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Study and Analysis of Shock Requirements in Shipboard Equipment

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***Abstract*— Over the last two and half decades there has been raising interest among shipboard equipment designers to adopt design style elements, standards and practices from commercial shipbuilding and other naval application equipment. Shipboard equipment works under shock from underwater explosions as their damaging mechanism. In severe cases shock can cause ruinous loss of watertight integrity, but in even moderate cases of shock the resulting acceleration environment inside the ship can damage or destroy the equipment. The research presented in this thesis attempted to analyse the experience of shock in one of shipboard equipment i.e. Generator and quantify the effect of adopting simpler structural styles upon this damaging acceleration environment. The objective of this work is to analyse Shock Analysis of generator set, mounted on shipboard by using finite element method in ANSYS Mechanical APDL, and results of this work are validated with the literature.**

Keypoints: Shock loads, CAE, Shipboard equipment, Finite element analysis and ANSYS Mechanical APDL

I. INTRODUCTION

This report consists the characteristics and use of Navy HI (High-Impact) class shock machines. In addition the report will present recent views relating to shock tests and test procedures. One of shipboard equipment i.e. Generator has been analyzed (structural analysis) for the underwater shock or when shock occurs due to any reason and passes to the equipment.

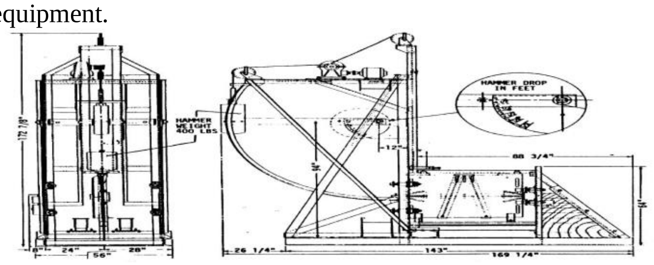

Figure – 1 : High impact shock testing machine for light weight components

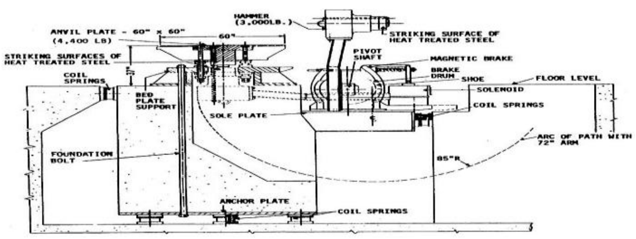

Figure – 2 : high impact shock testing machine for medium weight components

Shock loads [2]: Shock, is generally understood as a sudden and violent blow or impact. It is characterized as a dynamic disturbance with a short duration compared to the natural frequency of the affected equipment. Equipment subjected to shock beyond its fragility level can fail structurally and functionally.

Design against Shock [2]: For critical shipboard equipment, there are typically two approaches with regard to equipment protection against shock. One is to install resilient mounts (Shock-mounts) between the equipment and its foundation to attenuate the shock entering the system where feasible. The other is to harden the equipment that needs to be rigidly mounted due to performance considerations.

Shock Qualification [2]: Besides requirements definition, qualification is another important aspect of shock management. Shock qualification provides the technical evidence that the equipment design has fulfilled the requirements for design against shock. The qualification can be achieved through testing, analysis or similarity. The decision hinges on the availability of qualification data, cost and, to a lesser extent, the project schedule. Analysis and testing can be synthesized; where testing cannot be carried out, analysis is used for inference. For developmental equipment, both approaches of qualification by testing and analysis have been applied.

Qualification is done to ensure that the equipment is able to withstand the effects of a predetermined shock input from handling, transportation and service environments while maintaining its functional performance as well as to ensure that the equipment remains attached to the shock mounts.

Generator Set & its Analysis:

The generator is intended for use on shipboards, it will comprise of a DC machine and an AC synchronous machine mounted on same shaft.

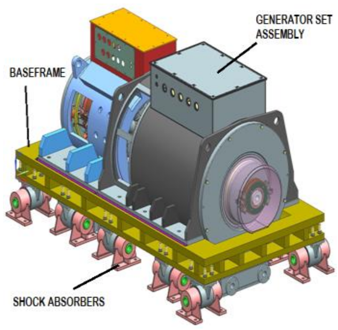

Figure – 3 : 3D model of Generator Set Assembly (UG-NX-10.0)

Generator has associated shock requirements that it must withstand. The shock requirement for Generator is related to severe ship motions like pitch and roll. Generator shall be specifically designed to endure some defined lifetime of shock loading and are required to endure harsh environment, vibration and shock environments.

Using shock data and incorporated into the finite element analysis of a specific load-bearing component to illustrate components fatigue life in order to optimize its material and design. Shock acceleration data to be taken as per shock qualification standards before conducting any analysis because acceleration data is not generally available or applicable to unique equipment configurations.

Finite element response modelling requires the input of a CAD model of the component under consideration, and definition of the associated constraints and forces on the component at appropriate nodes along the mesh. It is also necessary to input the material properties of the component. Depending on the analysis to be done, these material properties will likely be density, Young's and shear moduli, yield strength, ultimate tensile strength, and Poisson ratio. Shock analysis is performed for shock qualification of the main motor generator. Following are the analysis which has to be carried out after preparation of suitable FE models for main motor generator:

a) Modal Analysis to get natural frequencies of the system.

b) Transient Dynamic Analyses have will be performed for four cases separately,

- Axial shock along X-direction.
- Two vertical shocks for Y-directions (+Y and -Y)
- Lateral shock in Z-direction.

II. LITERATURE REVIEW

A shock environment, in general, refers to that category of dynamic environment which is of high intensity and short duration such that the equipment is set into a vibratory motion and continues to respond after the disturbance has passed. It begins and ends, as opposed to a vibration environment that continues for some long period of time. The shock can come from a blow or short-duration force, such as an air blast, or it can come from the foundation of the equipment being set into a momentary violent motion. The latter method, the base-excited shock motion, is specifically the subject of this report. [3]

Fundamental Design Assumptions [3]: It is assumed that the equipment (and its associated shock isolator, if any) is attached to a rigid fixture such that the equipment attachment points do not move with respect to each other; it is assumed that this fixture undergoes the shock motion. Initially, it is assumed that the equipment to be installed is light with respect to the foundation and, thus, does not affect the foundation motion. In general, the motion of the rigid base can be described by simultaneous translations along three mutually perpendicular axes together with rotations about these same axes. Input motion of this generally is too complex to be considered here; it is fortunate that the lateral dimensions of most equipment are small enough and the magnitude of rotational motion experienced are small enough that the effect of pitch, roll, and yaw can be neglected.

III. PROBLEM FORMULATION

This work is focused on the understanding of shock loads which comes on shipboard equipment's while the functioning. When any explosion happens inside the water (there may be other reasons also, which is listed on introduction, chapeter-1) shock transfers to the shipboard hull and affect the equipment's mounted on it. Shock analysis problem under normal upward load through the base and axial disturbance through rolling and pitching action, those loads shall be applied while analyzing the equipment in ANSYS Mechanical APDL.

The variables considered are

- **Materials**

1. Mild steel (As per IS:2062, Grade : E250)
2. Mild steel (As per EN:10028, Grade : E450)
3. Steel (As per IS:5517, Grade : 1000)
4. CRNGO sheets (As per IS:513, Grade : E280)
5. Copper (As per IS:13730, Grade : G3, Tensile strength : 255MPa)

- **Loading**

1. Shock load on the fixing bolts locations of equipment.
2. Axial load due to rolling & pitching action.

- **Boundary Conditions**

1. Fixing bolts location movement is zero in vertical direction.
2. Rotor fixing as two sided cantilever
3. Lateral direction movement restricted as equipment is bolted with high shear strength SS bolts.

IV. METHODOLOGY

The aim of this thesis is to analyses the system stability while shock loads transferred to the Generator mounted on shipboard with various parameters such as boundary condition, aspect ratio etc. This work is further extended to study shock load comes and affect the equipment when the underwater explosions, launching of torpedoes (in submarines) happens.

Flow-Chart of whole analysis procedure is as below:

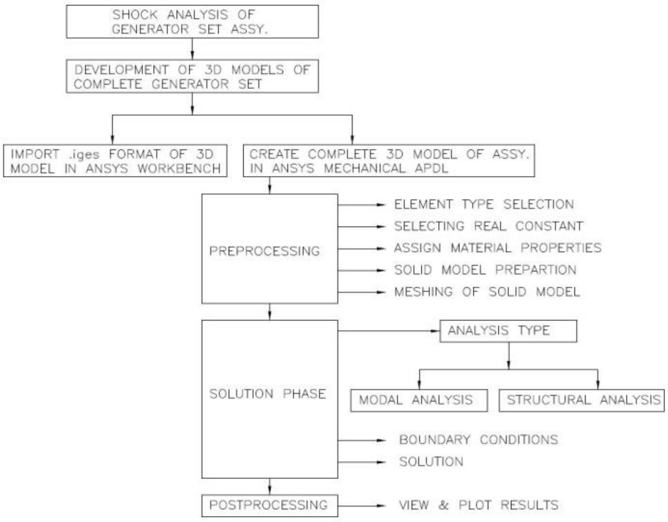

Figure-3 shows the complete 3D model of Generator set Assembly,

Preprocessing: Figure-4 & 5 shows the complete 3D model of Generator set Assembly model created in Ansys Mechanical APDL and then meshed, it's a complete preprocessing phase.

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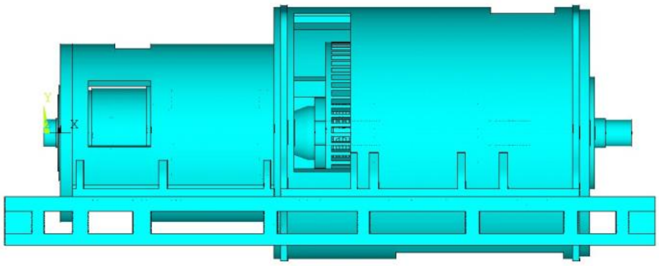

Figure –4 : 3D model of Generator Set Assembly (Ansys Mechanical APDL)

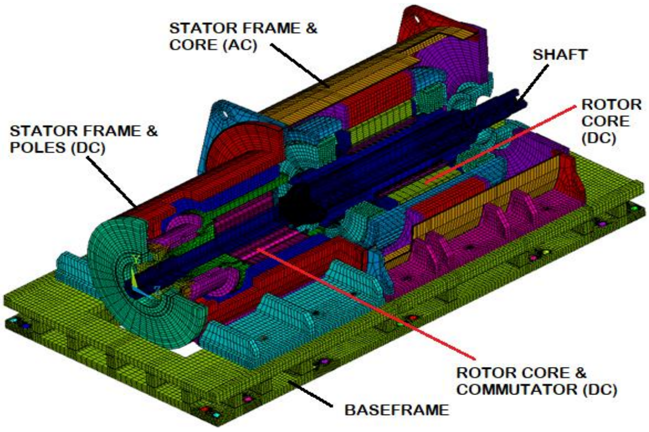

Figure – 5 : Meshed model of Generator Set Assembly (Ansys Mechanical APDL)

Solution Phase: FE analysis is performed for qualification of the Generator set Assembly against the specified shock loads. FE Models of the components of the assembly have been developed as per the CAD Models and the following analysis have been carried out.

Analysis Type:

1. Modal Analysis to get natural frequencies of the Generator set assembly.
2. Transient Dynamic Analyses have been performed for three cases separately,
   a) Axial shock in X-direction.
   b) Vertical shocks in Y-direction
   c) Lateral shock in Z-direction.

Boundary conditions:

Mentioned under in problem formulation heading.

Solve:

In this step problem is solved. The solution will be aborted if any error is present in the model. Time taken vary according to the mesh size.

Postprocessing: In this phase of the analysis, results are viewed and plotted. It includes plotting of contours, vector display, deformed shape and tabulating of results obtained at nodes. In shock analysis, model is checked for stresses and deformation only.

V. RESULTS & DISCUSSIONS

A Generator set has been analyzed for shock load specified by naval standard. This generator set has to withstand a dynamic shock pulse of 25 'g' for a period of 70 millisecond as per the standard in this weight category equipment's mounted on shipboard.

Validation of results:

Modal Analysis of the Generator Set:

Modal analysis has been carried out to get the natural frequencies and mode shapes. To get the natural frequencies, FE model with boundary conditions has been prepared, as shown in Figure 6.

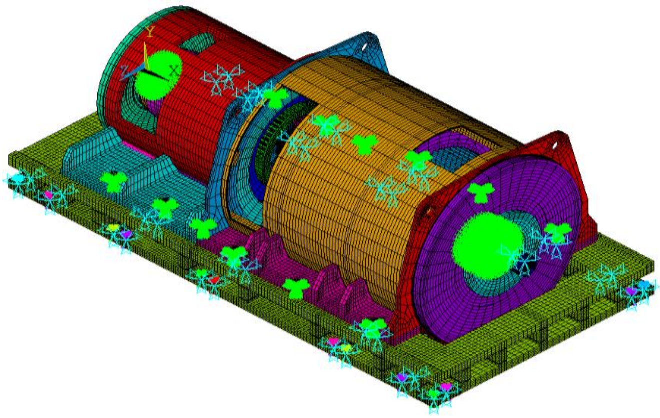

Figure – 6 : Model of Generator Set Assembly (Ansys Mechanical APDL) with boundary conditions

First three modal frequencies are given in Table-1 and first three mode shapes are shown in Figure 7 to 9.

Mode No	Freq. (Hz)
1	55
2	67
3	98

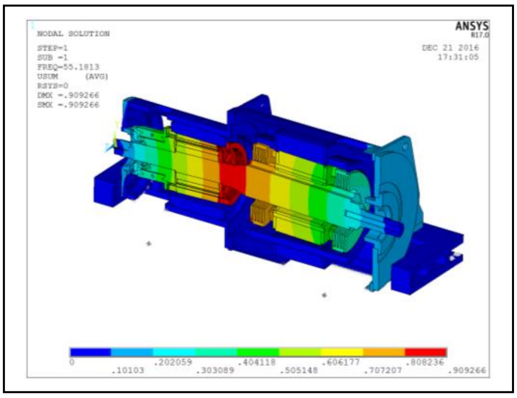

Figure – 7 : Mode shape as frequency 55 Hz

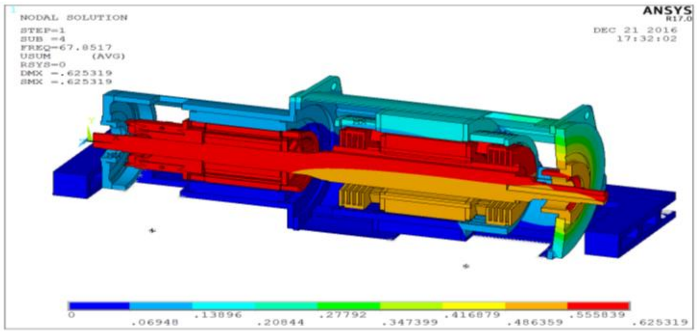

Figure – 8 : Mode shape as frequency 67 Hz

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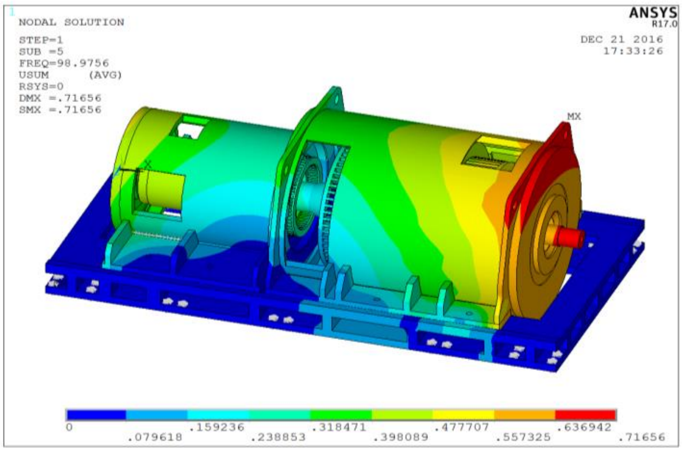

Figure – 9 : Mode shape as frequency 98 Hz

Transient dynamic analysis:

Shock analysis has been carried out for the shock pulse specified in all the three directions. Shock pulse has been applied at the bolt locations of the base plate. Three independent analysis has been carried out for three directions (X, Y and Z direction).

- *Axial Shock (X-Direction):*

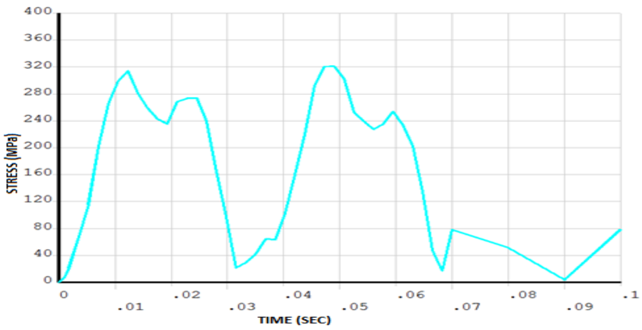

Figure – 10 : Stress variation at max stress location in for X-direction shock

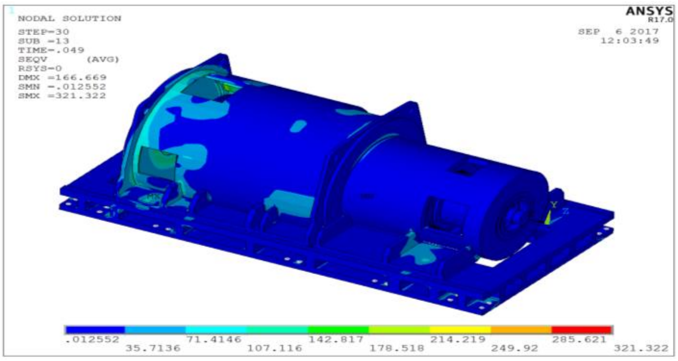

Figure – 11 : Stress contour plot for x-direction shock at 49 ms

Figure – 11 showing the variation on stress values throughout the generator assembly in X-Direction (at 49 milliseconds, i.e. maximum stress value while applying the time dependent shock loads). Minimum value are with blue colour and maximum value of stress is with red colour.

- *Vertical Shock (Y-Direction):*

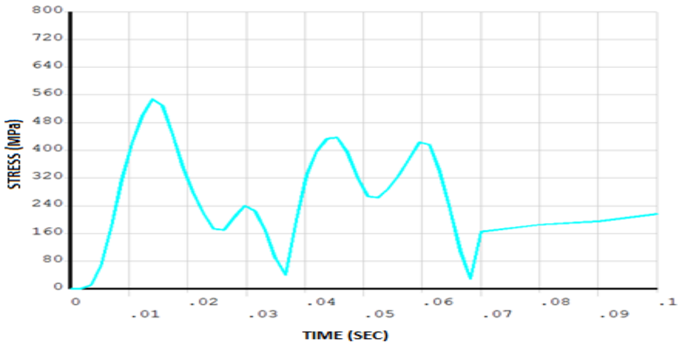

Figure - 12 Stress variation at max stress location in rotor for Y-direction shock

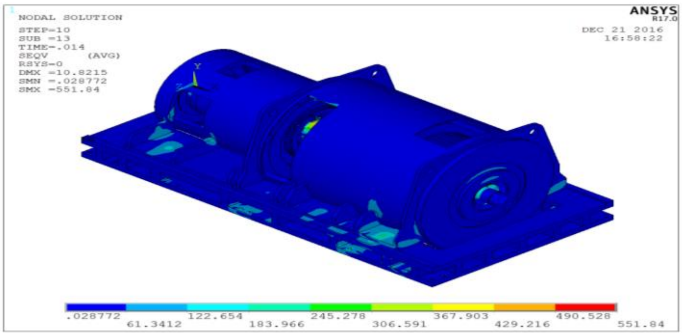

Figure -13 Stress contour plot for y-direction shock at 14 ms

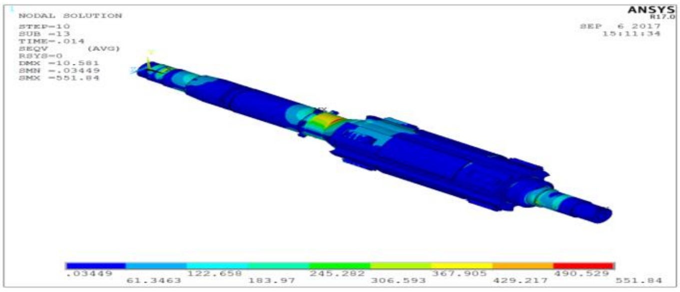

Figure - 14 stress contour plot of rotor for y-direction shock at 14 ms

Figure – 13 showing the variation on stress values throughout the generator assembly in Y-Direction (at 14 milliseconds, i.e. maximum stress value while applying the time dependent shock loads). Minimum value are with blue color and maximum value of stress is with red colour. As found that stresses are maximum in shaft (Refer figure-14).

- *Lateral Shock (Z-Direction):*

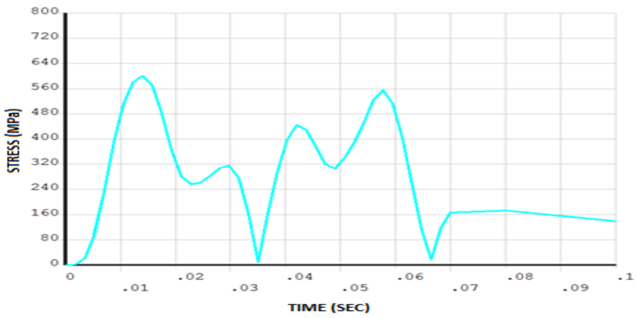

Figure – 15 : Stress variation at max stress location for Z-direction shock

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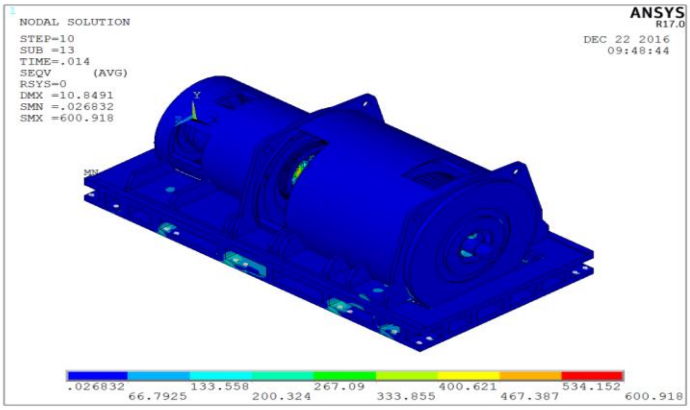

Figure -16 Stress contour plot for Z-direction shock at 14 ms

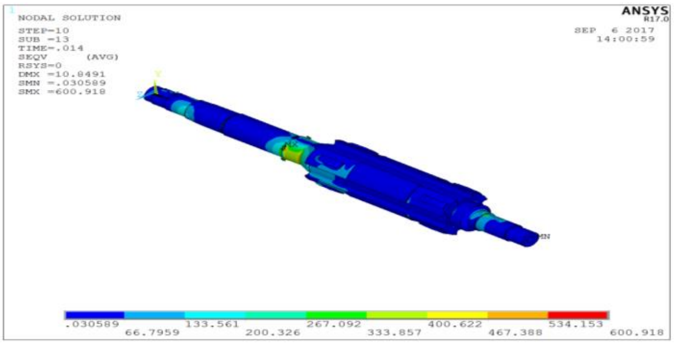

Figure - 17 stress contour plot of rotor for Z-direction shock at 14 ms

Figure – 16 showing the variation on stress values in Baseframe in Z-Direction (at 14 milliseconds, i.e. maximum stress value while applying the time dependent shock loads). Minimum value are with blue colour and maximum value of stress is with red colour. As found that stresses are maximum in shaft (Refer figure-17).

SUMMARY OF RESULT:

Table -2

Component	Loading Direction	Stresses (MPa)	Allowable Stress (MPa)
Stator Frame	X-Dir	321	430
	Y-Dir	367	430
	Z-Dir	307	430
Rotor	X-Dir	174	800
	Y-Dir	552	800
	Z-Dir	601	800

Table – 2 showing the value of stresses in all the 3 direction i.e. X, Y & Z for the static part and rotary part against the allowable limits. It clearly indicates that the in Static part stresses are maximum i.e. 367MPa in Y direction (lateral direction) against the allowable limit 430MPa and in rotary part stresses are maximum i.e. 601MPa in Z-direction (normal direction) against the allowable limit 800MPa.

Table-3

Loading direction	Base Frame (MPa)	Allowable Stress (MPa)	Shaft (MPa)	Allowable Stress (MPa)
Axial	314	430	193	800
Vertical (+ve)	366	430	547	800
Vertical (-ve)	323	430	502	800
lateral	306	430	605	800

Table –3 showing the value of stresses in case of time dependent transient analysis in the Normal, Axial and Lateral direction for the static part and rotary part against the allowable limits. It clearly indicates that in Baseframe maximum stresses are 366MPa in Vertical (+ve) direction against allowable limit 430MPa, and in shaft the maximum stresses are 605MPa against allowable limit 800MPa.

VI. CONCLUSION

Shock analysis of Generator set is done through ANSYS Mechanical APDL, Stress values at various location analyzed and identified the critical locations where stress are more and same is considered in designing of the components and selecting the materials.

Following are the conclusions drawn based on this work:

- Stresses are more at the bolting location of Generator set, high tensile material is used to design the foot for Generator set assembly.
- Stresses are more at the bolting location of Baseframe of Generator set, high tensile material is used to design the foot for Baseframe.
- Cross section identified in rotor assembly (shaft of rotor assembly) where stress was very high, special high tensile material is used for manufacturing shaft.

Finite element method is very powerful tool for engineers to analyzed complicated problems. The software package ANSYS uses finite element method to analyzed various problems. In present work, Shock analysis is of Generator set assembly which is mounted on shipboard is done by ANSYS Mechanical APDL for full sine wave shock load of 25g for 70milliseconds. With the use of ANSYS, both time and efforts are saved considerably. Results obtained by ANSYS are in good agreement with that obtained from higher order theories

VII. SCOPE OF FUTURE WORK

Shock analysis of Generator shows the design consideration and helps in material selection for different load carrying components those are having most stresses while functioning. The analysis is further extended to study and analysis of complete shipboard design against shock which is having a large numbers of equipment's / components mounted on it.

- The study can be further extended to study and analysis of complete shipboard design against shock which is having a large numbers of equipment's / components mounted on it.

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- Analysis will help in design consideration and material selection of different assemblies.
- Results can be obtained for natural frequencies calculation by modal analysis, direct load of specified shock values on equipment, time dependent shock load on equipment.
- Consideration of analysis results for designing the complete shipboard against shock.

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