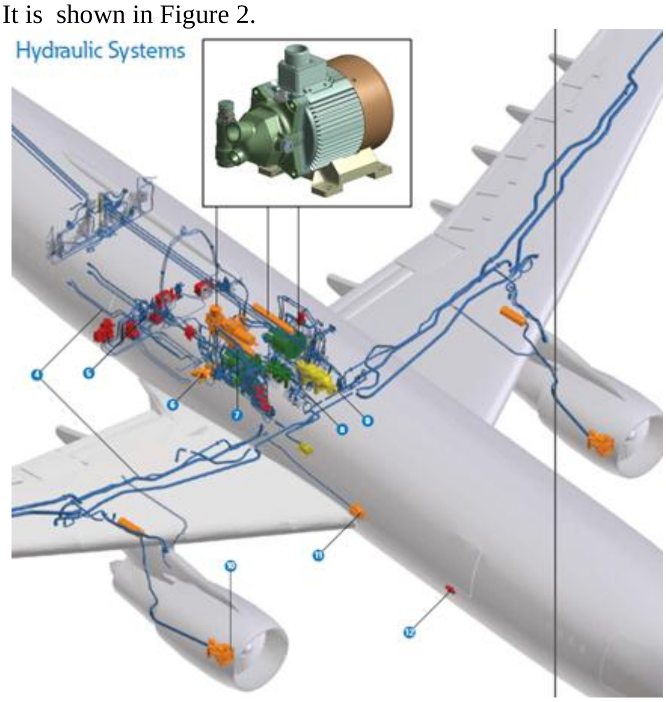

Figure 2: ACMP Motor Location in Aircraft

The ACMP consist of one of the major components from ACMP assembly which is directly interacted with vibration. Please see Figure 3:

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

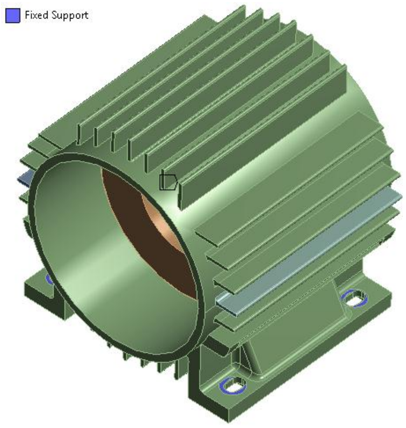

Figure 2: Motor Housing CAD Model

Typical failures in aerospace components (motor) mounting lugs :

Due to vibration induced stresses there is typical failures happen in the Motor Housing at Mounting lugs. Please refer figure 4 :

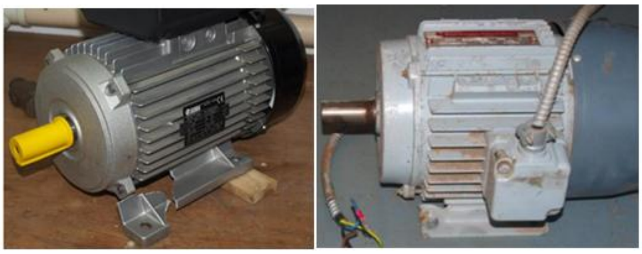

Figure 3: Motor Housing Mounting Lugs Failure [7]

Figure 4 shown that typical mounting failure happen during working of motor in daily working conditions where It is observed that whenever the natural frequency of vibration of a motor housing coincides with the frequency of the external excitation, there occurs a phenomenon known as resonance, which leads to excessive deflections and failure. The system failures brought about by resonance and excessive vibration of components and systems and adverse effect on functionality of the product such as functionality and missed the intent function of the product which causes the failure of the system. Typical behavior of the vibration induced stress results in fatigue failure as shown in following figure 6.

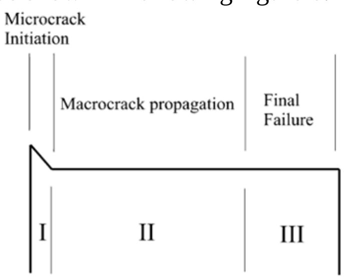

Figure 4: Schematic section through a fracture showing the three stages of crack propagation[5].

II. LITERATURE REVIEW

After the critical literature survey of the research papers the following useful outcomes were obtained:

1. Forced vibration modal analysis method and an accelerated vibration test specification load is defined as per aerospace standard (e.g. DO-160, MIL-STD 810F (2000)) is defined vibration input load is used for the evaluation of stresses in presence of vibration loading.
2. Vibration (PSD) approach is usually used for input loading which results stain and time history. The sinusoidal processes can be classified as wide band and narrow band.
3. The frequency domain methods for vibration-fatigue estimation focus on the structural dynamics.
4. A crucial part of a vibration induced stress analysis is the modal analysis that exposes the natural modes and frequencies of the vibrating structure and enables accurate prediction of the local stress responses for the given excitation through nodal solutions for calculating the maximum stress, minimum stress.

5. The mathematical approach developed to modify the output power spectral density takes the uniaxial/ multi-axial stresses into account at the point of consideration and provides the needed input loading (PSD) power spectral density.

6. Furthermore, An ideal damage-estimation method for use in a design process should be consistent across different spectra and different slopes of the S–N curve.

III. NEED OF PROJECTS

The motor support if fails it may lead to

- Accidental opening or leakages of hydraulics lines.
- Vibration fatigue failure for structural alinement.
- Difficult for design for manufacturing and assembly.
- Difficult for inspection for Maintenance, Repair and Overall (MRO).

Hence it is important to ensure the satisfy of motor mountings lugs.

Methodology:

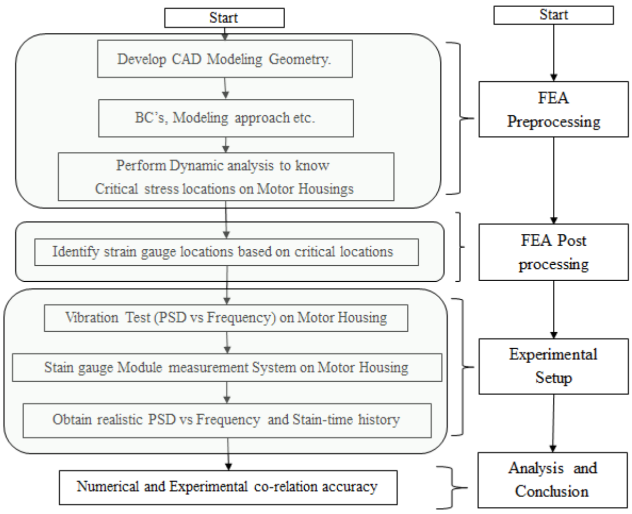

Figure 5: Proposed Methodology

Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

This work includes study of vibrational loading the stress analysis of motor mounting lugs using modal analysis numerically and measurement of stresses with experiments. The data for the analysis will be taken using aerospace standards (DO-160, MIL-STD 810G etc.) for vibration loading as per mounting components location

IV. OBJECTIVES

1. To investigate motor mounting lugs through numerically modal analysis using Finite Element Analysis (FEA). And
2. To investigate motor mounting lugs through experimentally effect of vibration on induced stresses.

The ACMP (Alternate Current Motor Pump) is one of major hydraulic system in aircraft which supplies hydraulic fluid to various major system in aircraft as a surge pump and mounting location is crucial in aircraft in regards vibration transfer in Y-direction in mountings location lugs shown in Figure **6**. The weight of Motor Housing is 1.81 KG.

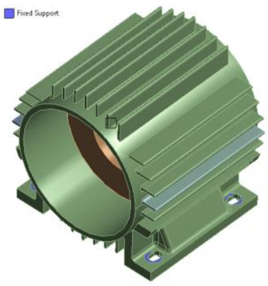

Figure 6: Motor Housing Mounting Lugs

In this work an Alternate current motor pump (ACMP) lugs support is chosen for the vibration studies Function of ACMP: Auxiliary power is provided by a 20-35 N/mm2, 12-gpm, 8000 rpm fluid - cooled motor pump. This protects the electrical wiring from being exposed to caustic hydraulic fluid environment.

Fixture Design as shown in following diagram and material for fixture is Steel which is having very high Stiffness and weight of Fixture is (4.2 KG) where we can make arrangement for Vibration Test as shown in *Figure 7*:

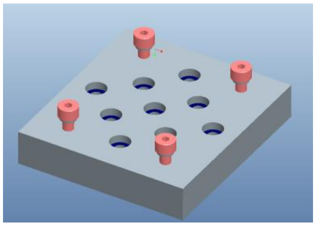

Figure 7: Fixture Design for Motor Mounting Lugs Testing

The actual Boundary Condition is simulated in ANSYS 14.5 as shown in following *Figure* **8.**

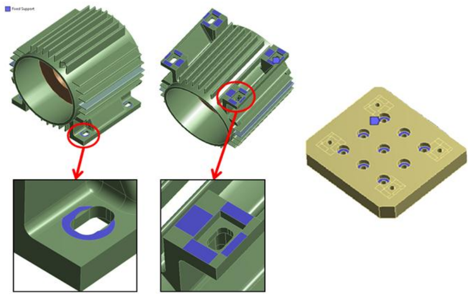

Figure 8: Boundary Condition for Fixture and Motor Housing Lugs

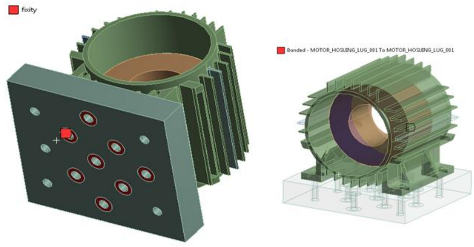

Figure 9: Defined Fixity condition for Vibration Fixture and Motor

In this section we will discuss about Forced Vibration loadings ,Modal Analysis, Stress Analysis with Vibration Test Procedure from various aerospace standard.

VIBRATION LOADING REQUIREMENT :

A vibratory system is a dynamic one for which the variables such as the excitations (inputs) and responses (outputs) are time dependent.

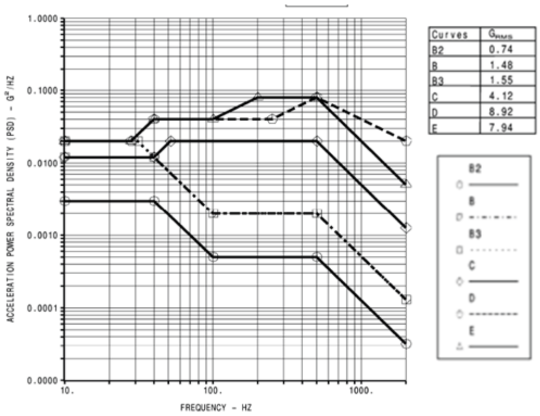

Figure 10: Vibration Force Diagram [10]

MODAL ANALYSIS:

Modal analysis is the study of the dynamic properties of structures under vibration excitation such as natural frequency, mode shapes, deflection. Resonance is the tendency of a system to oscillate with greater amplitude at some frequencies than at others.

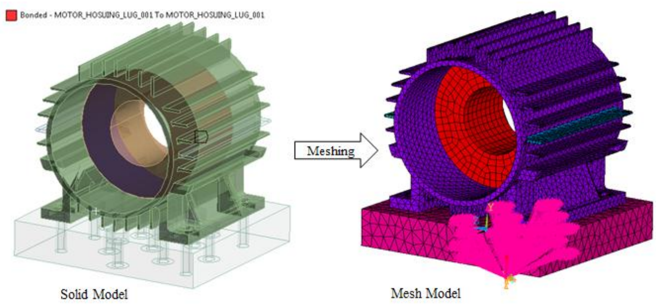

Figure 11: Meshing of Motor Housing Lugs and Vibration Fixture

Meshing for Motor Housing and Fixture is done in ANYSIS 14.5 as shown in following Figure 11Error! Reference source not found. and Nodes created as shown in following *Table 1*.

Statistics	
Nodes	107178
Elements	55026
Mesh Matrix	None

Table 1:Meshing Statistics

Modal Analysis run for Motor Housing and Vibration Fixture as shown in figure :

Participation factor calculation : X Direction

MODE	FREQUENCY	RATIO
1	1153.39	0.000563
2	1423.78	1.000000
3	2342.65	0.006480
4	2744.09	0.081729
5	2850.39	0.019758
6	3118.62	0.472210

Participation factor calculation : Y Direction

MODE	FREQUENCY	RATIO
1	1153.39	0.000563
2	1423.78	0.033939
3	2342.65	0.014625
4	2744.09	1.000000
5	2850.39	0.147504
6	3118.62	0.112390

Participation factor calculation : Z Direction

MODE	FREQUENCY	RATIO
1	1153.39	1.000000
2	1423.78	0.001079
3	2342.65	0.001755
4	2744.09	0.047131
5	2850.39	0.198228
6	3118.62	0.001224

Table 2: Modal Analysis Results

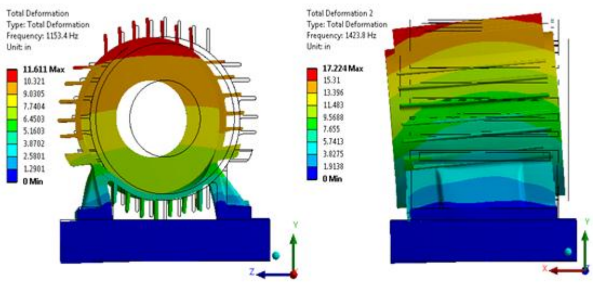

Figure 12: Mode Shape 2 and 4 in Y-Direction

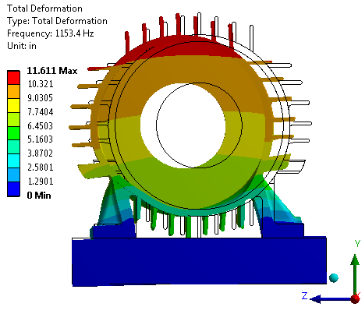

Figure 13: Mode Shape 6 in Y-Direction

FEA post processing expected outcome is input load vs frequency graph where components expected to reach resonance.

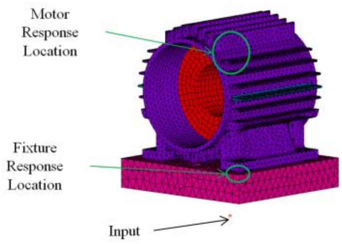

Figure 14: Accelerometer position and Responses (Testing Unit and Fixture)

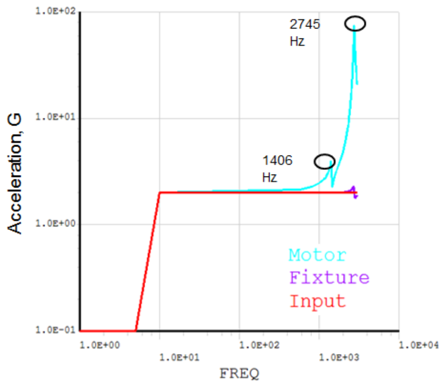

Figure 15: FEA Load vs Frequency (I/p and O/p) for Motor and Fixture.

From FEA analysis we have find out critical stress locations where stress is very high and for further Find out critical location so we can placed strain for experimental analysis so we can utilized those results.

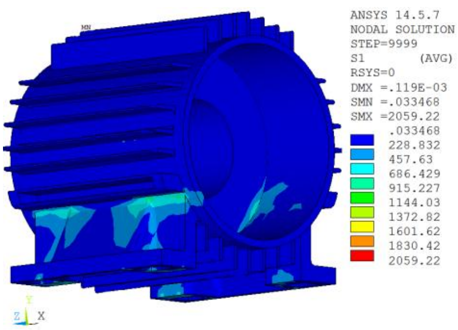

Figure 16: FEA Stress Critical Locations

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

V. EXPERIMENTAL SETUP

. Experimental test Setup as shown in following Figure 17

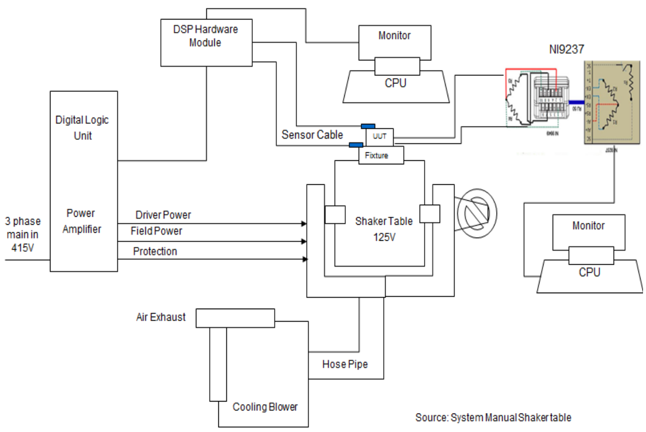

Figure 17: Experimental Test Setup

The Motor Housing Mountings Lugs was tested on forced vibration shaker table 125SV (Sdyn) and Stain Module NI9237. The accelerometer used for control and monitor frequency and stain gauge used for measuring formation in mounting lugs. See following Figure **17** setup at PCCOE lab.

VI. ANALYSIS AND RESULTS

The effect of various geometrical parameters on the resonance frequencies of the motor mounting Lugs and stresses developed was discussed.

Frequencies achieved through shaker table as per Figure 21:

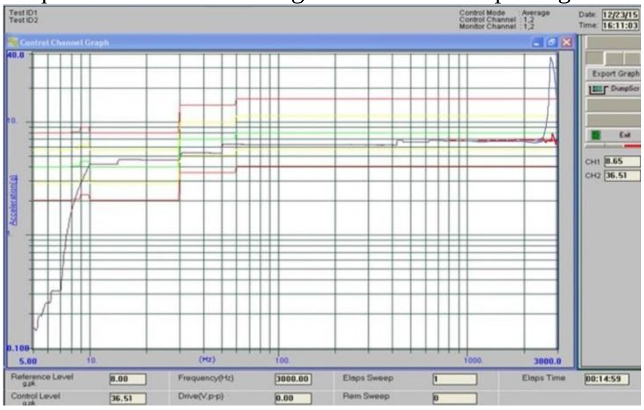

Figure 18 :Output acceleration frequency curve

Strain measurement module (NIcDAQ9237) : It gives the result from stain gauges reading which has acquired shows in following Figure 19:

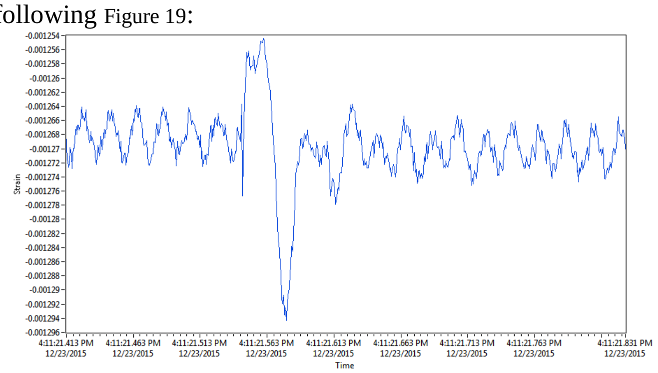

Figure 19: Strain Gauge measurement at resonance of Motor Mounting Lugs

As we have discussed that whenever a material is loaded, within its elastic limit, the stress is proportional to strain. Mathematically stress, Stress (σ) proportional Strain (ε) =Modulus of Rigidity (E) X proportional Strain (ε)
AlM6 Aluminum Modulus of rigidity is 80x103 N/mm2

Sr. No	Stresses developed in Numerical method (N/mm^2)	Stresses developed in experimental method (N/mm^2)
01	3.15	2.56

Table 3: Stress co-relation Numerically and Experimentally

Above co-relation will give close to 82 % which is following on material properties where we can predict and claim design methodology for aerospace components in harmonic or sinusoidal vibration forces

VII. CONCLUSIONS

In this investigation, the motor mounting lug was studies for its response to vibratory loading. Numerically the modal analysis was carried out and with nodal solution the location of highly stress region was identified on motor mounting lug. In the experimental studies the strain gauges were mounted in the critical area identified. The numerical work and the model was excited using shaker table and strain measurement captured using NI stain gauge module. This work leads to following finding: Good co-relation is obtained between experimental and numerical stresses. Variation in numerical results might high because of model simplification, material properties and lugs geometry.

While performing this work it is observed that performance of structural analysis individual parameters are responsible for affecting stresses in the motor mounting lugs. Develop step by step process Finite Element Analysis model simplification, homogeneous material properties and lugs geometry

ACKNOWLEDGMENT

I would like to thank and express my sincere deep felt gratitude to Mr. A. A. Panchwadkar, Mr. H. R. Jawanjal and I am also thankful to the staff of Mechanical Departmental Engineering and Laboratory, PCCOE for helping and providing very good facility to me during the experiments. Last but not the least, I would like to thank my family and all well-wishers for their immense help and co-operation during the project work.

REFERENCES

[1] Singiresu S. Rao ‘ Mechanical Vibrations, Fourth Edition’.[P-249-P269,P572-P595,P771-P824,P1014-P1033]
[2] Y.S. Chen , C.S. Wang, Y.J. Yang: Combining vibration test with finite element analysis for the fatigue life estimation of PBGA components, Microelectronics Reliability 48 (2008) 638–644,
[3] MuratAykan Mehmet Celik : Vibration fatigue analysis and multi-axial effect in testing of aerospace structures, Mechanical Systems and Signal Processing 23 (2009) 897–907.
[4] Tae-Hwan Kang , Yutaka Kaizu: Vibration analysis during grass harvesting according to ISO vibration standards, Computers and Electronics in Agriculture 79 (2011) 226–235.
[5] Do-Hyun Junga, Alisher Gafurova: Reliability achievement of the driving system parts through development of vibration-fatigue evaluation method, Procedia Engineering 10 (2011) 1906–1916.
[6] Engineering Failure Analysis 24 (2012) 1–8, Jerzy Z. Sobolewski : Vibration of the ball screw drive.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 02, February-2016

[7] K.M. Shafiullah, Christine Q. Wu : A Generation and validation of loading profiles for highly accelerated durability tests of ground vehicle components, Engineering Failure Analysis 33 (2013) 1–16,

[8] Yung-Li Lee, Hong-Tae Kang: Vibration Fatigue Testing and Analysis, Metal Fatigue Analysis Handbook. DOI: 10.1016/B978-0-12-385204-5.00009-4.

[9] Department Of Defence Test Method Standard- MIL-STD-810G.514.6:Vibration (www.everyspec.com)

[10] RTCA,DO-160F, Section:8 Vibration(www.rtca.org)