Analytical Investigation of Double Hull Structure Subjected to Bulbous Bow Collision

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Abstract -*In ship collision and grounding, the penetration of ship side and bottom can result in severe economic loss and potential environmental damage. Over the last two decades, double-hull structures have become an internationally agreed standard for tankers in order to reduce oil spillage in collision accidents. In this study the behaviour of double hull structure subjected to different shaped bulbous bow collision is investigated. The investigation of the behaviour of double hull structure subjected to bulbous bow collision by varying the angle and also by the stiffener sections. The determination of the impact resistance of the double hull structure and also the comparison of the behaviour of double hull structure subjected to actual bulbous bow collision and simplified shaped bulbous bow collision. The FEM model is prepared using ANSYS software. (Version 17, workbench).*

Key Words: Double hull Structure, Simplified bulbous bow, Actual bulbous bow, Collision angle, L-profile stiffener

1. INTRODUCTION

A ship undergoes wave loads as well as extreme accidental loads in its lifetime. Among many types of ship accident, collision is directly related to the ship structural strength. Especially, collisions of the hazardous substance carriers such as oil tankers, LNG/LPG can cause serious environment threats when occurring near the coastal areas or narrow channels. Furthermore, the ship collision also can be classified into two groups, side collision and head-on collision. The side collision generally represents a ship-to-ship collision situation. In other words, a striking ship collides with the side structure of the struck ship. A typical head-on collision represents a situation when a bow of a ship collides into a fixed embankment such as pier or bridge crossing international shipping route or gravity-supported offshore installations. Even though the head-on collision might be treated as a less serious case as compared with grounding case and side collision, there must be no priority in preventing disaster. Most of the works are concentrated on double hull structure subjected to collision with actual bulbous bow.

- To investigate the impact resistance and penetration depth of double hull structure subjected to collision with actual and simplified bulbous bow.
- To optimize the better performing bulbous bow as compared with actual bulbous bow.
- To study the penetration depth of double hull structure subjected to collision with selected bulbous bow under various collision angle (30^0,60^0,120^0,150^0) degrees.
- To optimize the most severe collision angle with respect to penetration depth

2. SOFTWARE USED

The FEM model is developed and analyzed using the ANSYS software. ANSYS 17, workbench is opted. The software is chosen for the reason that, since it is parametric software the corrections, dimensions can be changed as concerned which is not possible in case of non-parametric software. Also, it is user-friendly and design modeling and parametric studies can be done efficiently.

3. SCOPE

The scope of this study is helpful for understanding the resistance offered by the double hull structure which is subjected to collision with actual and simplified shaped bulbous bow. The simplified shapes which are chosen for the study are hemispherical end, cylinder with hemispherical end, wedge shaped end, and trapezoidal prism shaped end. These studies help us to understand the penetration depth in double hull structure when it is subjected collision with different shaped bulbous bow. The initial case helps as to assess the better performing bulbous bow with respect to penetration depth. By knowing the effective shape of bulbous bow then the investigation is continuing by changing the collision angle to determining the most severe collision angle. All the studies which I have performed are on steel double hull structure and bulbous bows and the study is limited to the ANSYS software. This work can be extended with the crack propagation in inner and outer hull case with future scope.

4. MODEL

In this paper, 15 finite element models representing double hull structure subjected collision with bulbous bows are developed using the ANSYS software. Transient dynamic analysis (sometimes called time-history analysis) is performed. It is a technique used to determine the dynamic response of a structure under the action of any general time-dependent loads. For performing the analysis fixed support is provided in the inner plate. For the initial study the collision angle is 90 degrees and the striker are considered as rigid structure. For the further studies the collision angle is change to 30^0,60^0,120^0, and 150^0 degrees to determine most severe collision angle from the selected bulbous bow collision

The main dimensions of double hull structure are 12000×9600mm. The double hull structure consists of one outer panel, one inner panel, two web frames and one stringer. Three frames spacing and two stringers spacing included and their respective span length are 4.0m and 4.8m. The plate thickness of the outer panel is17mm and its stiffeners are 400×14mm bulb flat profiles. The plate thickness of web frame is 20mm and their stiffeners are 200×20mm flat bar profiles. The plate thickness of stringer is 12mm and their stiffeners are 200×15mm flat bar profiles. The height of web frame and stringer is 2.4m.

In order to determine the effective shape for the bulbous bow four different shapes were selected for the analysis. The four different shapes chosen for the comparison are hemispherical, wedge, trapezoidal prism and cylinder with hemispherical end. The areas of cross section of these four different shapes were kept as almost equal. The end supporting condition was provided as fixed. Dimensional details of the bulbous bow specimens were given in the Table 1. For all the specimens, the structural steel chosen. The models prepared for the study is shown below.

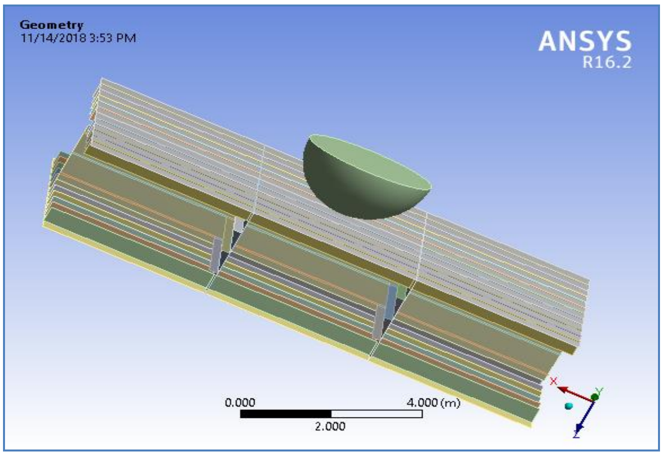

Fig -1: Model of hemispherical end shaped bulbous bow

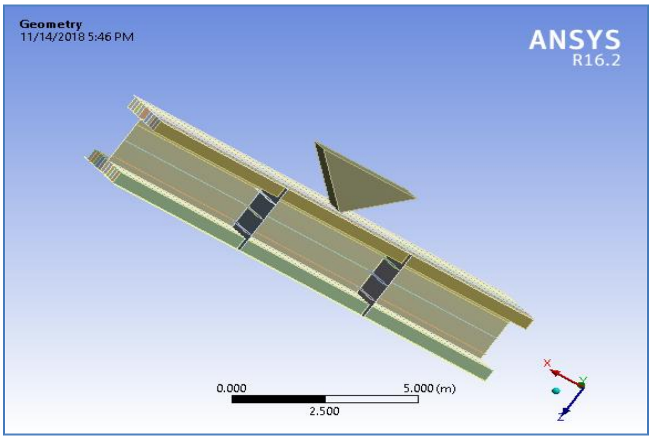

Fig -2: Model of trapezoidal prism shaped end bulbous bow

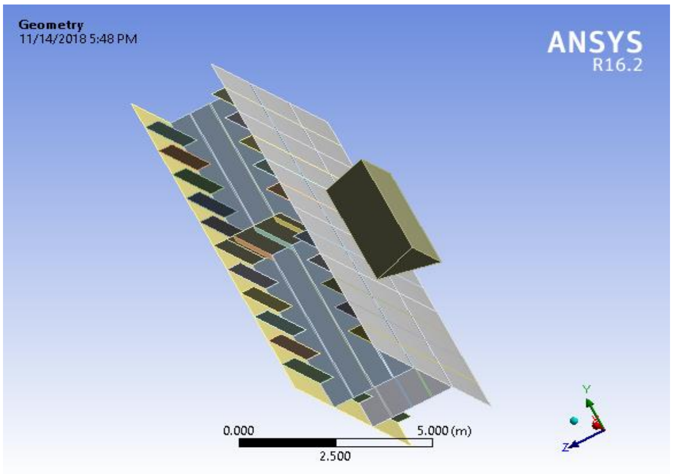

Fig -3: Model of wedge-shaped bulbous bow

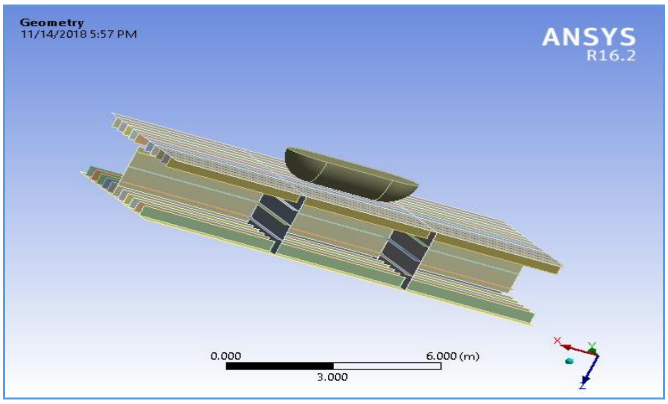

Fig - 4: Model of cylinder with hemispherical end shaped bulbous bow

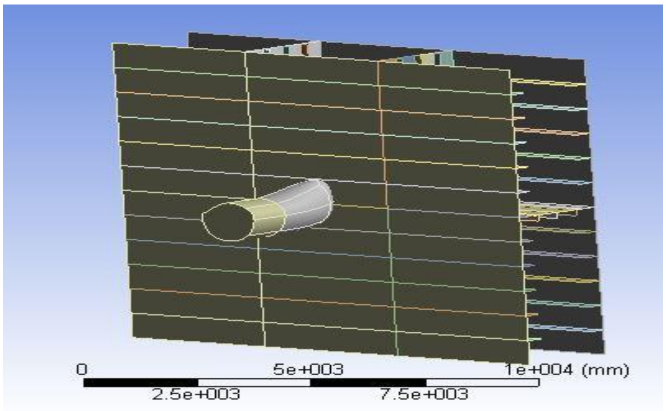

Fig - 5: Model of actual bulbous bow

Fig 1, 2, 3, 4,5 represents the model for double hull structure subjected to collision with different shaped bulbous bow under 90-degree collision angle.

Table -1: SPECIFICATION OF MODELS

Model Name	Specification(mm)
Hemispherical	Diameter=3000
Wedge	3000×1500
Trapezoidal prism	2000×1500×500
Cylinder with hemispherical end	3000×1000
Actual bulbous bow	3800×2400

5. ANALYSIS

For the study, transient dynamic analysis is performed for all the models. Impact loading is providing at a speed of 2m/s. Load is applied as displacement according to displacement convergence method. Penetration depth is studied. The deformation diagram obtained for actual bulbous bow, hemispherical bulbous bow, wedge shaped bulbous bow, trapezoidal prism bulbous bow, and cylinder with hemispherical end shaped bulbous bow were shown below.

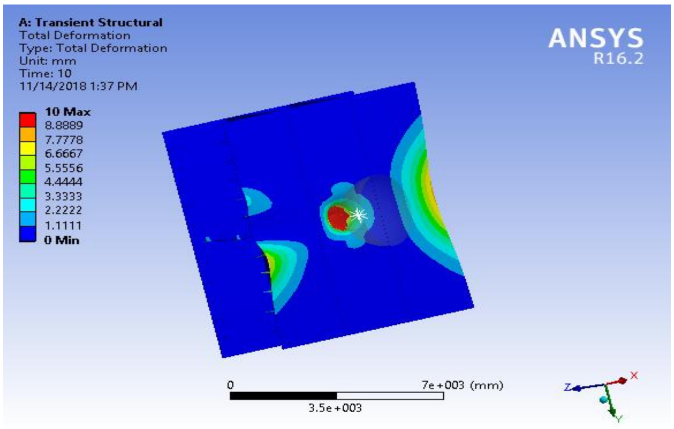

Fig - 6: Hemispherical end shaped bulbous bow

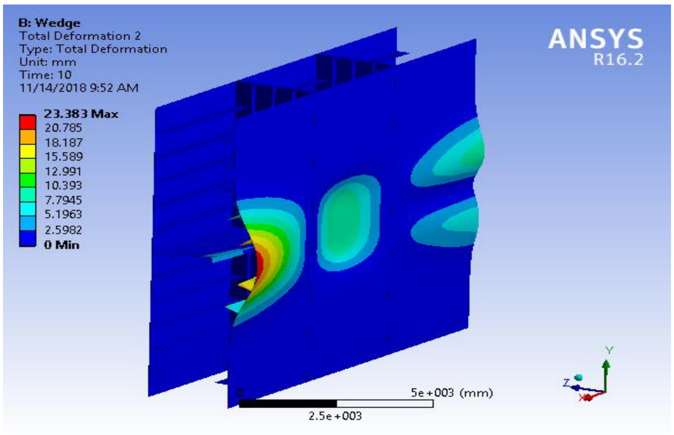

Fig - 7: Wedge end shaped bulbous bow

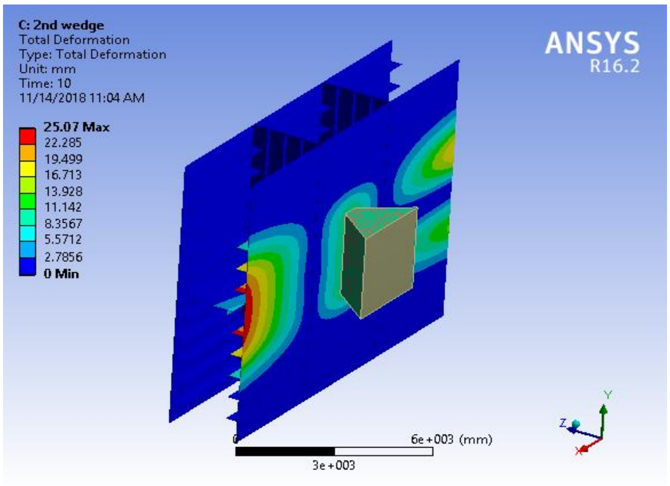

Fig - 8: Trapezoidal prism shaped bulbous bow

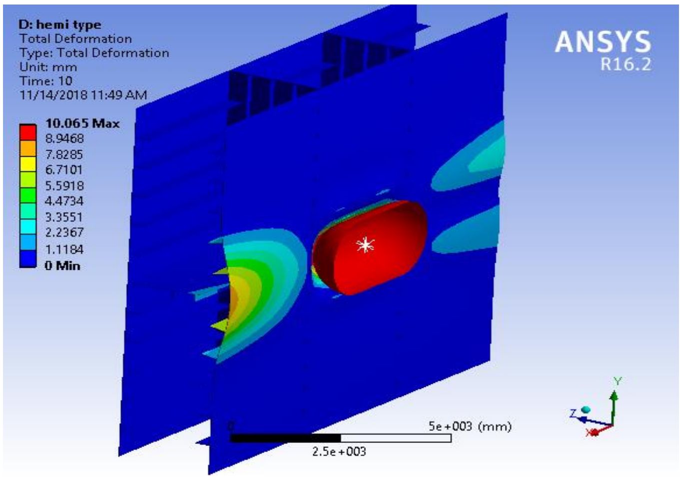

Fig - 9: Cylinder with hemispherical end shaped bulbous bow

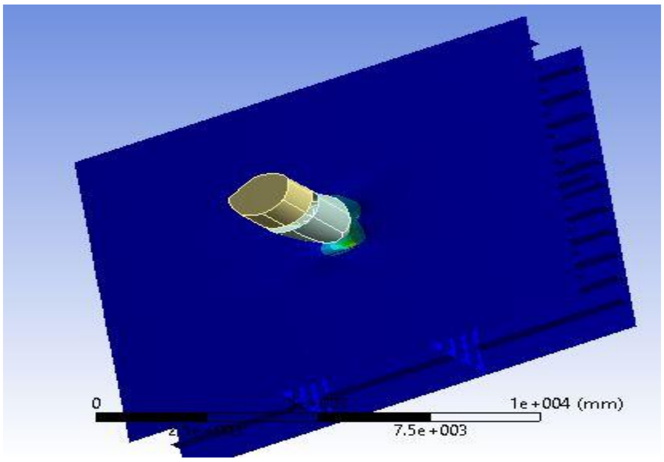

Fig - 10: Actual bulbous bow

6. RESULTS AND DISCUSSION

The specimens were analyzed using finite element analysis in ANSYS workbench. The results of the finite element analysis are included in this chapter. After analyzing the specimens, the deformations at each and every load were obtained from ANSYS. The maximum deformation of the different shaped bulbous bow is taken into account to determine the effective shape of bulbous bow. The comparison of the different shaped bulbous bows is shown in the Fig 11 and the results shown in Table II.

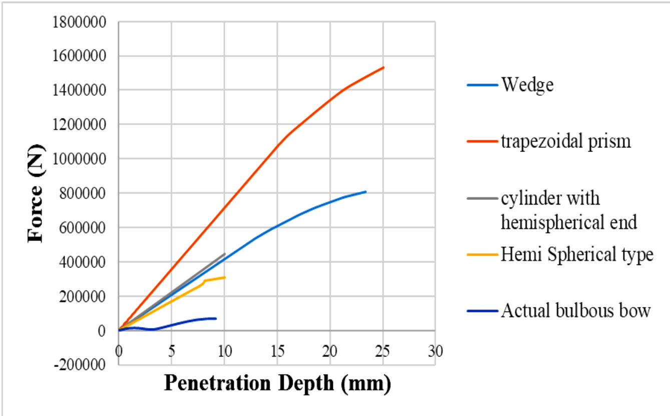

Chart -1: Comparion chart of force VS penetration depth

Table -2: MAXIMUM PENETRATION DEPTH

Bulbous Bow Shapes	**Maximum Penetration Depth in mm**
Hemispherical	10.00
Wedge	23.383
Trapezoidal prism	25.07
Cylinder with hemispherical end	10.065
Actual bulbous bow	9.168

Penetration depth for both the hemispherical end shaped bulbous bow and cylinder with hemispherical end shaped bulbous bow is comparatively lesser and similar with respect to actual bulbous bow penetration depth. From these graphs it is very clear that the circular shaped bulbous bow is the specimen that carries minimum penetration depth. This is because of circular sections has lesser penetration during collision with double hull structure. And also, circular columns are symmetric about any centroidal axis. The least deflection carrying both the hemispherical and cylinder with hemispherical end shaped specimen Hence these two shapes are selected for further studies.

7. MODEL

For the further studies the collision angle is change to 30^0,60^0,120^0, and 150^0 degrees to determine most severe collision angle from the selected bulbous bow collision.

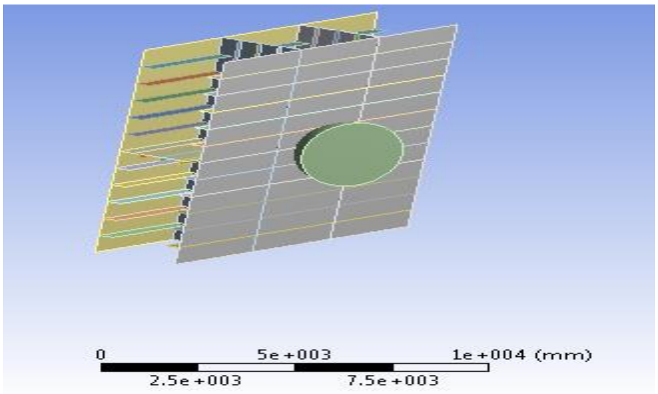

Fig - 11: Model of hemispherical end shaped bulbous bow under 30⁰

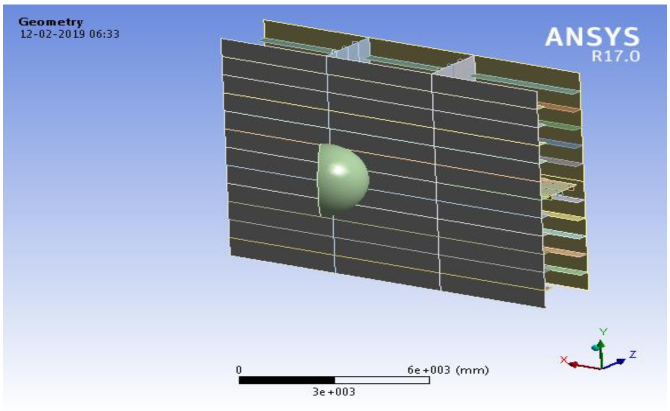

Fig - 12: Model of hemispherical end shaped bulbous bow under 60⁰

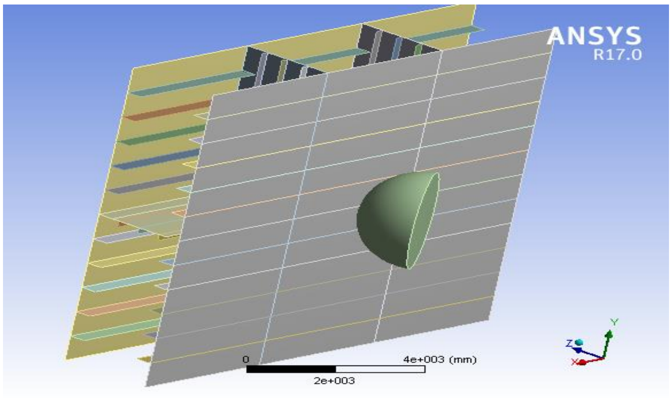

Fig - 13: Model of hemispherical end shaped bulbous bow under 120⁰

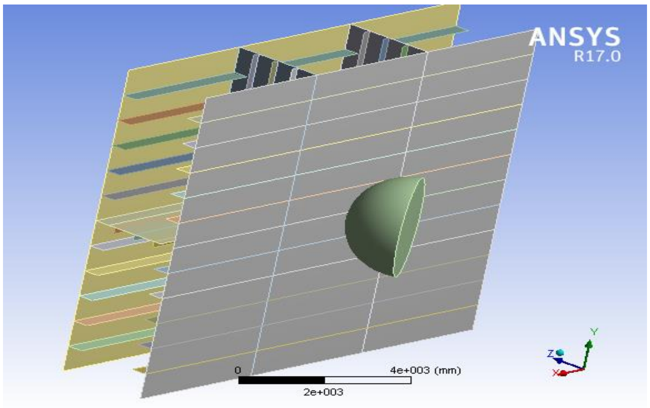

Fig - 14: Model of hemispherical end shaped bulbous bow under 150⁰

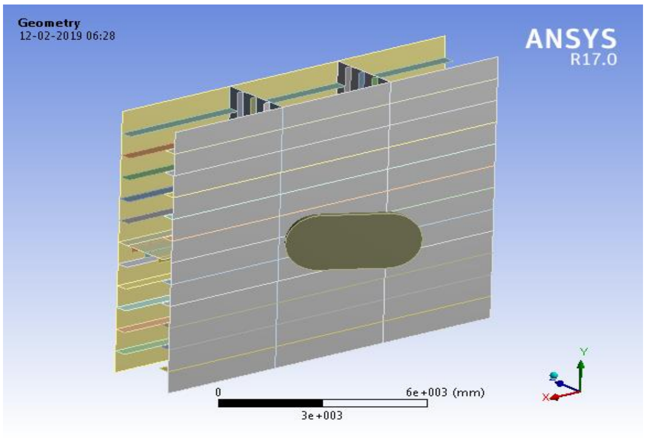

Fig - 15: Model of cylinder with hemispherical end shaped bulbous bow under 30⁰

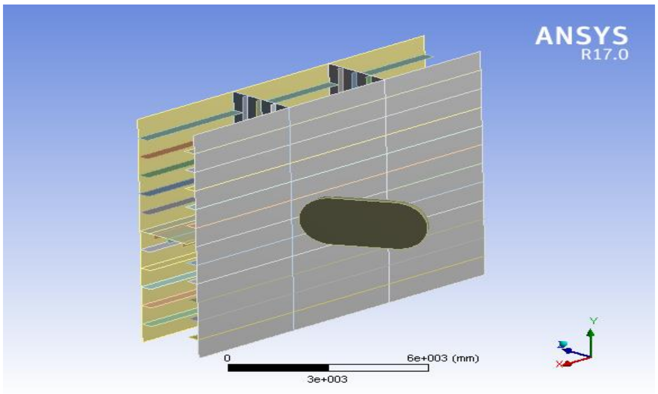

Fig - 16: Model of cylinder with hemispherical end shaped bulbous bow under 60⁰

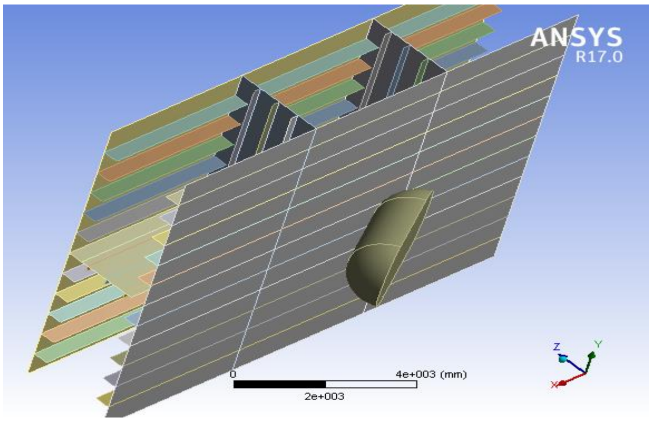

Fig - 17: Model of cylinder with hemispherical end shaped bulbous bow under 120^0

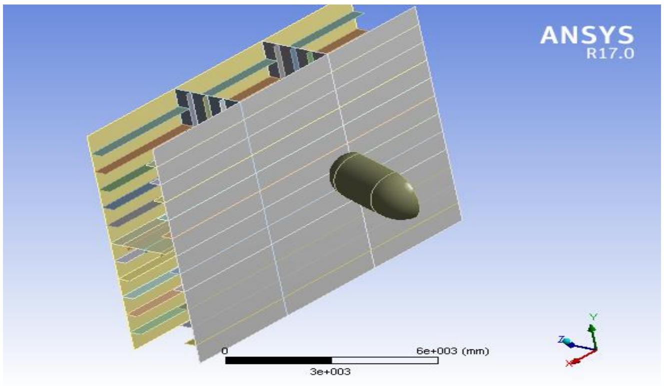

Fig -18: Model of cylinder with hemispherical end shaped bulbous bow under 150^0

8. ANALYSIS

For the study, transient dynamic analysis is performed for all the models. Impact loading is providing at a speed of 2m/s. Load is applied as displacement according to displacement convergence method. Penetration depth is studied. The deformation diagram obtained for hemispherical bulbous bow, and cylinder with hemispherical end shaped bulbous bow under different collision angles were shown below.

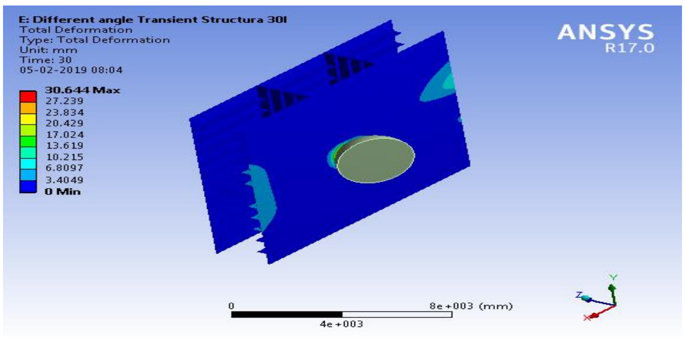

Fig -19: Hemispherical end shaped bulbous bow under 30^0

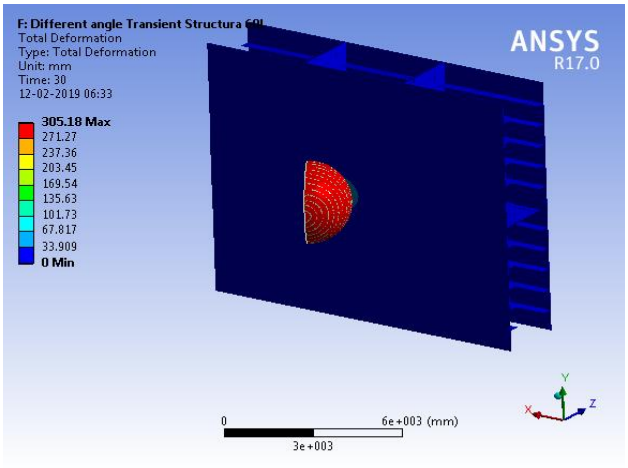

Fig - 20: Hemispherical end shaped bulbous bow under 60^0

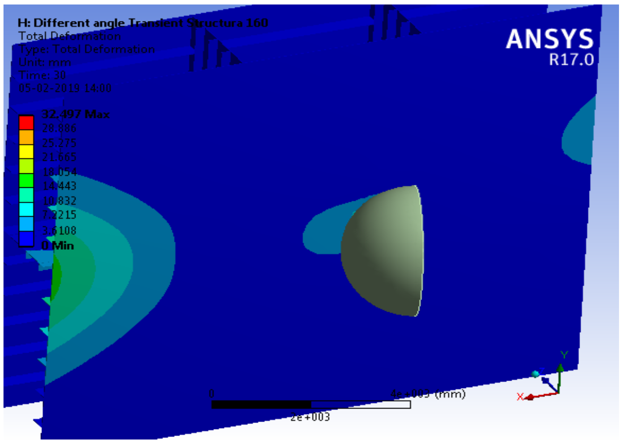

Fig -21: Hemispherical end shaped bulbous bow under 120^0

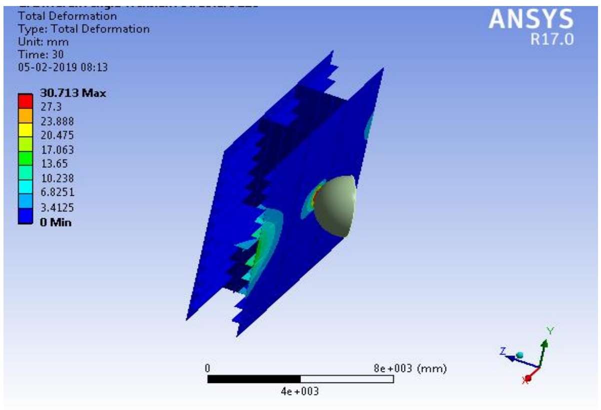

Fig -22: Hemispherical end shaped bulbous bow under 150^0

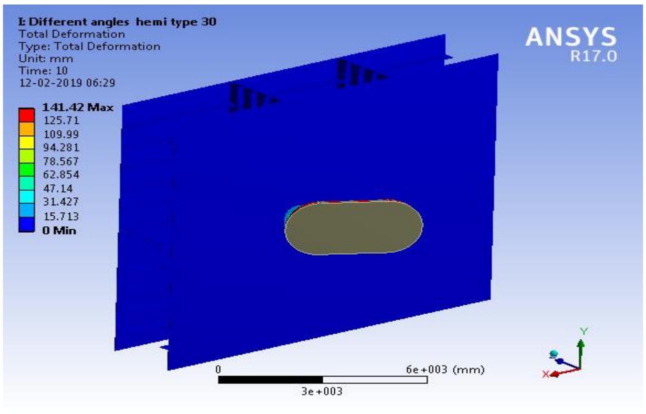

Fig -23: Cylinder with Hemispherical end shaped bulbous bow under 30^0

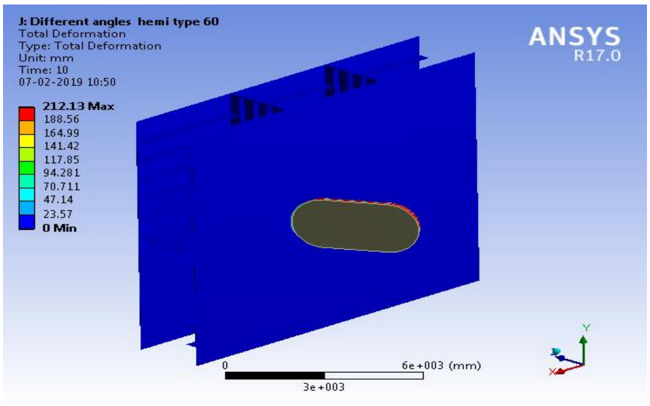

Fig - 24: Cylinder with Hemispherical end shaped bulbous bow under 60^0

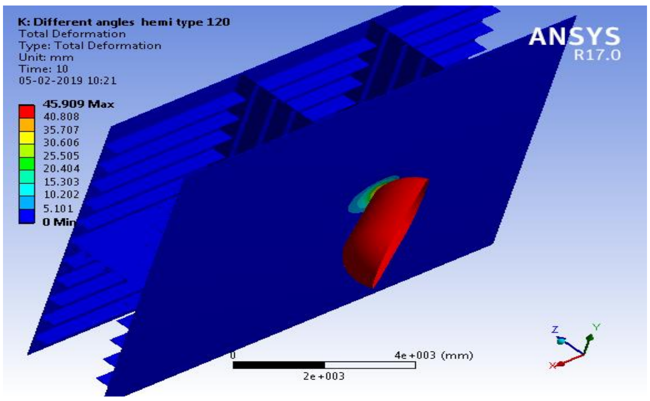

Fig - 25: Cylinder with Hemispherical end shaped bulbous bow under 120^0

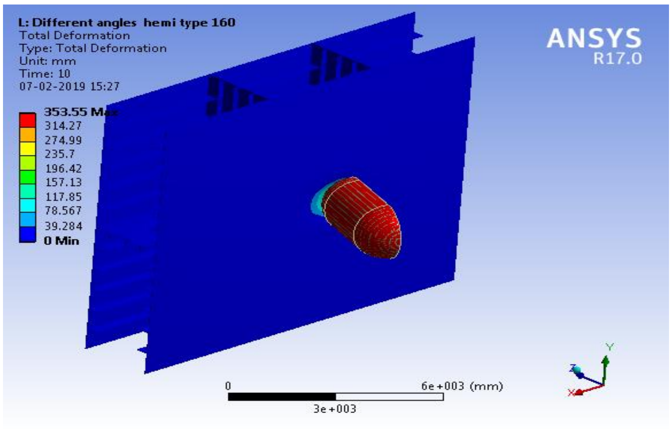

Fig - 26: Cylinder with Hemispherical end shaped bulbous bow under 150^0

9. RESULTS AND DISCUSSION

The specimens were analyzed using finite element analysis in ANSYS workbench. The comparison of hemispherical and cylinder with hemispherical end shaped bulbous bow collision with double hull structure under 30^0,60^0,120^0,150^0 degrees is analyzed. The maximum penetration depth of the hemispherical and cylinder with hemispherical end shaped bulbous bow under different collision angle is taken into account to determine the most severe collision angle. The comparison of the different collision angle of hemispherical and cylinder with hemispherical end is shown in the Chart .27 and Chart .28 and the results shown in Table 3.

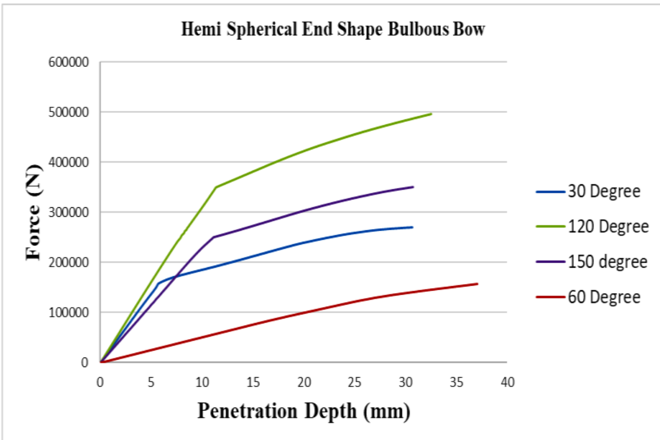

Chart -2: Comparion chart of force VS penetration depth

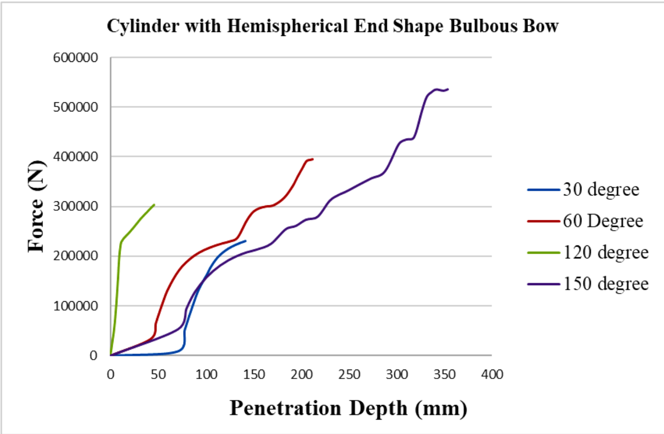

Chart -3: Comparion chart of force VS penetration depth

Table -3: MAXIMUM PENETRATION DEPTH

	Hemi Spherical End Shape Bulbous Bow	**Cylinder with Hemispherical End Shape Bulbous Bow**
	Maximum Penetration Depth in mm	
30^0	30.644	141.42
60^0	37.04	212.13
120^0	32.497	45.909
150^0	32.497	353.55

From these graphs it is very clear that the circular shaped bulbous bow is the specimen that carries minimum penetration depth. This is because of circular sections has lesser penetration during collision with double hull structure. And also 60^0-degree angle of hemispherical end shows maximum penetration depth hence it is the most severe collision angle and 150^0-degree angle of cylinder with hemispherical end shows maximum penetration depth hence it is the most severe collision angle.

10. CONCLUSIONS

Double hull structures subjected to collision with four different shaped bulbous bows are modeled and analyzed. Then the better performing bulbous bows are selected as compare with actual bulbous bow. Analysis of double hull structure under different collision angle is completed. Some of the conclusions obtained from the analysis are as follows.

- Penetration depth due to hemispherical shape bulbous bow and cylinder with hemispherical end is lesser and also similar to actual bulbous bow as compared to the wedge and trapezoidal prism shape bulbous bow.
- Hence the better performing bulbous bows are hemispherical shape bulbous bow and cylinder with hemispherical end.
- Results shown that double hull structure possess better impact resistance towards the hemispherical and cylinder with hemispherical end as compared to the wedge shape and trapezoidal prism shape.
- From this analysis the most severe collision angle is obtained.
- Most severe collision angle possess maximum penetration depth.
- Hence the most severe collision angle for hemispherical end shaped bulbous bow is 60 degrees and 150 degrees for cylinder with hemispherical end.

The study can be extent with the L profile stiffener section under these severe collision angle. Also, the penetration depth, impact resistance and internal energy dissipation can be analyzed.

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BIOGRAPHY

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