

# Modelling and Structural Analysis of a Pressure Hull under Dynamic Load

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## 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 is 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 disassembled very frequently for battery charging and other maintenance purpose. It is observed that the disassembling 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 hulls have been modeled considering the elliptical cross section. The modeling of the pressure hull has been carried out by pro-5.0 and analysis software is ANSYS 14.0 software packages

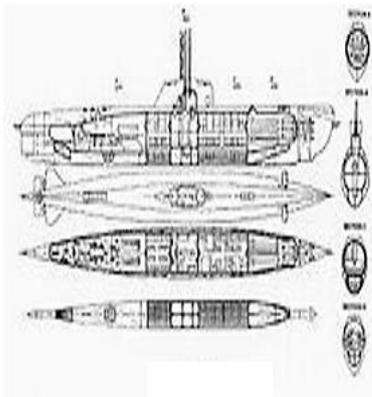
**Keywords :** Pressure hulls, steel, Static analysis, dynamic analysis.

## 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.

Type XXI U-Boat, late WWII, with pressure hull almost fully enclosed inside the light hull Modern submarines is 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.

## SUBMARINE HULL



## 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 millimetres 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.

## II. METHODS AND MATERIAL

### A. 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 is connected with bolts is designed. These shells are to be disassembled very frequently for battery charging and other maintenance purpose. It is observed that the disassembling 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 analysis

a comparison is made between existing in terms of deflections and stresses, to choose the best one.

### B. 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 chosen 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 pressure hull without 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.

### C. 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.

Sr.no	parameters	value
1	Total length of pressure hull(Eye to Eye)	245mm
2	Diameter of pressure Hull	125 mm
3	Thickness of pressure Hull	3 mm
4	Applying the pressure	6.326 N/mm <sup>2</sup>
5	Young's modulus of steel	2.1e5 N/mm <sup>2</sup>
6	Density of pressure Hull	7860 kg/m <sup>3</sup>
7	Yield strength	500 N/mm <sup>2</sup>
8	Tensile strength	620 N/mm <sup>2</sup>
9	Passion ratio	0.3

## D. Structural and Dynamic Analysis of Pressure Hull

### A. Pressure Hull with Bolts

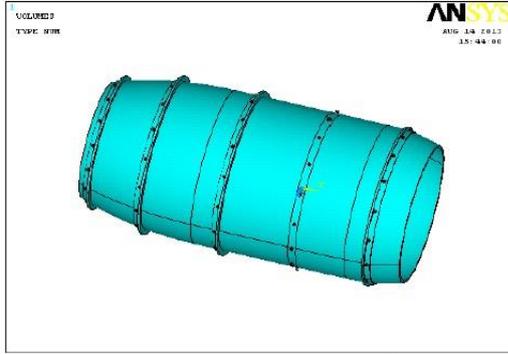


Figure 2. Analysis of pressure hulls without bolts

### 1. Structural Analysis

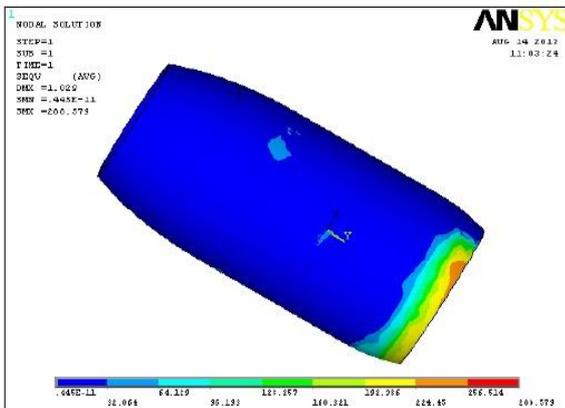


Figure 3. stress distribution for pressure hulls

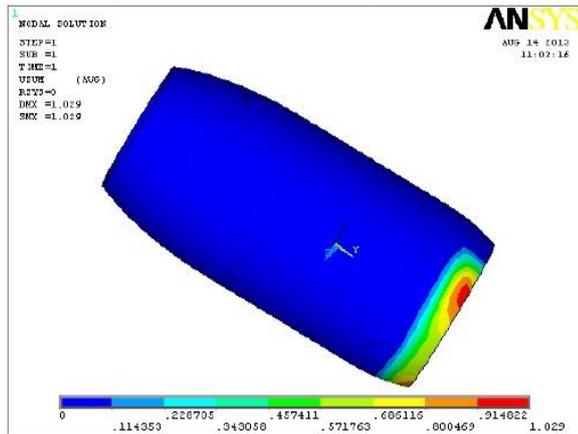


Figure 4. Displacement pattern for pressure hulls

### 2. Dynamic Analysis : 10 Secs

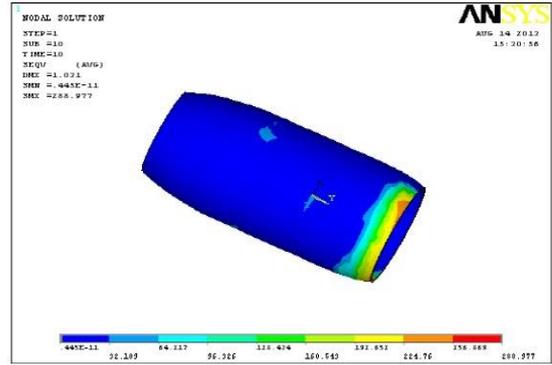


Figure 5. Stress distribution for pressure hulls

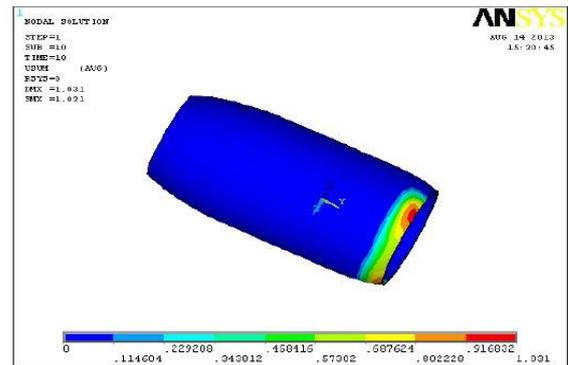


Figure 6. Displacement pattern for pressure hulls

### 3. Dynamic Analysis : 20 Secs

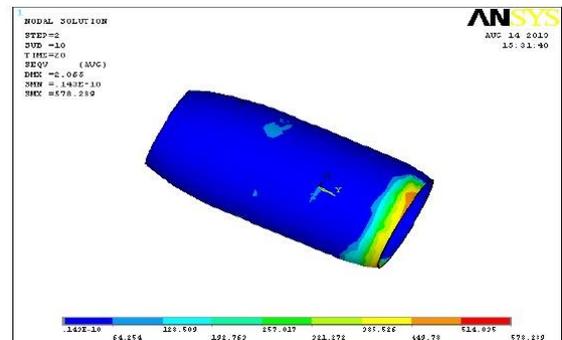


Figure 7. Stress distribution for pressure hulls

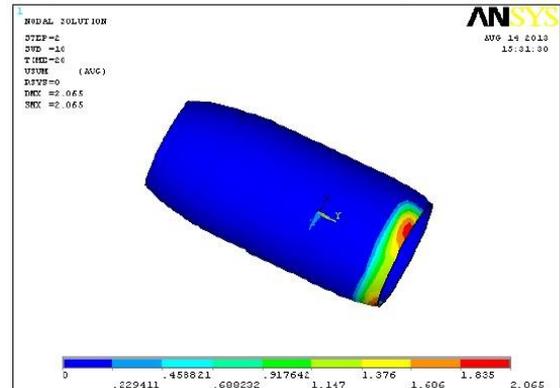
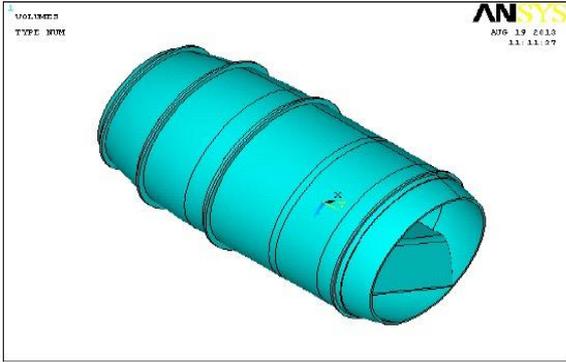


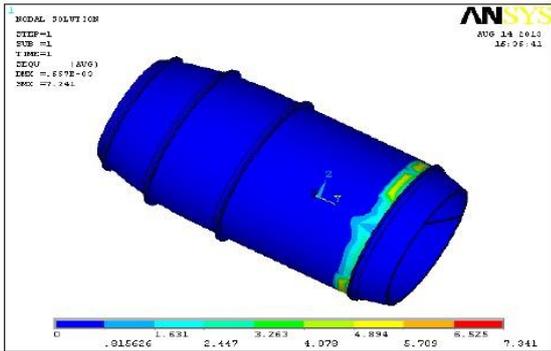
Figure 8. Displacement pattern for pressure hulls

**B. Pressure Hull with Out Bolts**

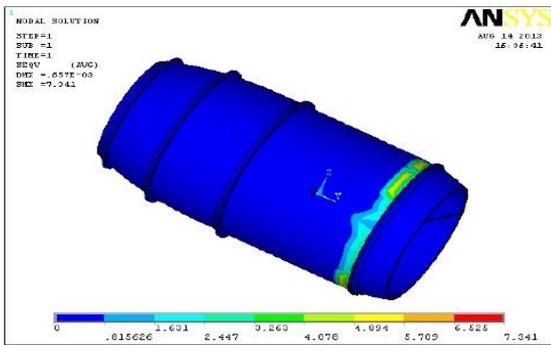


**Figure 9.** Analysis of pressure hulls without bolts

**1. Structural Analysis**

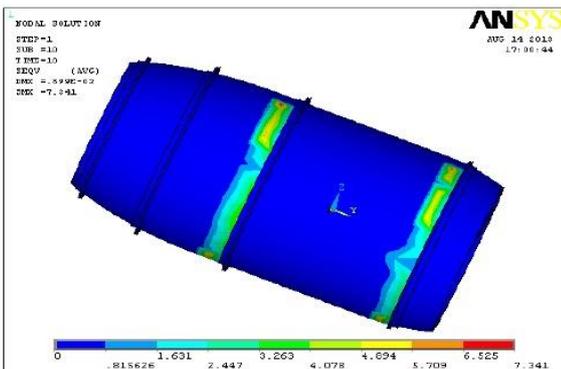


**Figure 10.** Stress distribution for pressure hulls

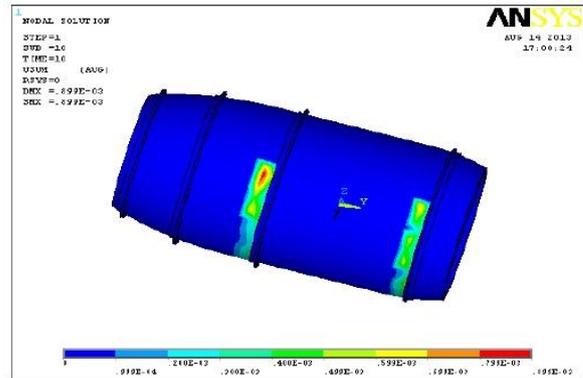


**Figure 11.** Displacement pattern for pressure hull

**2. Dynamic Analysis : 10 Secs**

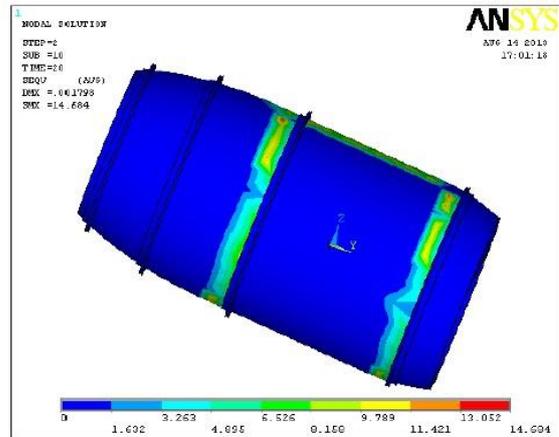


**Figure 12.** Stress distribution for pressure hulls

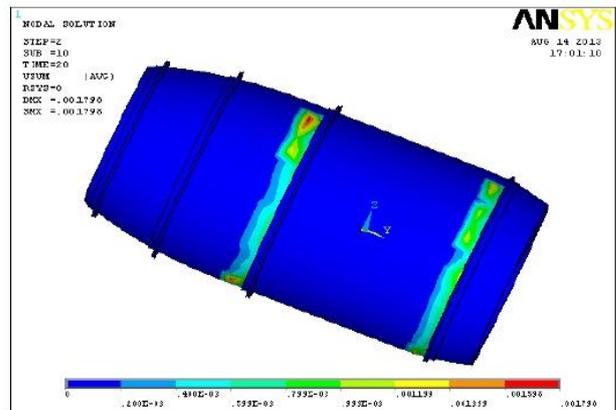


**Figure 13.** Displacement pattern for pressure hulls

**3. Dynamic Analysis : 20 Secs**



**Figure 14.** Stress distribution for pressure hulls



**Figure 15.** Displacement pattern for pressure hulls

**III. RESULT AND DISCUSSION**

**A. Structural Analysis Results**

**Table 2 :** Comparative structural analysis of a pressure hull with bolts and without bolts

Sr. No	PH	Stress (N/mm <sup>2</sup> )	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.

### 1. Dynamic Analysis Results

**Table 3 :** Comparative dynamic analysis of a pressure hull with bolts and without bolts.

Sr. No	parameters	Time	PHWB	PHWOB
1	STRESS (N/mm <sup>2</sup> )	10 sec	288.97	7.341
		20 sec	578.289	14.684
		30 sec	867.749	22.06
2	Displacement (mm)	10 sec	1.031	0.000899
		20 sec	2.065	0.001798
		30 sec	3.099	0.002697
3	Strain	10 sec	0.001863	0.000046
		20 sec	0.003729	0.000094
4	STRESS (N/mm <sup>2</sup> )	10 sec	288.97	7.341
		30 sec	0.005595	0.000141

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

### 2. Modal Analysis Results

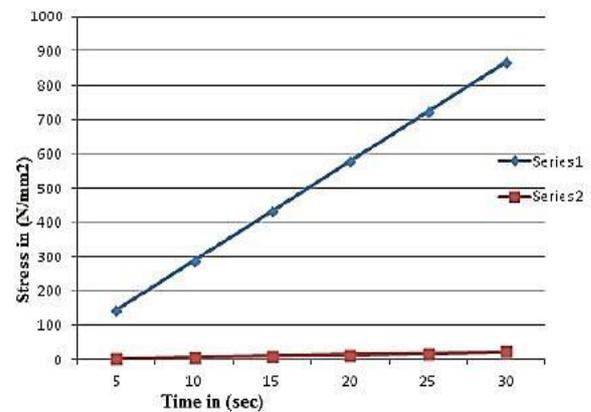
**Table 4 :** Comparative modal analysis of a pressure hull with bolts and without bolts

Sr.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	25.742	0.10598	0.000007
4	0.276541	26.2929	0.228769	0.0000081

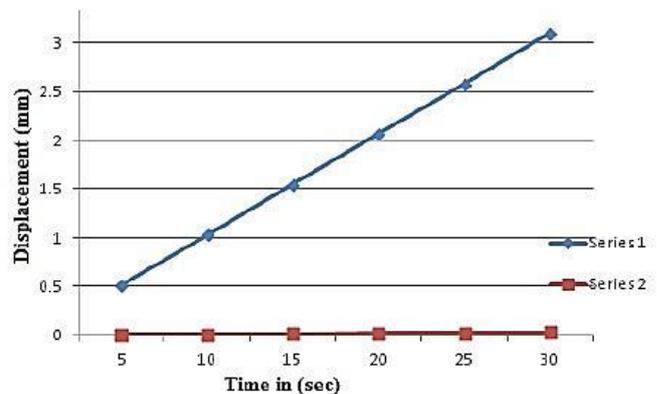
Notes: 1. PHWB = pressure hull with bolts,  
 2. PHWOB = pressure hull without bolts

## B. Graphs

### Pressure Hull with bolts and without bolts for dynamic analysis



**Figure 16.** Time – Displacement curves for PHWB AND PHWOB



**Figure 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

## IV. CONCLUSION

To observe the all results and to compare the pressure hull with bolts and without bolts with respect to weight, stiffness and strength.

By employing the pressure hull without bolts for the same load carrying capacity, there is reduction in are 32%- 41% higher than pressure hull with bolts and 52%- 63% stiffer than pressure hull with bolt.

Present used material for pressure hull with bolts is Stainless steel. I have considered pressure hull with bolts

and pressure hull without bolts. Based on the results, it was inferred that pressure hull without bolts has superior strength and stiffness and lesser in weight compared to pressure hull with bolts.

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

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