International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-1S2, May 2019

Structural Response of Free – Fall Lifeboats During Emergencies

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***Abstract*: A lifeboat is a small floating structure released from ships during an emergency for the rescue of people onboard. This task is accomplished by dropping the structure from a predetermined height (drop height) and inclination (fall angle). The structure is now a freely falling body under the influence of gravity with the bow pointed down. The beginning of the lifeboat's trajectory includes an initial flight in air followed by its diving in water and then emerging out of water under the buoyancy effects. During sudden impact on the surface of water, large slamming loads act on the structure, especially at the bow. Slamming is of great concern as it results in severe structural damage of the bow as well as its supporting frames and scantlings. The study of slamming involves an interaction between the structural components of the lifeboat and the fluid load on the hull. Bow impact is a salient feature since high accelerations are exerted upon the lifeboat when it first hits the water surface during its water entry phase. In the present study an approach for the design of a typical life boat is presented. Fluid pressure on the bow has been estimated using a computational fluid dynamics (CFD) approach coupled with a six degree of freedom (6DOF) solver. A user defined function (UDF) has been written in C language and has been complied within the solver for accomplishing the body motions. Geometric modeling and meshing have been carried out using ANSYS ICEM CFD and FLUENT has been used as the solver. The impact peak pressure has been applied at the bow and a 3D structural analysis has been performed initially at the bow region of the bare hull without scantlings and later with scantlings. The results seem to provide guidance for the design modifications in terms of scantling dimensions.**

***Index Terms*: Lifeboat, slamming, bow impact, buoyancy, scantlings, hull.**

I. INTRODUCTION

The most common understanding of a lifeboat is a small or infallible raft structure used for emergency evacuation. Free-fall lifeboats represent an evident improvement in safety over conventional type lifeboat systems. Conventional lifeboats are the one which are lowered with the help of ropes, pulleys or other means of lowering systems. When conventional lifeboats are lowered into the sea, it is sometimes difficult for the lifeboats to move away from the parent vessel or from the distressed vessel because high sea current and wind continually returns the lifeboat back to the parent vessel. The return of lifeboat back to its parent vessel can also be due to the malfunctioning in the propulsion system. During its launch, the lifeboat may impact the sides of the distressed vessel, become severely damaged, and the occupants may fall into the sea suffering injury and even death. This situation is even more dangerous during a fire. By the application of kinetic energy the lifeboat propels away from the distressed vessel during and after water entry. Free fall height ranges from six meters on smaller ships to over 30 meters on drilling platform. Fig.1 shows a life-boat about to be launched.

Fig.1Figure showing free-fall lifeboat placed on its launching rail

Calculation of realistic design loads is challenging in the case of free – fall lifeboat. Experimental calculations are time consuming and expensive. CFD (Computational fluid dynamics) provides a platform for performing simulations in all stages, where the impact pressures are clearly depicted so that portion incapable of overcoming these impact pressures especially bow region and the hull are studied in detail.

An investigation of launching parameters was carried out by Ahmed Fauzan Zakki et. al using penalty coupling algorithim method. Determination of wind forces and moment coefficients was carried out by Vicki. L. willis. A theortical model was derived for all the stages of the launch of a FFLB in Boef, W.J.C. 1992 in PART I. Discussed about impact theory of cylinder and equations were derived. In part II Boef, W.J.C. 1992 evaluated the effects of impacts on occupants. Dynamic response of lifeboats suspended by cables was studied by Magulta et al. Influence of high speed impact was also studied using linear – elastic and non linear beam models, also with non linear transient dynamic finite element analysis. Studies were also

Revised Manuscript Received on December 22, 2018.
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carried out in wedge shaped sections for slamming and planning by T. Tveitnes et al., 2008. Forces on wedge were calculated using constant water entry and water exit. Experimental studies were carried out on flat plates impact loads by M. Nikfarjam et al., 2017. An investigation was carried out by M. Tenzer et al., 2016 so as to provide an experimental data used to validate numerical tools. Studies were also carried out for davit launched lifeboat systems in all the stages beginning from lowering to that of sail away phase by Ole Gabrielsen. et al., 2011.

Lifeboat undergoes various phases in air as well as in its diving in water. Free – fall phase, water entry phase, re - emergence phase are most crucial phases since the structure undergoes large slamming forces. Slamming forces are of great concern because pressures act continuously on the lifeboat when it passes through various phases of its trajectory. In this paper, 2D Transient CFD simulations have been carried out for studying the impact pressure on the body. After getting the deformations from the impact pressure, scantlings of suitable thickness have to be designed and provided so as to resist the pressure which causes hull damage and collapse. Deformations on a bare hull are studied with these impact pressures and then scantlings of suitable thickness are provided.

SLAMMING PHENOMENON

The lifeboats stern (aft) portion and the bow portion may emerge from a wave and re – enter the wave with a very high impact. This will develop very high successive hydrodynamic loads on the structure. Very high pressure peaks are experienced by the hull of the ship due to this impact i.e. the impact between the hull of the boat and the water surface (slamming phenomenon). The effect of hull slamming on water surface is shown in Fig.2.

Fig.2 Figure showing the slamming effect of free-fall lifeboat.

There are many types of slamming loads such as bow flare slamming, bottom slamming, stern slamming, green water and bow impact loads. These loads have transient behavior and hence cause severe structural damages. Relatively high velocity occurs between the free surface of incompressible fluid and the hull portion and because of this the magnitude, rise time, duration of theses loads changes widely. The dynamic response of the hull structure is affected strongly because these transient impact loads are highly non – linear. Thus for a structural design purpose the magnitude of these impact loads and pressure is important. The following factors should be taken into consideration.

1. Intensity and duration of impact pressure.
2. Spatial distribution and duration of impact.
3. For strength assessment equivalent static pressure is needed.
4. Determination of scantlings.
5. Geometry of bow and stern.

In cases where the lifeboat is subjected to bow flare slamming loads, the side plating of the bow is subjected to a great impact as it is rapidly immersed into water. As a result of this, a large fluid pressure covers comparatively larger impact area. There are two types of bow flare impact pressure a) Non impulsive pressure b) Impulsive pressure. The magnitude of non-impulsive pressure is directly to the submergence whereas the magnitude of impulsive pressure rises rapidly and decays with time.

PHASES OF LIFEBOATfall AND ITS PHYSICS

The full journey of free - fall life boat is divided into different phases. The body interacts with different fluids, enters the water with high velocity, submerges and then re- emergence overcoming the buoyant forces. The entire trajectory is divided into several phases known as free–falling phase, water entry phase, submerged phase, re-emergence phase, and ascending phase. Main studies are concentrated on the water entry phase, submergence, and re-emergence phase and ascending phase. Various phases in the lifeboat fall is shown in Fig. 3.

a) LAUNCHING PHASE: Before lifeboat is launched it rests on a launching skid of the parent vessel. Several launching mechanisms are available. Among them releasing hook is the most common one. When the hook releases the lifeboat, it slides along the rail or the launching skid driven by the gravitational and frictional forces. When it rails and comes in contact with the end of the skid, the major part of the body will be freely falling while the aft portion of the lifeboat will be in contact with the skid.This will generate a rotation known as the rotation phase which will affect the water entry phase of the lifeboat. If the velocity with which the lifeboat slides down is greater, then the rotation will be smaller. If the velocity is smaller than the rotation will be greater.

b) ROTATION PHASE: Rotation phase starts when the lifeboat is at the end of

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the launching skid. Gravity force, frictional force parallel to the launch rail and a force normal to the rail are the main forces governing this phase. The reactive force on the launch rail and the weight of the boat together forms a couple. This couple creates a tendency which will make the lifeboat to rotate as it slides off the skid.

c) FREE- FALLING PHASE: Free – falling phase starts when the lifeboat is no longer in contact with the skid. Here the normal reaction force = 0. Main factors which affect the free – falling phases are the initial velocity from the skid, rotation, air resistance, skid plane angle, wind loads and also the launching height. The only forces acting are the gravity and wind force.. Air drag is considered in cases of large drop height. When the lifeboat is moving slowly and when it is at the end of the skid, there will be large variation in the angle of release. This angle has got great influence in the water entry phase of the lifeboat.

d) WATER – ENTRY PHASE: Hydrostatic and hydrodynamic forces are the force which acts upon the lifeboat during the water – entry phase. It is very interesting to know that two types of impact take place during this phase. The first one known as the bow impact arises when the lifeboat first hits the water surfaces. High accelerations are experienced by the bow of the boat. And the moment produced at the rotation phase gets reversed by the couple produced by the combination of weight of the lifeboat and the fluid forces. This reversed momentum reaches the stern (backside) portion of the lifeboat causing another impact called the stern impact.

e) WATER – EXIT PHASE: The phase in which the lifeboat leaves the water. It overcomes its buoyant forces and will proceed to its positive headway.

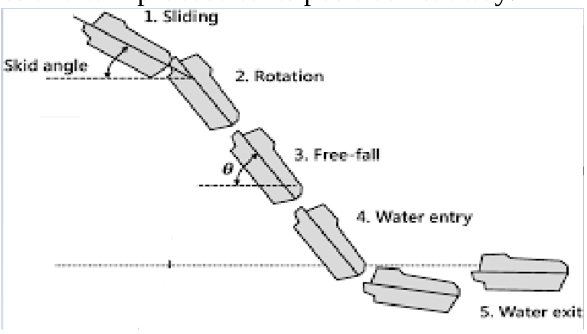

Fig.3 Figure showing the various phases of free-fall lifeboat

IV. NUMERICAL METHOD

Modeling involved a 2D creation of lifeboat. The lifeboat is developed from the lines plan of Hyundai Company. And the surrounding fluid domain is also created. The fluid domain implies the water surface around the body. The domain is 10L from the outlet and 10L from the inlet. The total length of lifeboat is 17.7 m and has a width of 4.151m is used in the numerical simulation. The body is assumed to be placed at 35 m from the sea level and it is modeled at an angle of 450. Each of the sides was named as inlet, outlet, top, bottom and these sides assigned for estimation purpose. The partial differential equations that govern fluid flow and heat transfer are not usually amenable to analytical solutions except for every simple case. Here for the analyses of fluid flow generated, the fluid domains must be sub divided into smaller and smaller domains.

Each sub domains are solved by descretizing the governing equations. The sub domains are so called elements or cells, and the collection of all elements or cells is called a mesh or grid. The process of obtaining or collecting proper grid is called grid generation or mesh generation. The most basic form of mesh classification is based upon the connectivity of the mesh whether it is structured or unstructured. The moving fluid zone including rectangular body is allowed to rotate by moment of hydrodynamic force acting on the body whereas the stationary fluid zone is fixed. The lifeboat has got a mass of 15000 kg. The boat is tilted at an angle of 450 and minimum mesh of 50 mm and a maximum mesh of 550mm is used. The model and the mesh of the domain in shown in Figs. 4 and 5.Table.1 depicts the boundary conditions given for the sea domain as well as for the lifeboat. Sea domain has been provided with an inlet, outlet, top and bottom. Inlet has been described as velocity inlet, outlet and top as pressure outlet, bottom as symmetry, lifeboat and overset as wall and overset. These conditions are input in fluent for solving.

Fig.4 Modeled Sea Domain

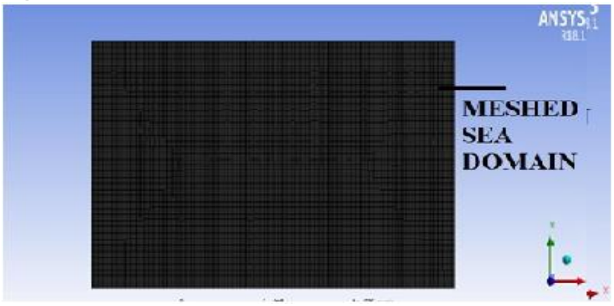

Fig.5 Meshed Sea Domain

Structured mesh is

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characterized by regular connectivity that can be expressed as two or three dimensional array. This restricts the element choices to quadrilateral in 2D or hexahedra in 3D.The regularity of the connectivity allow us to conserve space since neighborhood relationships are defined by the storage arrangement.

An unstructured mesh is characterized by irregular connectivity which cannot be readily expressed as a two or three dimensional array in computer memory. Compared to structured meshes, the storage requirements for an unstructured mesh is so large that neighborhood connectivity must be explicitly stored. Six degrees of freedom udf file was compiled so as to capture the motion of the body in each and every second when penetrated into the water that's to understand the fluid-structure interaction.

Necessity of overset grid

Overset grid also known as chimera grid or overlapping grid. This type of meshing is useful in cases where large relative motion occurs between components. It eliminates remeshing and smoothing. Mainly used for different bodies with the domain of interest. Overset meshing is a new method that allows to create a mesh set on the top of another one. The result will be calculated by the transfer of data at the boundaries of the overlapping mesh sets. An overset is provided around the lifeboat. A circular overset of diameter 25m is provided and is shown in fig.6. Figure 7 shows the meshed overset around the lifeboat.

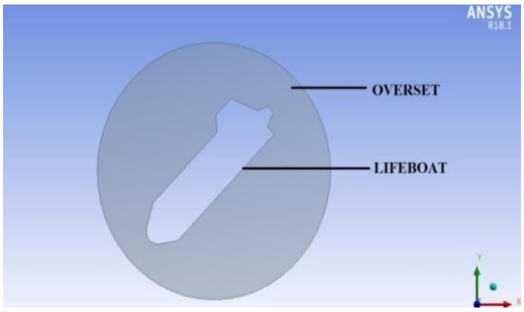


Fig.6 Overset provided around the lifeboat

Fig.7 Meshed overset

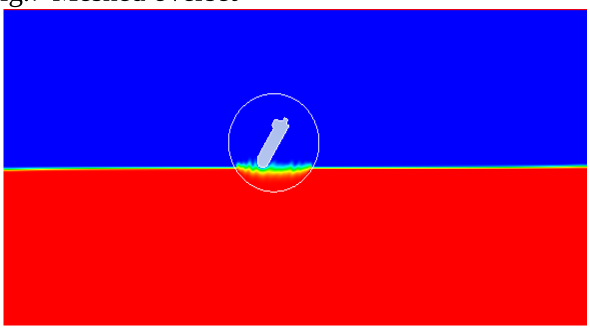
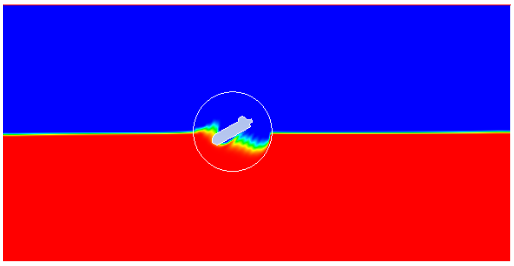


Fig.8 Simulations of water entry of lifeboat



.Fig.9 Simulations of submergence of lifeboat.

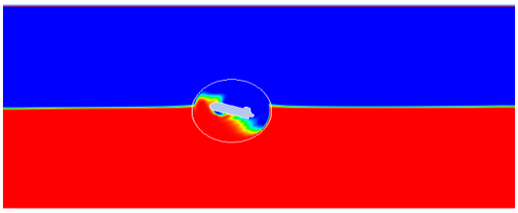


Fig.10 Simulations of emergence of lifeboat.

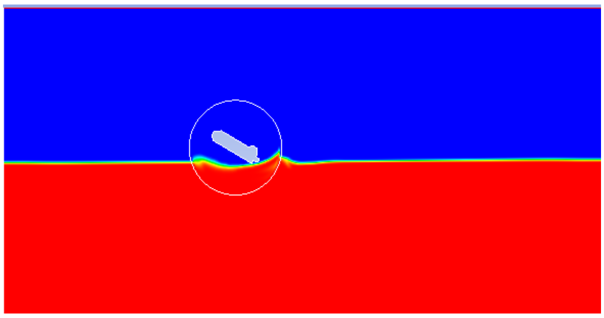


Fig.11 Simulations of lifeboat jumping in air.

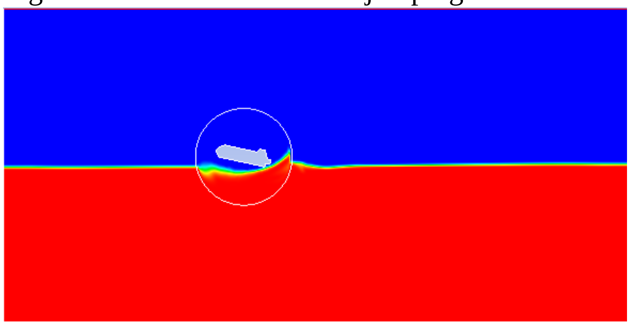


Fig.12 Simulations of lifeboat about to stabilize.

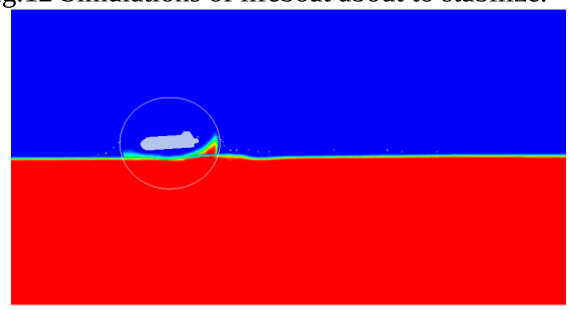


Fig.13 Simulations of lifeboat in its ascending phase.

Simulations are carried out in Fluent. All the stages are clearly depicted. The free – fall phase and water entry phase of a free fall lifeboat is shown in fig. 8. Fig. 9 and 10 shows the submergence and the re – emergence of free – fall lifeboat. The jumping of free – fall lifeboat in air is clearly captured in fluent. Slamming phenomenon occurs at the stage of

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submergence and re emergence. Maximum pressures are plotted and are shown in figure 14 and 15. Table 2 represents pressure points.

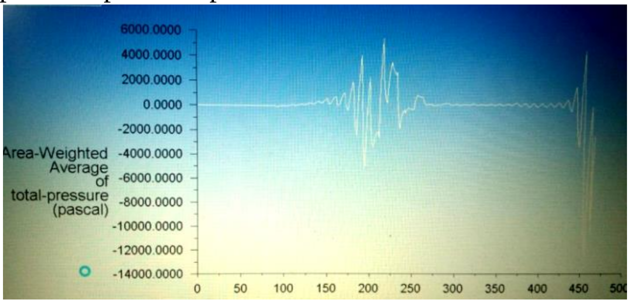

Fig.14 graph showing pressure values.

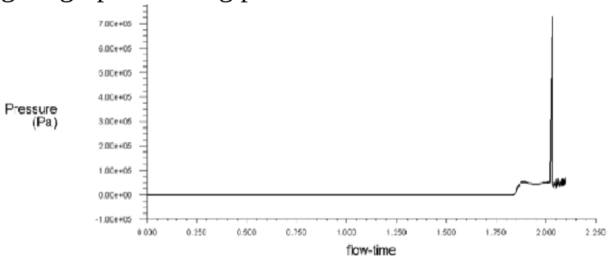

Fig.15 graph showing maximum pressure values

Table 2. Pressure Points

SL.NO	FLOW TIME (s)	PRESSURE (Pa)
1.	0.9	1x103
2.	1.05	-1x103
3.	1.1	2x103
4.	1.15	-3x103
5.	1.2	4 x103
6.	1.29	-4 x103
7.	1.35	6 x103
8.	2.125	7x107

V. STRUCTURAL ANALYSIS

Structural analysis helps in predicting the effect of loads in structures. Helps to develop a structure which will withstand all loads and deformations throughout its design life. Structural analysis forms basis of structural design. Finite element method is used for structural analysis. The hull is taken and developed for the analysis.

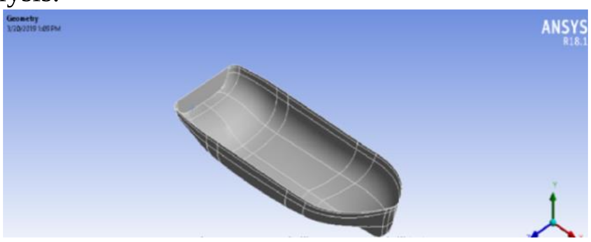

Fig.16 Modeled 3d lifeboat hull

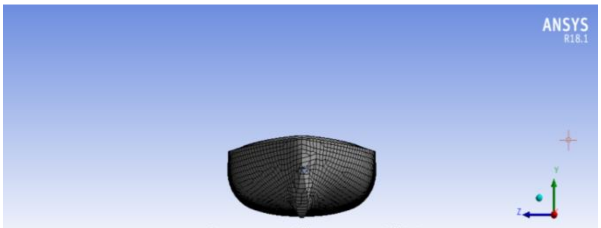

Fig.17 Meshed 3D lifeboat hull

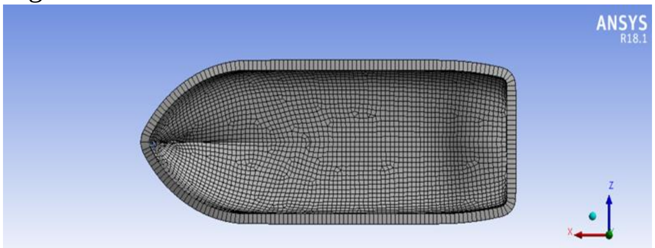

Fig.18 Meshed inner part of a 3D lifeboat hull

Transient structural analysis is carried out. Total deformation and corresponding stresses are analyzed. Lifeboats hull is modeled in ANSYS Workbench. Material used is CFRP (Carbon fiber reinforced polymer).Carbon fiber reinforced polymer materials reduces the overall weight. Carbon fiber reinforced polymers are specially used for the construction of lifeboats. The model is meshed and has given fixed end support at one end. Deformations at the bow part are clearly depicted. Structural analysis is carried out in ANSYS Workbench. 3D model is modeled and is imported to ANSYS workbench for structural analysis. Dynamic response of both bow (during bow impact) and hull slamming (During emergence and re – emergence) are founded out by ansys workbench (transient structural).

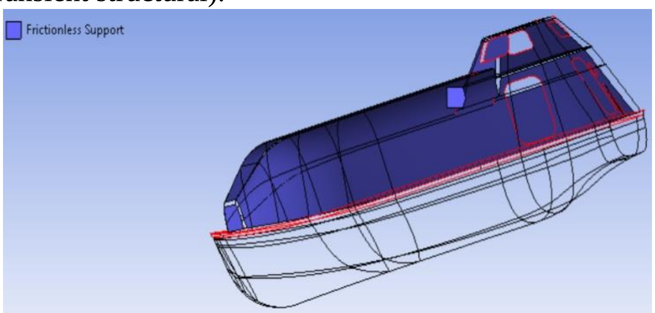

Fig.19 Frictional less support condition given at the canopy of lifeboat.

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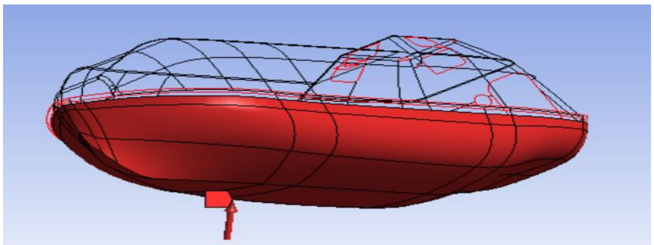

Fig.20 Pressure applied at the hull portion.

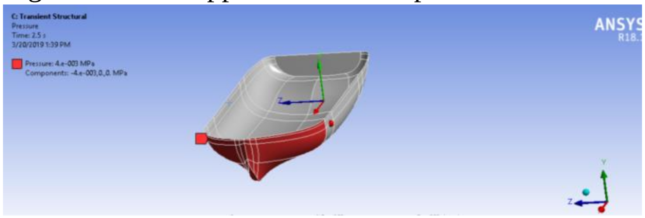

Fig.21 Pressure applied at the bow portion.

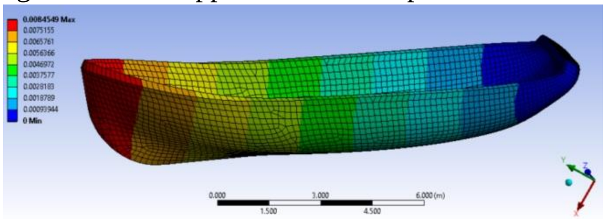

Fig.25 Total deformations at the bow and hull

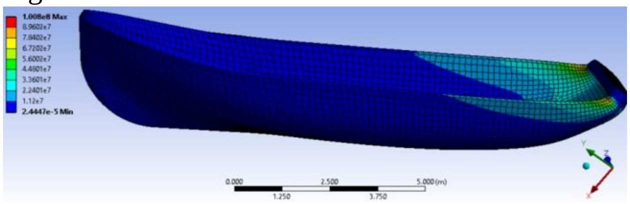

Fig.26 Equivalent stress at bow

VI. CONCLUSIONS

The sudden impact pressure of lifeboat during its water entry phase is obtained. Deformations in air water interface are captured and structural behavior at the bow portion and that of hull of free fall lifeboat (FFLB) is clearly depicted. Maximum deformation obtained 0.0068 m.

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