DESIGN AND FINITE ELEMENT ANALYSIS OF HOMING HEAD SHELL OF TORPEDO

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ABSTRACT

Under water vehicles viz. torpedoes, submarines etc are used in defence applications. These are designed for moderate to extreme depths of operation with minimum structural weight for increasing performance, speed and endurance. The present paper deals with the design and FEM analysis of homing head shell of a torpedo. Here various configurations of the homing head shell have been prepared and comparison study was made before finalizing the present design.

By using theory of shells methodology and British Standard BS: 5500 the finalized configuration was analysed. As the torpedo is carried either on a ship or submarine, the vibration loads due to these platforms has to be considered. Static analysis was carried out to see whether the natural frequency is within the operating range of these platforms. While launching of these torpedoes, the torpedo experiences the water entry shock. The shell was analysed for the shock load. The stresses developed due to the above shock load were found to be within the acceptable limit.

Keywords: ***Homing Head, Torpedo, Shell Theory, Static Analysis, Self-Propelled, FEM Analysis, Dynamic Analysis***

I INTRODUCTION

The Torpedo is one of the oldest weapons in the Naval Inventory, having been invented over 130 years ago, But at the same time it remains one of the deadliest anti-ship and anti-submarine weapon, it is far more lethal to submarines and surface ship than any other conventional weapon.

Torpedo warhead explodes under water, and that increases its destructive effect. When projectile explodes, the surrounding air absorbs a part of its force. Homing torpedoes are a relatively recent development they have been perfected since the end of World War II. With homing torpedoes, a destroyer can attack a submerged submarine, even when its exact position and depth are unknown. The outline of the torpedo is shown in fig1. The Torpedo consists of six sections. The homing head is one of the parts of the torpedo. The present thesis deals with the design analysis of the shell for homing head of the torpedo.

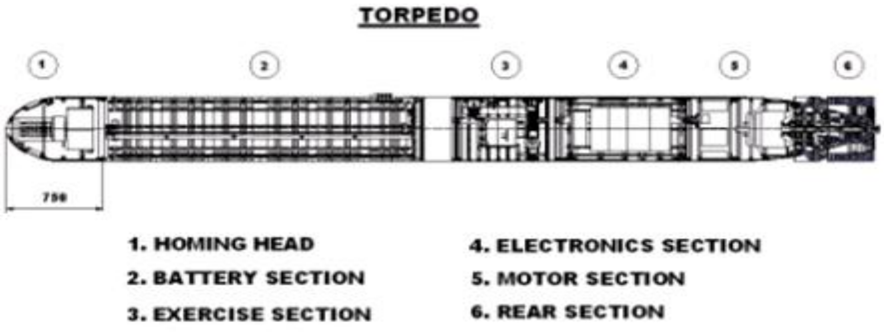

Fig:1 Torpedo Sections View

II MATERIAL

To meet the required specifications and in view of the housing with intricate features for placing the sonar transducers, SOBID elements, echo sounder the material Chosen is Aluminium casting and the casting process should choose with the following requirements.

1. The design has most intricate features, both external and internal. Casting helps in shaping the features with ease and as a result, many other operations, such as machining, forging and welding may be minimized or eliminated.
2. Construction is simplified and the housing is obtained as a single piece.
3. Machinability and vibration damping capacity is good.

“With the above requirements in view aluminium alloy material with following material is selected"

TABLE I

CHEMICAL COMPOSITION (IN %BY WT)

Material	Cu	Mg	Si	Fe	Mn	Zn	Ni	Ti	Pb	Al
Chemical composition	0.1	0.2 to 0.6	6.5 to 7.5	0.5	0.3	0.1	0.1	0.1	0.1	Reminder

TABLE III

AI CASTING ALLOYS: BS1490:

Alloy	**Si**	**Fe**	**Cu**	**Mn**	**Mg**	**Ni**	**Zn**	**Ti**
LM 2	9-11.5	1.0	0.7-2.5	0.5	0.3	0.5	2.0	0.2
LM 9	9-10	2.0	0.6	0.35	0.4-0.6	0.5	0.5	
LM 24	7.5-9.5	2.0	3.0-4.0	0.5	0.1	0.5	3.0	
LM 25	6.5-7.5	0.2	0.2	0.1	0.2-0.4		0.1	0.2
LM 30	16-18	1.3	4-5	0.1	0.45-0.65		0.1	

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III DESIGN &ANALYSIS

Homing head is the fore end part of the torpedo. Its main purpose is target detection and tracking. Torpedo being a fire and forget type of weapon, comprises an intelligent homing system which has to perform an optimum search, detect target amongst decoys and eventually guide the weapon on to the target to hit it for exploding the explosive on-board. For heavy weight torpedoes the torpedo sonar has a decisive influence on the probability of the weapon system's success. The arrangements of the transducer elements and the selection of the head shape are of vital importance for the sonar design.

Taking into consideration of all the requirements of the homing head, various configurations were tried out, without compromising on the functional aspects. Four configurations were worked out and they are as follows.

- Planar Array
- Conformal array
- Conformal Array (Inclined at an angle)
- Circular array

A. *Design Details*

The homing head is designed with the provision of circular array mapping for the transducer elements.76 numbers of elements can be accommodated in this array. To accommodate the elements a box type structure is made as shown in the model. The shell is required to withstand the external pressure corresponding to 720m depth of operation of the torpedo. For ease of fabrication the material is chosen to be Al alloy casting as per BS: 1490 .The material properties are as follows

Young's modulus E = 71000 N/m²

Density = 2700 kg/m³

Poison's ratio = 0.32

Yield strength of the material = 280 Mpa

The cylindrical shell and the spherical shell thickness are finalized using shell theory as follows. Assuming that the shell to be thin, the thickness of the shell is calculated for the test pressure of 72 Bars.

$$S = \frac{Pd}{2t}$$ Where,

s = hoop stress

p = pressure

d = diameter of the shell

t = thickness of the shell

For thickness of 12mm, the hoop stress induced in the cylindrical portion of the shell is 160.02 Mpa and is below the allowable stress value of 191 Mpa (With factor of safety of 1.2) For spherical portion of the shell 10 mm thickness is taken, for shell without openings for SOBID imaging array, homing transducer array and echo sounder.

The transducer mounting plate is cylindrical in nature and the thickness for the mounting plate is calculated using the above thin shell formula. The thickness of 8 mm is safe for the mounting plate without any holes. As there are holes on the plate, a stress concentration factor of 3 assumed and 25mm thickness is fixed.

B. Analysis:

ANSYS offers the engineers many analytic tools to solve a broad range of analysis. These tools include choices of analysis types, a large element library, nonlinear options, and material behaviour. There are seven types of structural analysis available in ANSYS. The primary unknowns (nodal degrees of freedom) calculated in a structural analysis are displacements. Other quantities such has strains, stresses and reaction forces are then derived from the nodal displacements.

i. Static analysis

   Static analysis is used to determine displacements, stresses, etc under static loading conditions. Both linear and nonlinear static analysis non linearities can include Plasticity, stress stiffing, large deflections, large strain, hyper elasticity, contact surfaces and creep.

ii. Modal Analysis

   Modal analysis is used to calculate the natural frequencies and mode shapes of a structure. Different mode extraction methods are available

iii. Harmonic analysis:

   Harmonic analysis is used to determine the response of a structure to harmonically time varying loads

iv. Transient Dynamic Analysis:

   This analysis is used to determine the response of a structure to arbitrarily time varying loads. All nonlinearities mentioned in static are allowed

v. Spectrum Analysis:

   An Extension of the modal analysis, used to calculate stresses and strains due to a response spectrum or a PSD input.

vi. Buckling analysis

   Used to calculate the buckling loads and determine the buckling mode shape. Both linear (Eigen value buckling) and nonlinear buckling analysis are possible.

C. Modelling :

The shell is designed using PRO-E. The solid model is transferred to ANSYS to carry out the analysis .The following fig shows the solid model of the shell.

The divergent opening at the top is for SOBID imaging array for transmission. In the middle the mounting plate is for the homing transducer array (conformal mapping). Below the homing transducer array, there is horizontal opening for the SOBID imaging array for reception. And at the bottom of the shell there is a circular opening for the echo sounder.

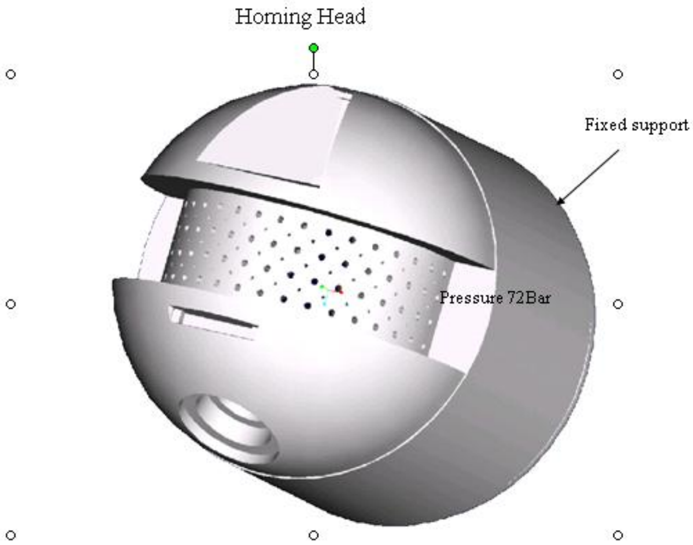

Fig:2 Torpedo sections vi Solid Model of the shell for homing head

D. Meshing:

Meshing is a process use to fill the solid model with nodes and elements, i.e. to create the FEA model. 3-D shell elements are used for structures, because of geometry materials, loading or detail of required results, cannot be modelled with simpler elements 3-D solid elements are also used when the model geometry is transferred, from a 3-D CAD system. The finite element mesh obtained to shown in the following fig.

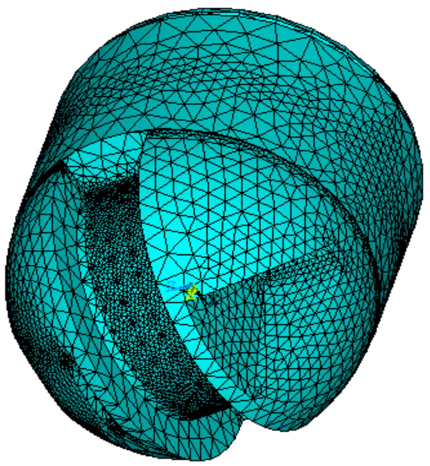

Fig:3 The Finite Element Mesh

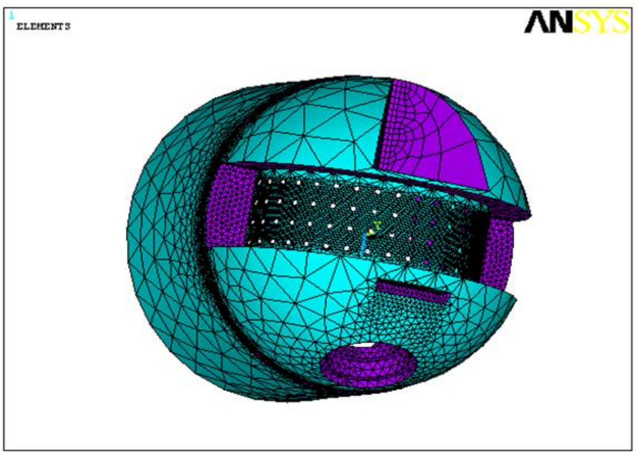

Fig:4 The Finite Element Mesh

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I. STATIC ANALYSIS

The following plot shows the von-mises stress values on the model. The maximum stress is 458.408Mpa, but this has no meaning as this is seen on a support region. Except the value at singularity the maximum stress is observed near the circumference of the homing transducer pocket opening and is equal to 152.803Mpa. The stress value is in the range of 160Mpa, which is in agreement with the theoretical value calculated.

Element	SHELL 93
Density	2.7×10^{9}
Poison's ratio	0.32
Young's Modulus	71000 MPa

Loads:

An external pressure of 72 bar is applied on the outer shell

Boundary conditions

Ux=Uy=Uz=0 at Y=0

Axis of the shell - Y axis

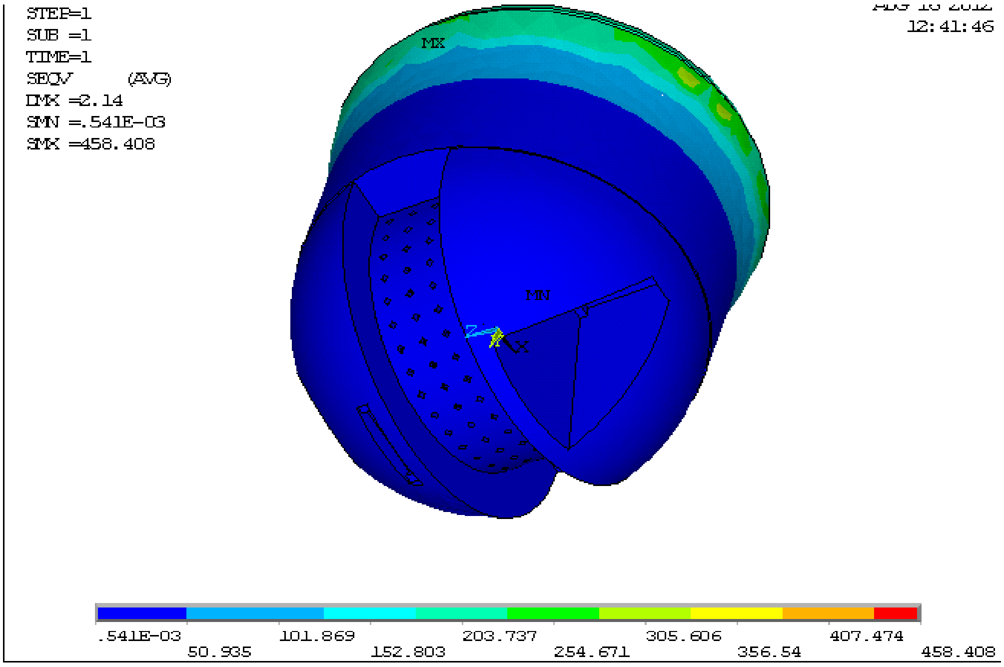

Fig:4 von-mises stress of static analysis

Theoretical stress	160.02N/mm²
FEM Result stress	152.803N/mm².

II. BUCKLING ANALYSIS

As the shell is subjected to external pressure and the length to diameter ratio is more the shell is prone to buckling failure. In the above analysis the model is checked for yield failure. In this section we will model the shell for buckling analysis with FEM. The stress variations at the singularities are found to be having boundless values.

The shell model is used to reduce the computational expenses. The solution for working analysis requires solving the eigen value problem with the size of matrix equal to the number of degrees of freedom of the model. By simplifying the model the size is brought down by many times compared to the model with solid elements.

The buckling analysis result is presented in the following figures. The shell with 72 bar external pressure is found to have a buckling factor of 0.69186. Different views of first mode shape of the buckling failure are shown in the following figures.

Element -SHELL 93

Density - 2.7×10^{9} N/mm²

Poison's ratio -0.32

Young's Modulus -71000 Mpa

Loads: An External pressure of 72 bar is applied on the outer shell

Boundary Conditions:

U_x=U_y=U_z=0

Axis of the shell - Y axis

SET BUCKLING FACTOR

1. 0.69186---------Critical Buckling Factor
2. 0.71185
3. 0.71324
4. 0.72510
5. 0.78632
6. 0.81938

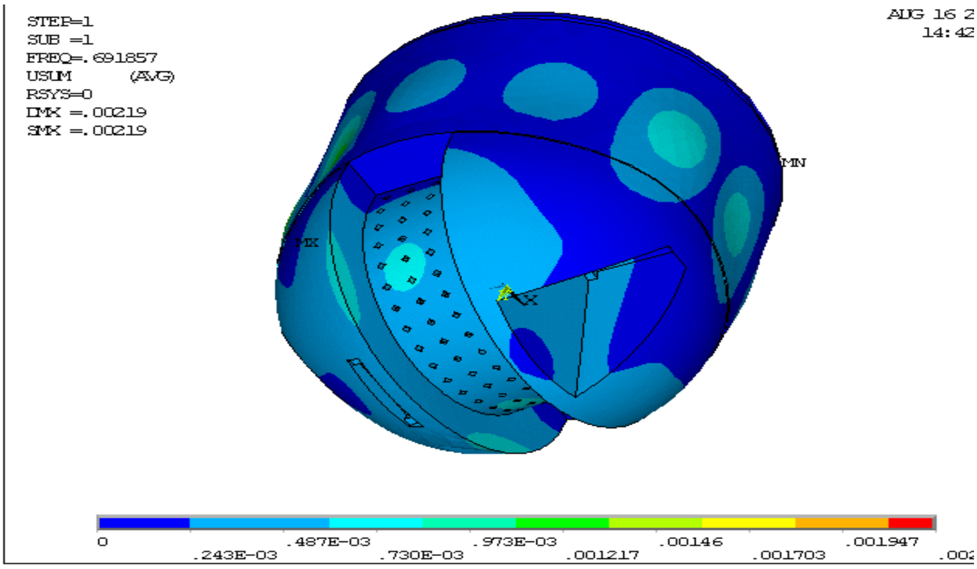

Fig 5 Buckling mode shapes

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III. MODAL ANALYSIS

Modal analysis was carried out to find out the first 10 natural frequencies of the shell. The large mass concept was used to constrain one end of the shell. The frequencies obtained are listed below. These vibration modes will be utilized for carrying out transient dynamic analysis.

FREQUENCIES

1	18.117
2	19.079
3	33.452
4	40.743
5	43.509
6	44.143
7	53.234
8	82.675
9	102.235
10	132.757

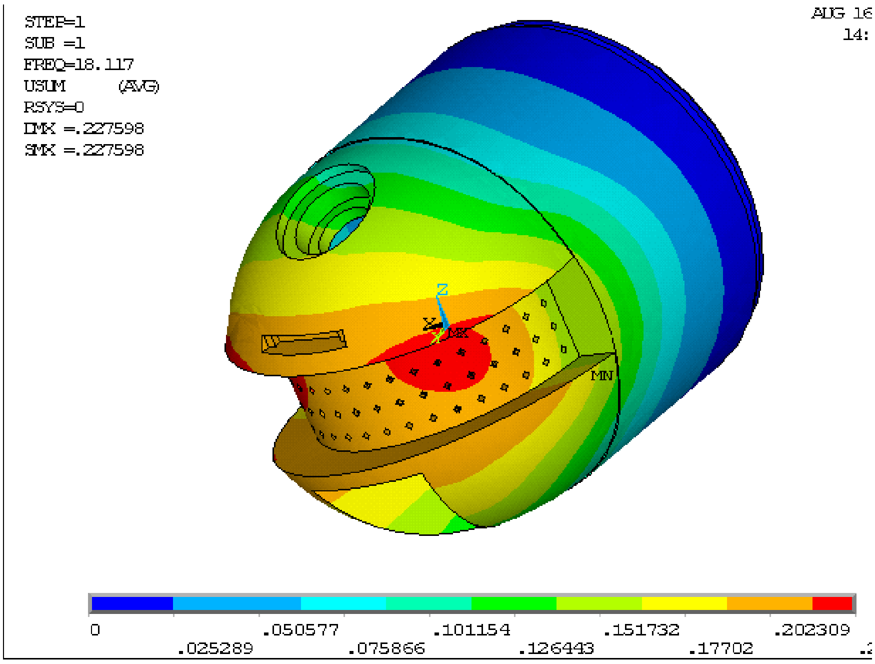

Fig.6 Mode shape @ 18.117Hz

Model analysis Frequency /Displacement:

S.NO	FREQUENCY	DISPLACEMENT
1	18.117	0.227598
2	19.079	0.222425
3	33.452	0.296909
4	40.743	0.258415
5	43.509	0.334412
6	44.143	0.577065
7	53.234	0.622031
8	82.675	0.801241
9	102.235	0.946325
10	132.757	0983994

In the model analysis we observed the dynamic characteristics of the modal, so in this structure we have taken natural frequencies and mode shape at lowest frequencies. i.e 18.117 Hz and the maximum displacement is 0.227598. these values have compare with static analysis, the results are within the safe limit.

STATIC DISPLACEMENT	DYNAMIC DISPLACEMENT	BUCKLING
2.14mm	0.227598mm@18.117Hz	0.00219

IV. RESULTS & CONCLUSIONS

The Homing head shell was designed to the required specifications of the user group. The design is analysed for static, buckling and dynamic loads and satisfied with the requirements.

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