

# Shock Experimentation of a Direct Oil Heater Used In Ships



Amol D. Lokhande, Niteen L. Bhirud, Gokul V. Mahajan, Govind E. Chavan, Dinesh R. Satpute

**Abstract:** Mechanical shock and vibrations are the major problems, which affects the machinery or equipment. In the present scenario, when exposed to the specified shock analysis, the equipment continues to work satisfactorily without time restrictions. Mechanical shock covers the transient mechanical response. In marine environment, an underwater explosion impart to the hull a force which causes rapid local movement both to the hull structure and machinery or equipment attach to it. This work is mainly focused on the shock analysis of a direct oil heater used in ships. It includes the following analysis are as follows: Shock analysis process & procedure, stress analysis and permissible proof stress analysis and finite element analysis of different parts namely shell, saddle support, plate flange, heating element. The analysis is made to check the shock strength of the equipment, which has been analyzed to operate under severe conditions of shock loading due to underwater explosion. The finite element analysis is an indirect method of stress analysis to analyze the different parts of a heater with considering the shock forces. The values of stresses obtained are compared with the permissible values of the stresses. The permissible stresses are found for different time durations (viz < 5ms, 48ms, >50ms). Factor of safety is found for shocks in different directions.

**Keywords:** Finite Element Analysis, Shock test, Shock Analysis, Stress Analysis, Vibrations.

## I. INTRODUCTION

### A. Direct Oil Heater

The direct oil heater is mounted on hull structure of the ship. This heater is used to heat the oil which is supplied to the marine engine. In marine engine, lubricating oil is used in the gear transmission system. The direct oil heater assembly consists of the following parts: 1. Shell 2. Saddle support 3. Heating element 4. Plate flange 5. Fasteners – nuts & bolts.

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Details of the components of the oil heater are as shown in figure.

### B. Lubricating Oil

In marine engine, lubricating oil is used to gear transmission (marine transmission) Viscosity grade of oil is SAE 30 / SAE 40. In hot countries or when oil sump temperatures are above + 80 °C.

### C. Shock Loads

In marine environments, an under water explosion bring to the hull a force which causes a rapid local movement both to the hull structure and machinery or equipment mounted on it. A shock represents a sudden application of force or other form of disruption for a very short duration, which results in a transient response of a system. The maximum value of the response is a good measure of the exacting of the shock and it is dependent upon the dynamic characteristics of the system. When a system is excited by a suddenly applied non periodic excitation, it is called transient response, since steady state oscillations are not produced; such oscillations take place at a damped natural frequency of the system with the amplitude change in a manner dependent on types of excitation. Due to motion of the ship into water, shock waves are generated. These shock waves impart high forces in opposite direction of the ship motion. This will result into deceleration of the ship. Also the shock waves from different directions will induce vibrations on the hull structure of the ship. This will impose shock on the machinery driving components like electric motors, engines and generators etc. Also, as these components themselves have moving parts, they also generate shock. The shock generated by the components affect more to the other small components attached to these components due to the shock waves imparted by the motion of the ship. The heater operates in highly shock environment. The shock for which this analysis is done assumed to be of magnitude 80g. It is considered that the oil heater is either fixed on the hull by fasteners or is not fixed on the hull but just kept on the hull. The analysis needs to be done for both the varieties.

### D. Transient Response

As we know a system subjected to periodic excitation has two components of motion, the transient and the steady state. In most of such cases the transient part is not important as it dies out soon, and the steady state part is one that persists. However, where the excitation is of the periodic nature like shock pulse or a transient excitation, the response of the system is purely transient. After the duration of the excitation the system undergoes vibration with its natural frequency with amplitude depending upon the type and duration of the excitation. It is in such cases that the transient vibration has importance.

The practical examples of shock excited transient vibrations are rock explosions, gun fires, loading or unloading of packages by dropping them on hard floors, punching operations, automobiles at high speed passing over pits or curbs on the road etc. The heater is to be analyzed. for static and dynamic response. For transient time function we for static and dynamic response to full sinusoidal pulse input. In present analysis we considered the undamped system,

$$M [x] + K [x] = [F]$$

Where as transient time function is taken as shown in figure.

### E. General consideration

The conditions are considered while analyzing the oil heater with shock loads. The heater assembly is considered as rigid. The heater assembly will not undergo any significant change of shape, either temporary or permanent when acted upon by shock forces. The static & shock forces are considered to check the strength of equipments. Design data -The shock load may act along any one of the three principal axis of the equipment. The amplitude & Duration of shock pulse transmitted to the assembly.

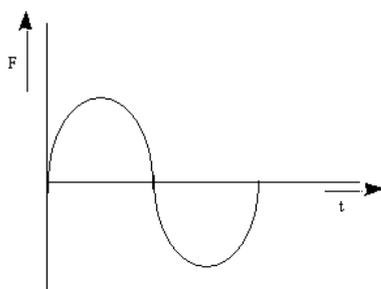


Fig.

## II. LITERATURE REVIEW

J. Mackerle (2015) [1] presented finite element literature published between 1976 & 1996 and into categories described below. Pressure vessel & piping analysis may have some/all phases as – elastic stress & deformation analysis where both mechanical & thermal loads may be applied, heat transfer analysis, dynamic analysis etc. There is in existence a large number of general purpose & special purpose finite element programs available for each phase of the analysis.

N.E1- Abbasi, S.A Meguid, A czekanski (2017) [2] presented three-dimensional finite element analysis of saddle supported pressure vessels. In this paper a 3D finite element method is made of a pressure vessel resting on flexible saddle supports. The analysis is carried out using a newly developed thick shell element & accounts for frictional contact between the support & the vessels. The seven parameter shell element is capable of describing the variation of the stress & the strain fields through its thickness. A variation in equalities based formulation of frictional contact problems. Different pressure vessel configurations are considered & the resulting contact stresses are examined. The effect of saddle radius, saddle width, plate extension and support overhang on the resulting stress fields in both vessel & support are evaluated.

N.C. singhal & A.R. chandrashekhran (2016) [3] gives the comparative study of behavior of some axisymmetric finite element under static & dynamic loadings. The paper includes axisymmetric finite element analysis which can be applied to several structures of importance e.g. pressure vessel, reactor

buildings, domes, fluid containers, cooling towers, chimney etc. This paper presents a comparative study of some axi symmetric finite element to judge their efficiency in solving axi symmetric thin as well as thick shells. The element studies are- 1. Paraline 2. Element with relative displacement degree of freedom 3. Cubilinear 4. Element with incompatible modes 5. Parabolic 6. Lagragian 7. Ahmad's shell element, to enable comparison of the result from these elements, a uniform circular cylindrical structure has been choosing for the analysis.

V.Ramamurti and P.Seshu (2014) [4] represented the static & dynamic analysis of a pressure vessel.

1. Static Analysis: - For a uniform internal pressure of 220 atmospheres, the static stresses are determined. The stresses as obtained by the two different approaches at the junction node are compared with those obtained by finite element method. (using the shape function which is a linear polynomial in radial & radial direction).

2. Dynamic Analysis: - The eigen pair are determined for three values of n(1,2&3). The first four mode shapes for each value of 'n'. A crude approximation of the pressure vessel is a cantilever beam. This validates the results for n=1 since the displacement (u) is very small compared to v & w (ratio varying from 1/100 to 1/10). Only 'w' displacement need be considered for potential and kinetic energy terms. The pressure vessel has too many detailed features which we have excluded in this study due to the complexity of creating geometry & performing analysis. We have prepared a step by step instruction set for modeling and analyzing a simple optimization study. The whole process is divided into four parts, 1. Creating Geometry - A quarter of a pressure vessel (including the saddle) was created which was sufficient to perform the study' the generation of the model was done by creating points, connecting these points to form curves to form the body. Many basic commands are introduced to the user in this section.

## III. SHOCK ANALYSIS PROCEDURE

### A. Shock analysis

When considering the design of an item to withstand shock, account must be taken of the fact that an acceleration may occur in any of the three principal planes of reference viz. x, y & z. When designing for shock, the two principal characteristics of the item which have first to be evaluated are its mass & the position of its centre of gravity. In many cases the mass & centre of gravity of individual parts of the item may also be required. The application of acceleration curves to the shock design of rigid items is generally quite simple and direct. The mass of an item, in kg gives the shock force in 'N'. This force can be assumed to act through the centre of gravity of the item or component part of an item & is used to find stresses.

### B. Procedure for stresses due to shock loading

Following procedure is followed to finding the stresses due to shocks.

a) Examine the equipment & select the points likely to suffer high stress levels under shock.

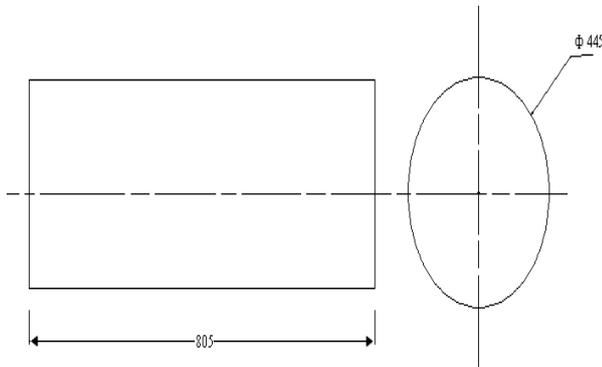
- b) Divide the equipment into mass units attached to these points & calculates the mass & CG of each.
- c) Calculate the total mass of the equipment and the position of its CG.
- d) Multiply the mass of item or any component by the appropriate acceleration to establish the shock force.
- e) Calculate the stresses & ensure that they do not exceed the design stresses permissible for the loading times.
- f) Carry out a static stress analysis in each loading direction for the points selected in step (a) and for securing arrangements.

**C. Stress analysis**

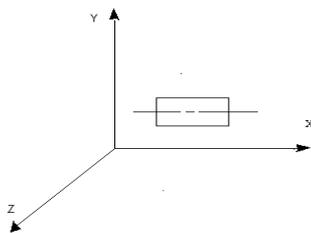
Stress analysis is done considering the static loads and loads due to shocks of different durations. Static loads equivalent to shock loads are found out and then the usual method of calculating stresses is adopted for different components.

- Stress analysis of shell- The data for the shell is as follows (Refer figure for details)

A shell is to be made of 6mm thick mild steel plate. The Outer Diameter of shell (Do) 445 mm and inner Diameter of shell (Di) is 433 mm. The shell is subjected to an internal pressure of (p) 5 N/mm<sup>2</sup>. The length of the shell is 805mm.



**Fig. Shell Figure**



**Fig. Shock in X direction**

A cylindrical shell may be thin or thick depending upon the thickness of the plate in relation to the internal diameter of cylinder. The ratio of  $t/d = 1/20$  can be considered suitable line of demarcation between thick and thin cylinder.  $t < d/20$ ,  $6 < 21.65\text{mm}$ . Hence, this is a thin cylindrical shell. Thin cylindrical shell - The weight of shell is 1483.55N. Load due to shock of 80g is 118640N.

- When the shock force is applied on the shell in x direction.

The internal pressure in the shell gives rise to stresses in the shell thickness, one in circumferential and the other in the longitudinal direction.

Stresses are produced in three directions due to internal pressure.

1. Circumferential/Hoop Stress ( $\sigma_p$ ) =  $pd /$

2. Longitudinal / Axial Stress  $\sigma_a = pd / 4t$ . Both the stresses are tensile. We consider the larger of these two values.

Tensile stress. In this case, the bending stress and shear stress will be zero.  $\sigma_b = 0$ ,  $\sigma_s = 0$ .

- When the shock force is applied on the shell in y direction.

Inside surface area of the shell is in mm<sup>2</sup>, Stress due to 80g shock 4.93 N/mm<sup>2</sup>

Total stress ( $\sigma_t$ ) = Stress due to 80g shock + circumferential stress.

When the shock force is applied on the shell, it will bend. For finding the bending stress by using the bending moment equation, Bending stress is in N/mm<sup>2</sup>.

The total bending stress  $\sigma_b$  = stress due to 80g shock + circumferential stress,

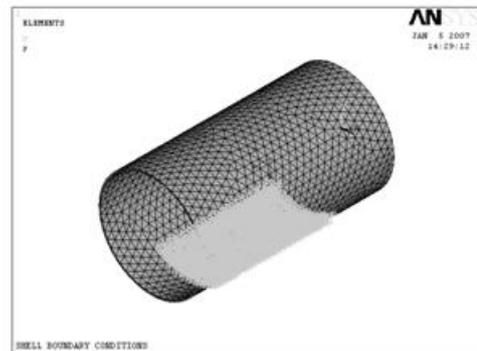
In this case shear stress will be zero.  $\sigma_s = 0$ .

- When the shock force is applied on the shell in z direction.

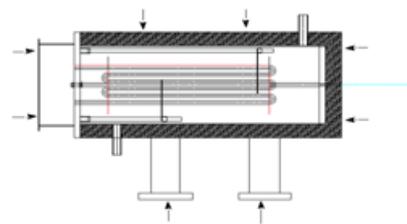
In this case, the tensile stress will be zero. We can find the bending stress and the shear stress.

Fig. Assembly of direct oil heater

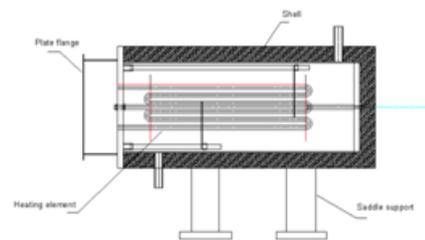
**IV. FINITE ELEMENT ANALYSIS**



**Fig.**



**Fig.**



**Fig.**

## A. Analysis of the Oil Heater

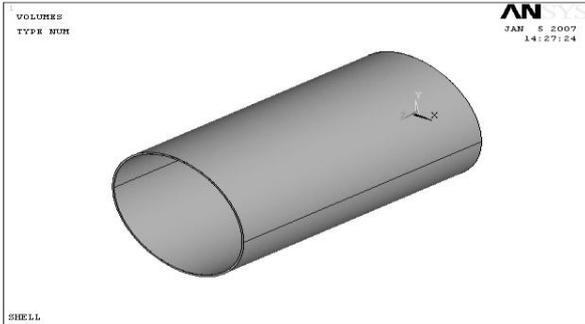
The components of the oil heater namely 1) Shell 2) Saddle support 3) Plate flange 4) Heating element are analyzed with the help of Pro-E and ANSYS.

## B. Analysis of the Shell

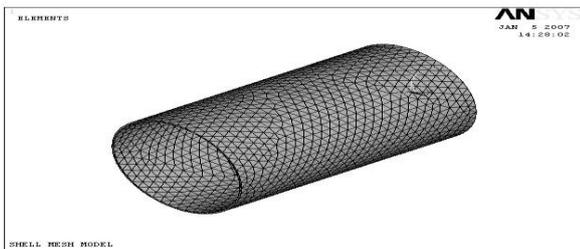
The following steps are used for analysis of shell,

1. Modeling
2. Meshing
3. Boundary condition
4. Results

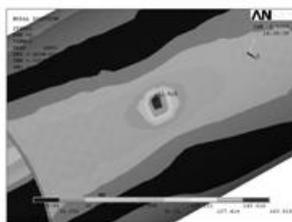
Details of results using the ANSYS software are as shown the following figures. These figures gives us the stresses in different directions at a shock of 80g as mention



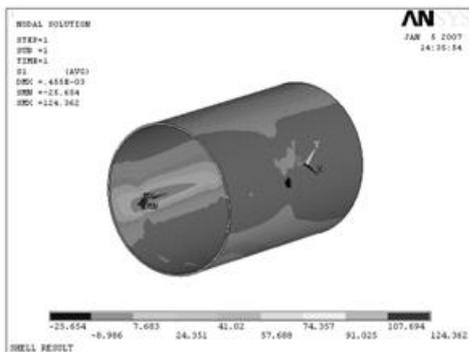
**Fig. Model of Shell**



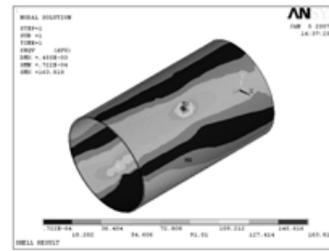
**Fig. Meshing of Shell**



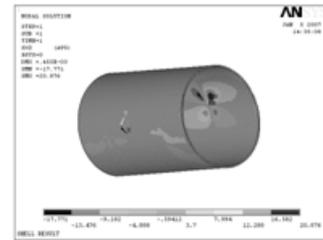
**Fig.**



**Fig. Shell Boundary conditions.**



**Fig.**



**Fig.**

The bending and shear stresses in different plane due to shock in x and z, direct stress are similarly obtained.

## V. RESULTS

The result of the analysis is presented in the following sections. Results of finite element analysis and shock analysis are also presented in sequential order. Stresses obtained due to shocks in different directions are presented.

### A. Results of stress analysis for time duration > 5ms

(Table No. 1, 2, 3 & 4). Similarly, We can find the stresses for any time duration.

**Table-I:**

Sr. No.	Component	Tensile stress		Bending stress		Shear stress	
		Actual	FEA	Actual	FEA	Actual	FEA
1	Shell	1.48	1.69	1.64	2.9	2.22	2.67
2	Saddle support	7.11	2.32	4.06	2.57	5.6	3.58
3	Heating element	2.72	2	2.24	2.6	5.97	
4	Shell flange	4.54	2.34	4.6	4.88	5.57	5.77

**Table-II:**

Sr. No.	Component	Tensile stress N/mm <sup>2</sup>			Bending stress N/mm <sup>2</sup>			Shear stress N/mm <sup>2</sup>		
		Actual			Actual			Actual		
		Allowable	Calculated	FEA	Allowable	Calculated	FEA	Allowable	Calculated	FEA
1	Shell	277.5			360.75	219.65	124.3	208.75	93.92	78.03
2	Saddle support	345			448.5	110.2	174.36	258.75	46.18	72.22
3	Heating element	315			409.5	182.12	157.09	236.25	39.52	
4	Shell flange	277.5			360.75	78.28	73.87	208.75	37.46	36.15

**Table-III:**

Sr. No.	Component	Tensile stress N/mm <sup>2</sup>			Bending stress N/mm <sup>2</sup>			Shear stress N/mm <sup>2</sup>		
		Actual			Actual			Actual		
		Allowable	Calculated	FEA	Allowable	Calculated	FEA	Allowable	Calculated	FEA
1	Shell	277.5	187.85	163.81	360.75	219.65	124.3	208.75		
2	Saddle support	345	48.47	148.71	448.5	110.2	174.36	258.75		
3	Heating element	315	115.44	157.09	409.5	182.12	157.09	236.25		
4	Shell flange	277.5	61.02	118.55	360.75	78.28	73.87	208.75		

**Table-IV:**

Sr. No.	Component	Tensile stress N/mm <sup>2</sup>			Bending stress N/mm <sup>2</sup>			Shear stress N/mm <sup>2</sup>		
		Actual			Actual			Actual		
		Allowable	Calculated	FEA	Allowable	Calculated	FEA	Allowable	Calculated	FEA
1	Shell	277.5	187.85	163.81	360.75	219.65	124.3	208.75		
2	Saddle support	345	48.47	148.71	448.5	110.2	174.36	258.75		
3	Heating element	315	115.44	157.09	409.5	182.12	157.09	236.25		
4	Shell flange	277.5	61.02	118.55	360.75	78.28	73.87	208.75		

## VI. CONCLUSION

The paper presents the stress analysis and permissible stress analysis of a direct oil heater.

The different parts of oil heater namely shell, saddle support, plate flange, heating element are analyzed. In part analysis, the stresses are found in three principal axis and in permissible stress analysis, the permissible proof stresses are determined in any different time duration. In finite element analysis, the shock force gives to the part namely shell, saddle support, plate flange, heating element, the stresses are found automatically. The stresses which found in part analysis and finite element analysis are within the acceptable limit. The stress analysis is made to verify the strength of the parts. The static and shock analysis of a direct oil heater is the best analysis which is used to resist the shock. The factor of safety found for different cases indicate that the components are sufficiently strong to withstand shocks. Though the actual shock would come in any direction, it was assumed that the shocks are only in these three directions (viz x, y and z). There is a variation in the values obtained analytically and those by finite element. Since both these methods are just to find the actual stresses due to an equivalent static force, exact analysis is not done. The components are analyzed in isolation. But actually they are in assembled condition and contain oil which will certainly reduce the effect of shock. Such analysis is essential in cases where shock loads (like in marine applications) are present. The scope of the present work consists of analysis and testing the oil heater with shock loading in different directions and of different magnitudes. The model needs to be rigorously tested. Since it is a distractive test, this testing becomes difficult for a single assembly. Number of assemblies can be tested in this case which is not feasible for every component. The analysis of the complete assembly can be done for shocks not only in the three directions but in any direction.

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