Modeling and Structural Analysis of A Pressure Hull under Dynamic Load

B. Mahendra[1], B. Ankanna[2], K.Tirupathi Reddy[3],M.Ravichandra[4],
*(PG student,School of Mechanical Engineering RGM College of Engg. &Technology, Nandyal-518501, India.)
** (School of Mechanical Engineering, RGM College of Engineering & Technology, Nandyal-518501, India)
*** (School of Mechanical Engineering, RGM College of Engineering & Technology, Nandyal-518501, India)
**** (School of Mechanical Engineering, RGM College of Engineering & Technology, Nandyal-518501, India)

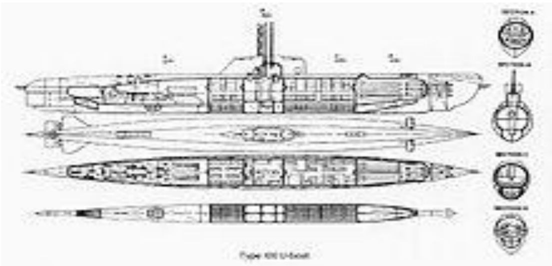
ABSTRACT: *Pressure hulls are the main load bearing structures of naval submarines, and autonomous underwater vehicles (AUVs). A pressure hull is a structure that is designed to withstand the compressive forces associated with hydrostatic pressure. In this thesis, the assembly of the pressure hull including Navigation compartment shell, Battery compartment shell which are connected with bolts is designed which is used at present. Around 16 M12 bolts are used to connect the Navigation compartment shell and Battery compartment shell. These shells are to be dissembled very frequently for battery charging and other maintenance purpose. It is observed that the dissembling and assembling process is a very time consuming because it requires unbolting and bolting of all the 16 bolts every time. A new design of pressure hull is proposed where the bolts are removed and the navigation compartment and battery compartment are welded. In the present paper, design calculations are done as per ASME codes to withstand the pressure of 65 Bar. The design constraints considered for the analysis were stresses and deflections. The pressure hull have been modeled considering the elliptical cross section. The modeling of the pressure hull has been carried out by pro-5.0 and analysis soft ware is ansys 14.0 soft ware packages.*

Keywords: *Pressure hulls, steel, Static analysis, dynamic analysis.*

I. INTRODUCTION

A light hull (casing in British usage) of a submarine is the outer non-watertight hull which provides a hydrodynamic ally efficient shape. The pressure hull is the inner hull of a submarine; this holds the difference between outside and inside pressure.

SUBMARINE HULL



Type XXI U-Boat, late WWII, with pressure hull almost fully enclosed inside the light hull Modern submarines are usually cigar-shaped. This design, already visible on very early submarines is called a "teardrop hull", and was patterned after the bodies of whales. It significantly reduces the hydrodynamic drag on the sub when submerged, but decreases the sea-keeping capabilities and increases the drag while surfaced.

TYPES

All small modern submarines and submersibles, as well as the oldest ones, have a single hull. However, for large submarines, the approaches have separated. All Soviet heavy submarines are built with a double hull structure, but American submarines usually are single-hulled. They still have light hull sections in bow and stern, which house main ballast tanks and provide hydro dynamically optimized shape, but the main, usually cylindrical, hull section has only a single plating layer.

LIGHT HULL

The double hull of a submarine is different from a ship's double hull. The external hull, which actually forms the shape of submarine, is called the outer hull, casing or light hull. This term is especially appropriate for Russian submarine construction, where the light hull is usually made of steel that is only 2 to 4 millimeters thick, as it has the same pressure on both sides. The light hull can be used to mount equipment, which if attached directly to the pressure hull could cause unnecessary stress.

PRESSURE HULL

Inside the outer hull there is a strong hull, or pressure hull, which actually withstands the outside pressure and has normal atmospheric pressure inside. The pressure hull is generally constructed of thick high-strength steel with a complex

structure and high strength reserve, and is separated with watertight bulkheads into several compartments. The pressure and light hulls aren't separated, and form a three-dimensional structure with increased strength. The interhull space is used for some of the equipment which doesn't require constant pressure to operate.
The list significantly differs between submarines, and generally includes different water/air tanks. In case of a single-hull submarine, the light hull and the pressure hull are the same except for the bow and stern.

II. SPECIFICATION OF THE PROBLEM

The objective of the present work is to design and analyses, of steel pressure hull including Navigation compartment shell, Battery compartment shell which are connected with bolts is designed. These shells are to be dissembled very frequently for battery charging and other maintenance purpose. It is observed that the dissembling and assembling process is a very time consuming because it requires unbolting and bolting of all the 16 bolts every time. A new design of pressure hull is proposed where the bolts are removed and the navigation compartment and battery compartment are welded. pressure hull is a created in Pro-E 5.0. Model is imported in ANSYS 14.0 for analysis by applying normal load and dynamic load conditions. After analyis a comparison is made between exisisting in terms of deflections and stresses, to choose the best one.

III. STRUCTURAL ANALYSIS OF PRESSURE HULL:

Dimensions of the structural and dynamic analysis the design of pressure hull without bolts and pressure hull with bolts. Pressure hull consists of 5 layers (thickness of each layer, 0.6mm). diameter of the pressure hull is 125mm. Since the properties of pressure hull vary with directions of a 3-D model of pressure hull is used for analysis in ANSYS 14.0. The loading conditions are assumed to be static and dynamic. The element choosen is SHELL LINEAR LAYER 99, which is a layered version of the 8-node structural shell model. The element has six degrees of freedom at each node : translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. The finite element analysis is carried out on pressure hull with bolts as well as pressire hull with out bolts .From the analysis the equivalent stress (Von-mises stress) and displacements were determined and are shown in figure 2-15. Table 2 - 4 shows the Comparative structural and dynamic analysis of a pressure hull with bolts and without bolts.

IV. SPECIFICATIONS OF EXISTING PRESSURE HULL :

Table 1 shows the specifications of a steel pressure hull of alister 3000. The typical chemical composition of the material is 0.565C, 1.8% Si, 0.7%Mn, 0.045%P and 0.045% S.

Table: 1 Specifications of pressure hull

S.No	**Parameters**	**Value**
1	**Total length of the pressure hull (Eye to Eye)**	**245mm**
2	**Diameter of the pressure hull**	**125 mm**
3	**Thickness of pressurehull**	**3 mm**
4	**applying the pressure**	**6.326N/mm^2**
5	**Young's Modulus of steel**	**2.1e5 N/mm^2**
6	**Density of steel pressure hull**	**7860 kg/m^3**
7	**Yield strength**	**500 N/mm^2**
8	**Tensile strength**	**620 N/mm^2**
9	**Passions ratio**	**0.3**

V. STRUCTURAL AND DYNAMIC ANALYSIS OF PRESSURE HULL:

5.1 PRESSURE HULL WITH BOLTS

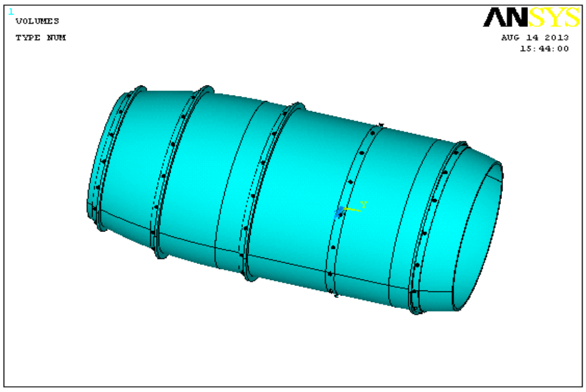


Fig2: Analysis of pressure hull with bolts

5.1.1 STRUCTURAL ANALYSIS:

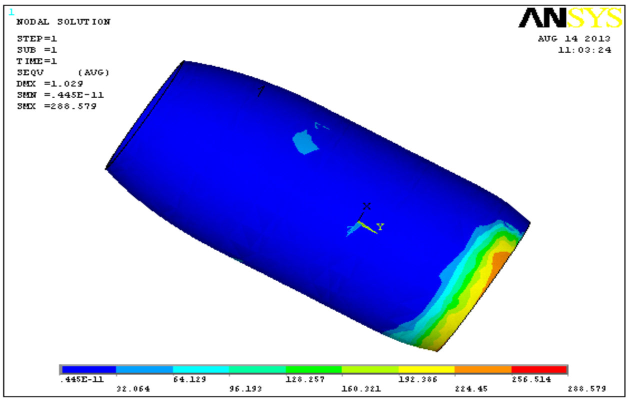


Fig3: Stress distribution for pressure hull

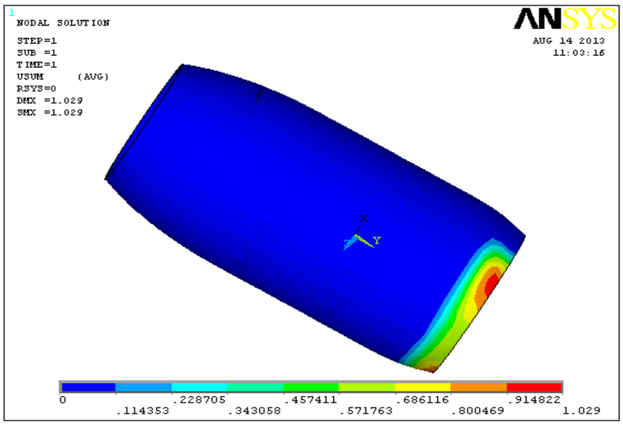


Fig 4: Displacement pattern for pressure hull

5.1.2 DYNAMIC ANALYSIS: 10SECS

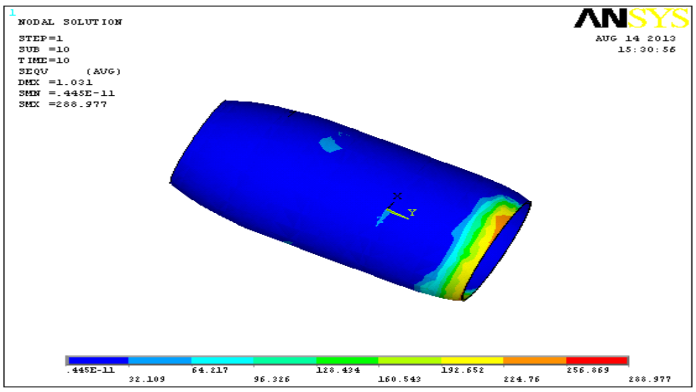


Fig5: Stress distribution for pressure hull

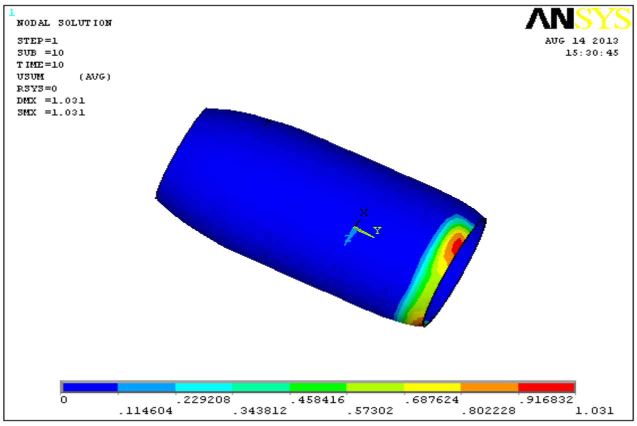


Fig 6: Displacement pattern for pressure hull

5.1.3 DYNAMIC ANALYSIS: 20 SECS

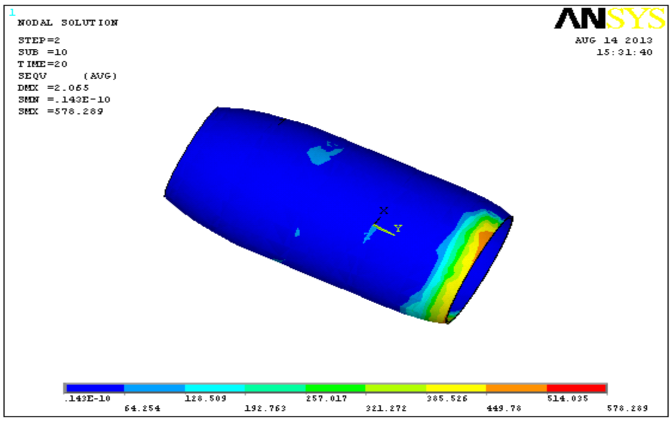


Fig7: Stress distribution for pressure hull

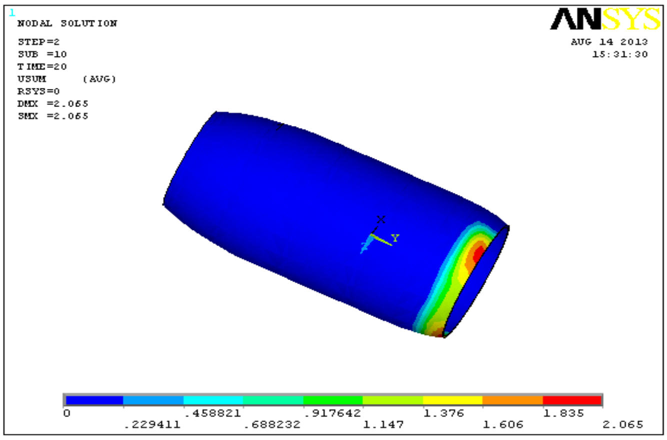


Fig 8: Displacement pattern for pressure hull

5.2 PRESSURE HULL WITH OUT BOLTS

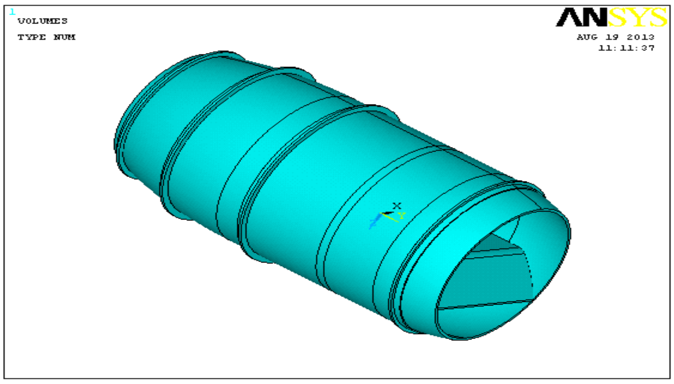


Fig9: Analysis of pressure hull without bolts

5.2.1 STRUCTURALANALYSIS:

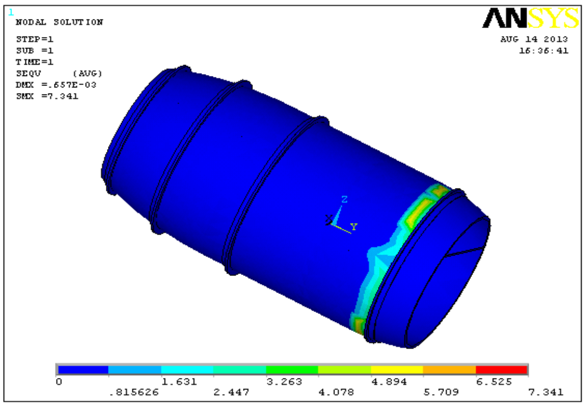


Fig10: Stress distribution for pressure hull

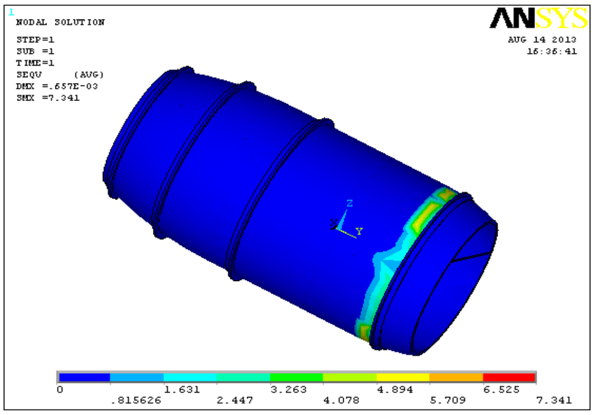


Fig 11: Displacement pattern for pressure hull

5.2.2 DYNAMIC ANALYSIS: 10SECS

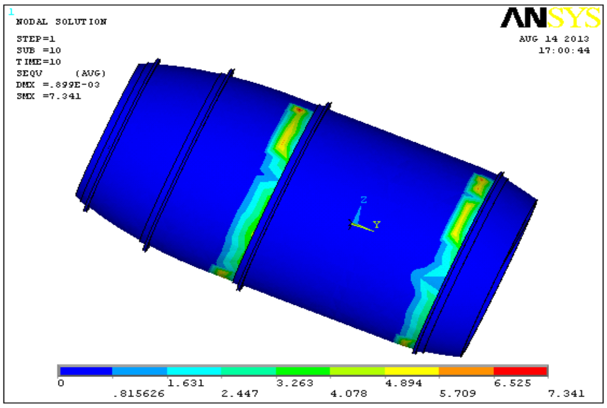


Fig12: Stress distribution for pressure hull

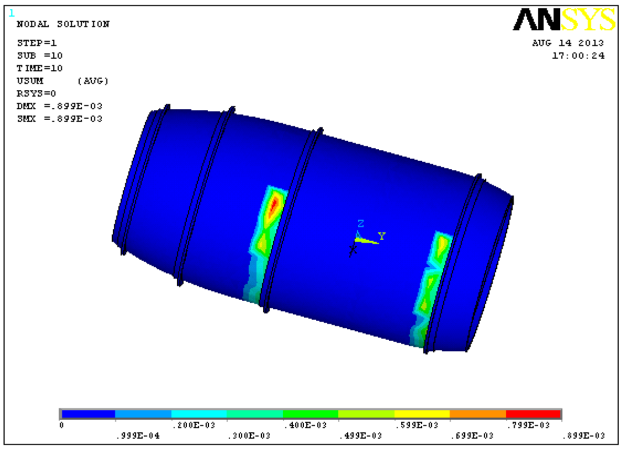


Fig 13: Displacement pattern for pressure hull

5.2.3 DYNAMIC ANALYSIS: 20SECS

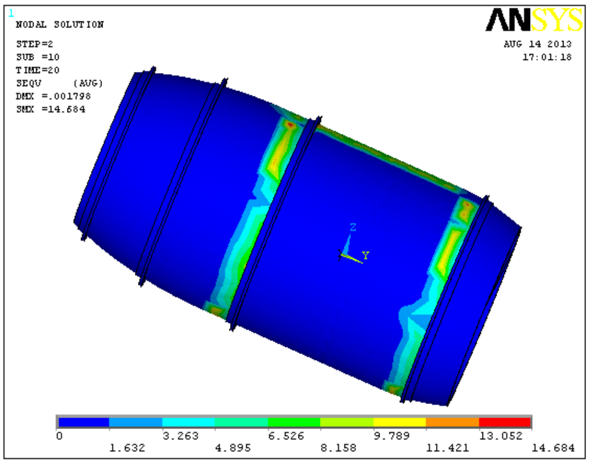


Fig14: Stress distribution for pressure hull

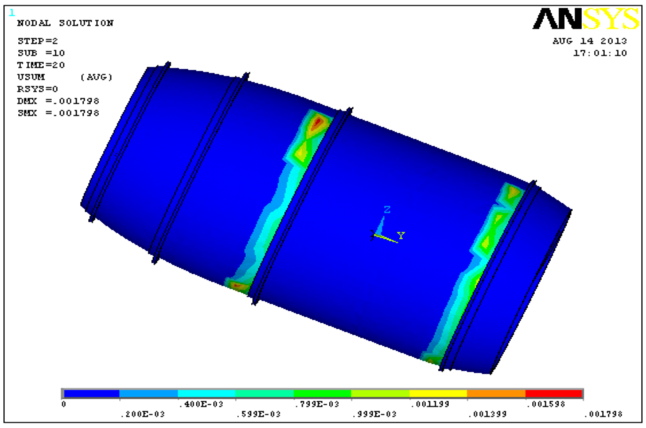


Fig 15: Displacement pattern for pressure hull

VI. RESULS

6.1 STRUCTURAL ANALYSIS RESULTS:

Table2: Comparative structural analysis of a pressure hull with bolts and without bolts.

S. no	PH	Stress (N/mm^2)	Displacement (mm)	Strain
1	WB	288.579	1.029	0.001861
2	WOB	7.341	0.000657	0.000046

Notes: 1. PH = pressure hull,
2. WB = With bolts,
3. WOB = Without bolts.

6.2 DYNAMIC ANALYSIS RESULTS:

Table3: Comparative dynamic analysis of a pressure hull with bolts and without bolts.

S. no	Parameter	Time	PH WB	PHWOB
1	Stress (N/mm^2)	10sec	288.977	7.341
2		20sec	578.289	14.684
3		30sec	867.749	22.06
4	Displace ment(mm)	10sec	1.031	0.000899
5		20sec	2.065	0.001798
6		30sec	3.099	0.002697
7	Strain	10sec	0.001863	0.000046
8		20sec	0.003729	0.000094
9		30sec	0.005595	0.000141

Notes: 1. PHWB = pressure hull with bolts,
2. PHWOB = pressure hull Without bolts.

6.3MODAL ANALYSIS RESULTS:

Table4: Comparative modal analysis of a pressure hull with bolts and without bolts.

S.no	PH with bolts		PH without bolts	
	Displacement(mm)	Frequency(Hz)	Displacement(mm)	Frequency (Hz)
1	1.0029	0	0.218416	0
2	0.32194	21.646	0.19668	0
3	0.23168	25.724	0.10598	0.000007
4	0.276541	26.2929	0.228769	0.0000081

Notes: 1. PHWB = pressure hull with bolts,
2. PHWOB = pressure hull Without bolts.

VII. GRAPHS:

7.1 Pressure Hull with bolts and without bolts for dynamic analysis:

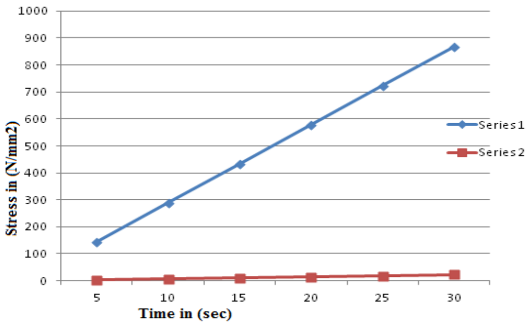


Fig 16: Time - Stress curves for PHWB and PHWOB.

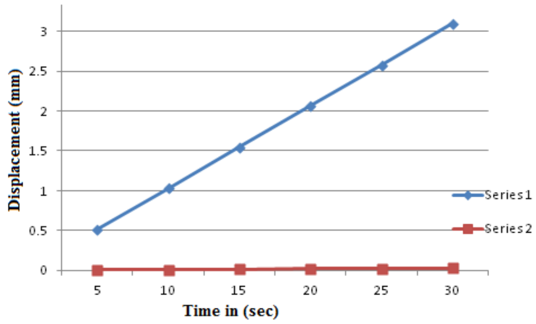


Fig 17: Time - Displacement curves for PHWB and PHWOB.

Notes: 1. PHWB = pressure hull with bolts,
2.PH WOB = pressure hull Without bolts,
3.Series 1 = PHWB curve,
4.Series 2 = PHWOB curve.

VIII. CONCLUSION:

To observe the all results and to compare the Pressurehull with bolts and pressurehull with out bolts with respect to weight, stiffness and strength.

By employing pressurehull without bolts for the same load carrying capacity, there is a reduction in are 32%~41% higher than pressurehull withbolts and 52~63% stiffer than the pressurehull with bolts**.**

Present used material for pressurehull with bolts is Stainlesssteel. I have considered pressurehull with bolts and pressurehull without bolts. Based on the results, it was inferred that pressurehull without bolts has superior strength and stiffness and lesser in weight compared to pressurehull with bolts.

From the results, it is observed that the pressurehull without bolts is lighter and more economical than the conventional pressurehull with bolts with similar design specifications.

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