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Design and Analysis of Acrylic Paneled Rectangular Towing Tank

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ABSTRACT: *In ship design, knowing drag resistance coefficient of a ship in the design phase is very important in proper calculation of the required propulsion power. Using rectangular towing tank and a scale model of the proposed designed ship is an important step to calculate the drag resistance coefficient where the scale model is towed in the tank and drag force calculated using load cells. In some cases using a transparent wall towing tank is important in order to monitor the model behavior during the drag test. In order to achieve a clear side view of the model during test a glass or acrylic wall towing tank is suitable in such situation. Glass is not considered unless it treated to absorb impact and side wall fluctuation due to water sloshing during the test. Acrylic wall has some advantage over glass wall as acrylic material is mush ductile than glass one. In this design of transparent wall towing tank acrylic wall is used. To avoid large deflection in the acrylic walls due to lateral pressure of the water, stiffeners are introduced in the design. Comparison of different cases of the stiffeners is carried out and results of these analysis are discussed later in this paper.*
Keywords: *Towing Tank, tank stiffener and transparent acrylic tank*

I. INTRODUCTION

The most comprehensive assessment of power requirements for a new ship is obtained by conducting experiments with a model hull in a towing tank. Traditional ship model tests provide still more accurate predictions of ship performance than existing computational fluid dynamics (CFD) methods can deliver. Various tests are performed to evaluate ship resistance, propulsion, maneuvering and seakeeping of all the types of hull forms. Towing tank may be constructed by regular foundation and concrete walls or by frame structure. To enable clear vision of the towed model, the walls of the tank have to be transparent. Glass is known as transparent material but it is of high density and more brittle than acrylic.

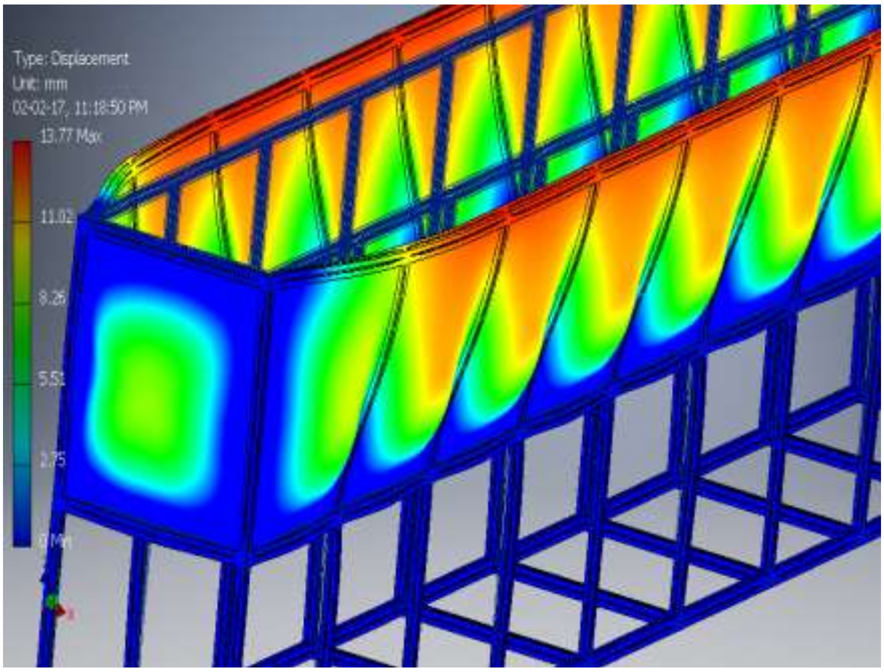


Fig. (1) Non-stiffened tank deflection (magnified 20 times)

Fig. (1)Shows the deflection of a non-stiffened tank, the displacement plot is magnified twenty times to show the way the acrylic panel and tank frame structure deform. Large deflection will increase the stress of the structure also it will affect acrylic panels sealing and hence a general damage of the towing tank [1].
In this study, a frame structure with acrylic panels towing tank is designed and different stiffing methods are introduced in order to maintain acrylic deflection as minimum as possible to avoid failure of the sealed material due to high deflection of non-stiffened walls.

II. DESIGN OF A RECTANGULAR TOWING TANK

The proposed towing tank designed as arectangular in cross section, 12m long, 1m wide, with a normal water depth of 0.8m as shown in Fig. (2). the size of the tank limits the length of ship models and the average drag speed to avoid tank crash. Tank frame structure is made of Al.6061 with ultimate tensile strength of 276 MPa [2].

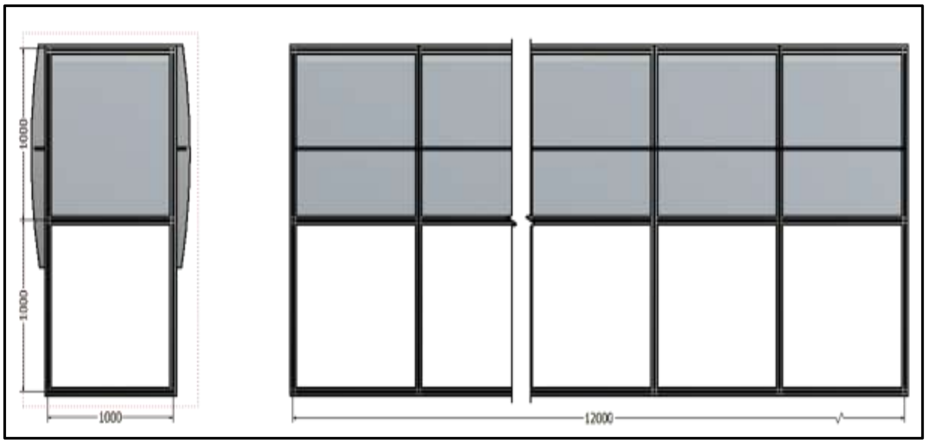


Fig.(2) Tank dimensions

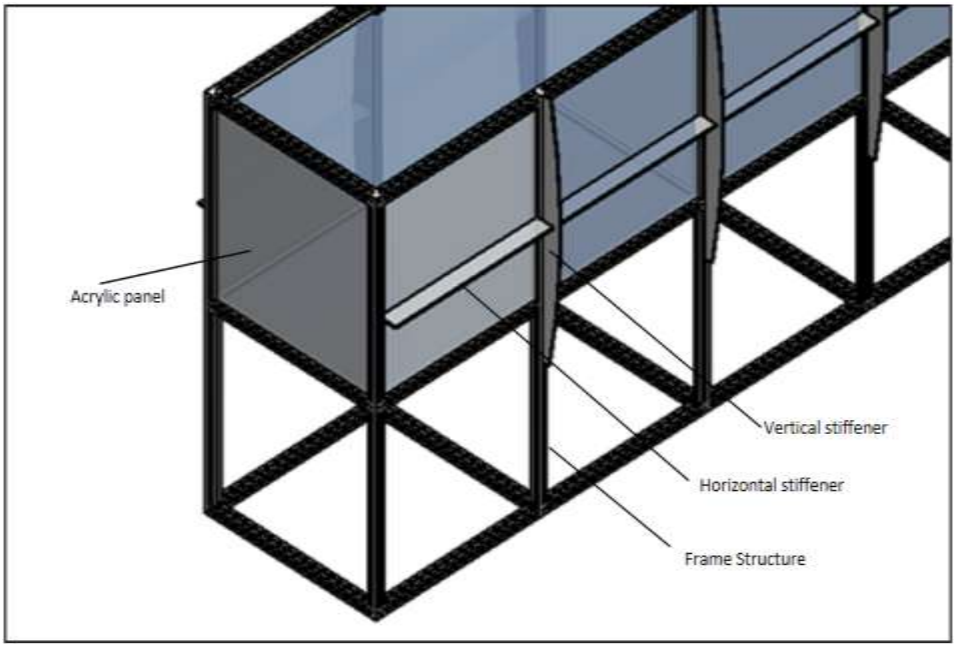


Fig. (3) Tank layout

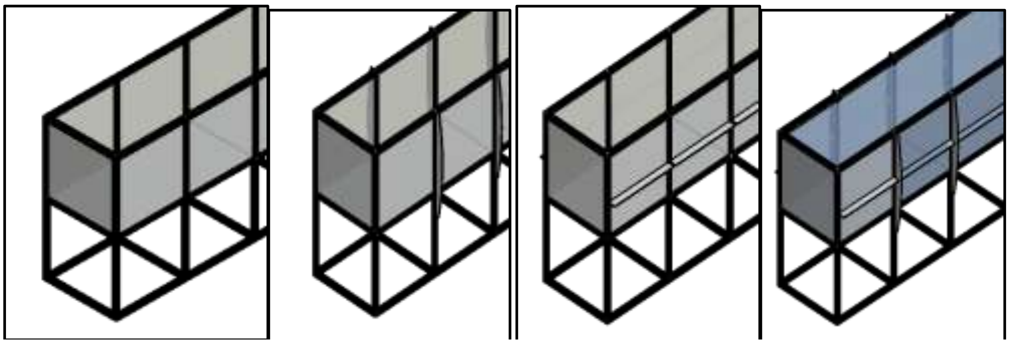
Fig. (3) Illustrates tank layout includes acrylic panels and stiffeners. The safe model drag speed is 8 knot. To enable monitoring of the test model; tank walls is designed from Acrylic sheet panels of 1m wide, 1m high and 8mm thickness. The ultimate strength of the used acrylic panels is 62 MPa [3]. By means of the acrylic panels the underwater portion of a model may be photographed; also, the shape and size of the waves generated during the drag test may be observed and photographed as shown in Fig.(4).The tank bottom is essentially leveled to facilitate water drain by time in the sake of tank maintenance. Tank bottom is made of aluminum sheets of thickness of 8 mm. the drainage system of the tank is designed such that water circulation can be applied to keep water fresh in the tank. This circulation is obtained by using closed water circle and introduce water pump in the circle. The pump also used to enable fast discharge of the tank for and emergency situation. From time to time an anti-algae compound is added to the water to reduce the organic matter.

Fig. (4) Transparent tank with Acrylic panels

The walls of Rectangular tank are subjected to bending moments both in horizontal as well as in vertical direction. The analysis of moment in the wall is difficult since water pressure results in a triangular load on them. The magnitude of the moment will depend upon the several factors such as length, breadth and height of tank, and conditions of the support of the wall at the top and bottom edge. If the length of the wall is more in compression to its height the moment will be mainly in vertical direction i.e. the panel will bend as a cantilever. If, however, height is larger in comparison to length, the moments will be in horizontal direction, and the panel will bend as a thin slab supported on the edges. The wall of the tank will thus be subjected to both bending moment as well as direct tension.

III. MATERIAL AND METHODS

Four cases of tank and acrylic panel stiffening are analyzed in this study; non-stiffened, vertical stiffened horizontal stiffened, and combined stiffened (horizontal and vertical stiffened) as shown in Fig.(5).



non-stiffened horizontal stiffened vertical stiffened combined stiffened

Fig.(5) Different cases of tank stiffening

During the design of non-stiffened tanks, are necessary to design as two– dimensional plates, under the liquid induced load, pressure above the liquid. Stiffened plates can be corrugated or trapezoidal and theseplates are designedto the same load as unstiffened plates.The design of unstiffened plates is derived according to the EN 1993-1-3 [4].Dimensioning of elements is carried out to bending in horizontal plane, where bending isthe result of pressure of the liquid which is acting perpendicular to the tank wall. In designit is necessary to consider the membrane tensile stresses occurring in the walls as a result ofhydrostatic pressure on the walls perpendicular to the wall that is being analyzed.

Static analysis of water tank normal carried out numerically [5, 6]. Finite element analysis using ANSYS solver is used to analyze the previously mentioned four cases of tank stiffening. The boundary condition of the model is such that ground support of the tank is restricted in vertical movement and one side of the model is restricted in horizontal movement. Atmospheric pressure is applied to water surface, Fig. (6).

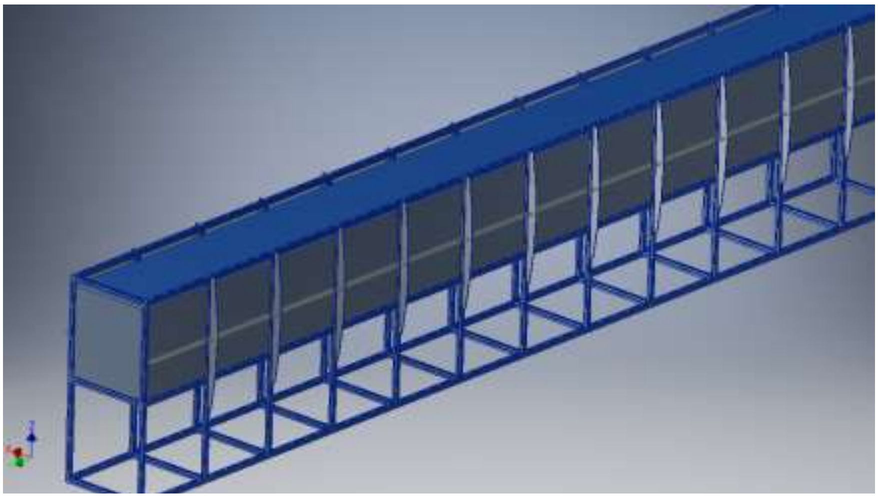


Fig. (6) Finite element model

The finite element model is in the order of 300,000 quadratic element. Contact between water and tank walls is set to be sliding with no friction. Finite element mesh for tank structure, acrylic panels and water is shown in Fig. (7). In each analysis case, the displacement plot is illustrated as an indication of the sealing effect and stress distribution over the frame structure and acrylic panel is plotted and discussed.

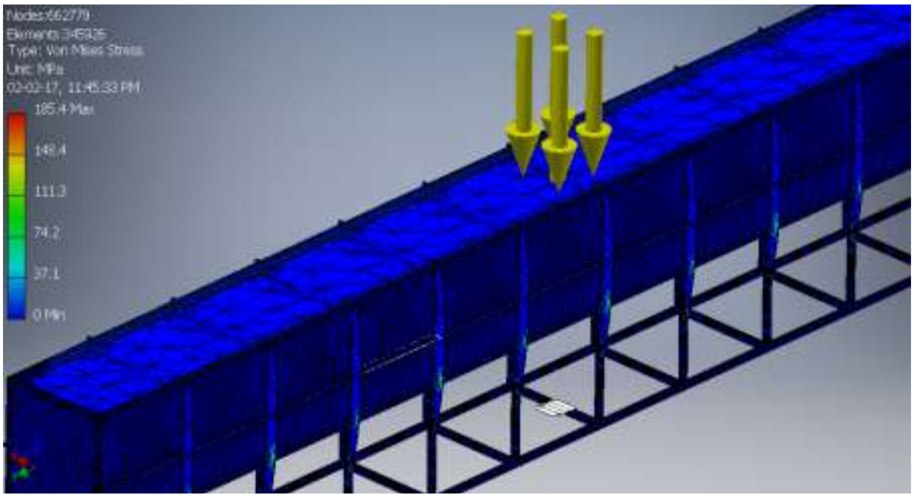


Fig. (7) Finite element model mesh

IV. RESULTS AND DISCUSSION

Case 1: Non-stiffened tank

Finite element analysis is carried out for a non-stiffened tank and the displacement plot is shown in Fig.(8). As shown in the figure the maximum displacement of tank walls is about 13 mm and the displacement at a three selected reference points are shown to be 10.76 mm, 6.96mm and 3.47mm. Displacement at the middle of the tank wall acrylic panel is in the order of 11mm.

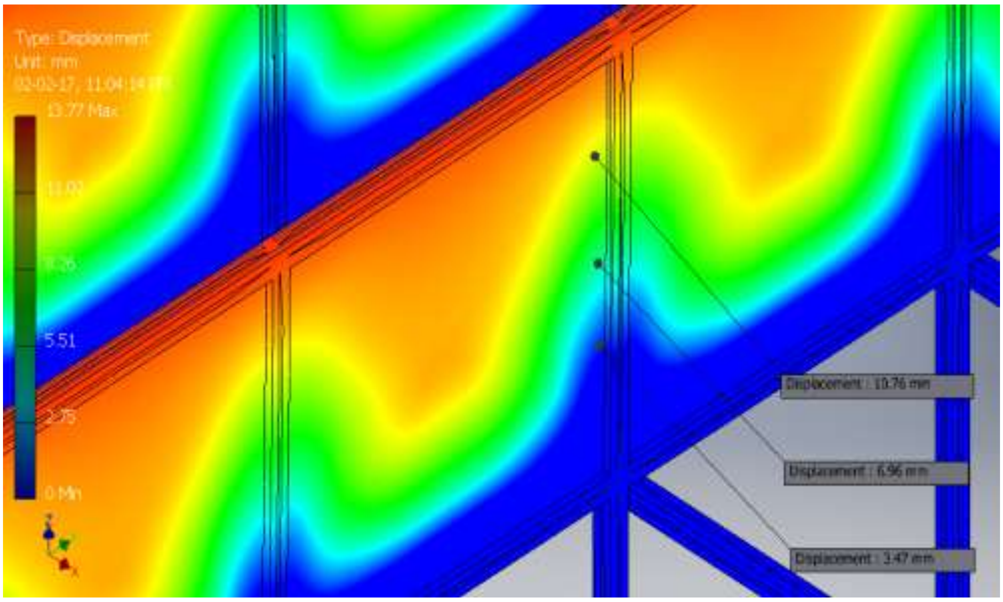


Fig. (8) Displacement plot of non-stiffened tank

Von-Mises stresses is illustrated in Fig. (9). As shown in the figure, stress at a reference point in the frame structure connection is about 187 MPa while the ultimate tensile strength of the AL 6061 T6 is 276MPa.

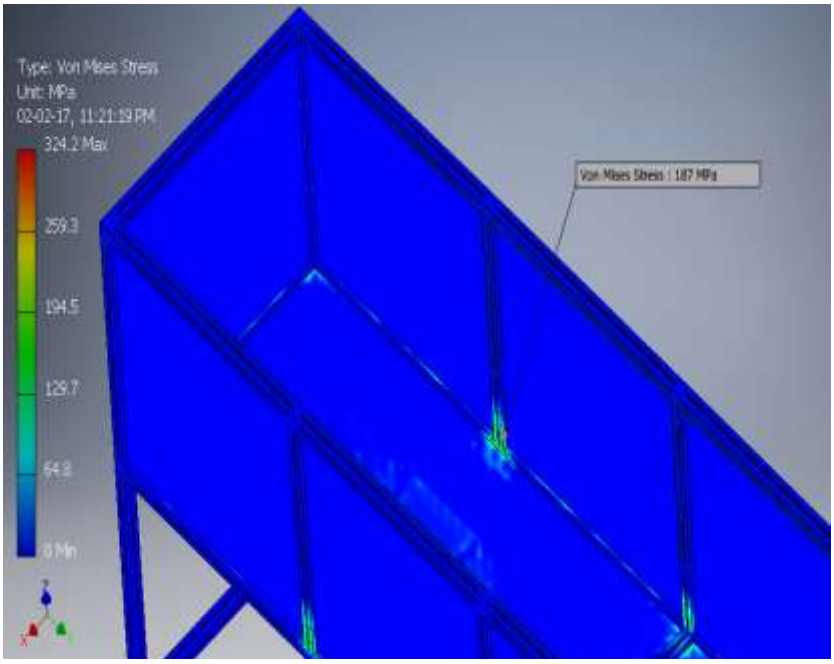


Fig. (9) Von Mises stress distribution of non-stiffened tank

Fig. (9) also illustrate the stress distribution of the acrylic panel which shown in the order of about 50 MPa while the ultimate tensile strength of the acrylic material is 62 MPa.

Case 2: vertical stiffened tank

Finite element analysis is carried out for a vertical stiffened tank and the displacement plot is shown in Fig. (10). As shown in the figure the maximum displacement is about 12.5 mm and the displacement at the three selected reference points shown to be 8.35mm, 5.87mm and 3.36mm. Displacement at the middle of the acrylic panel is in the order of 12mm.

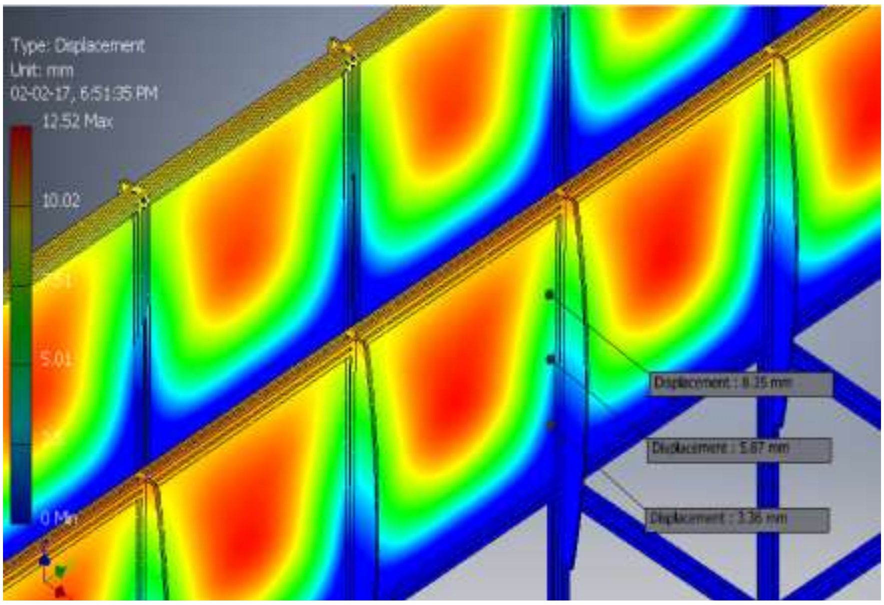


Fig. (10) Displacement plot of vertical stiffened tank

Von-Mises stresses is illustrated in Fig. (11). As shown in the figure, stress at a reference point in the frame structure connection is about 122 MPa

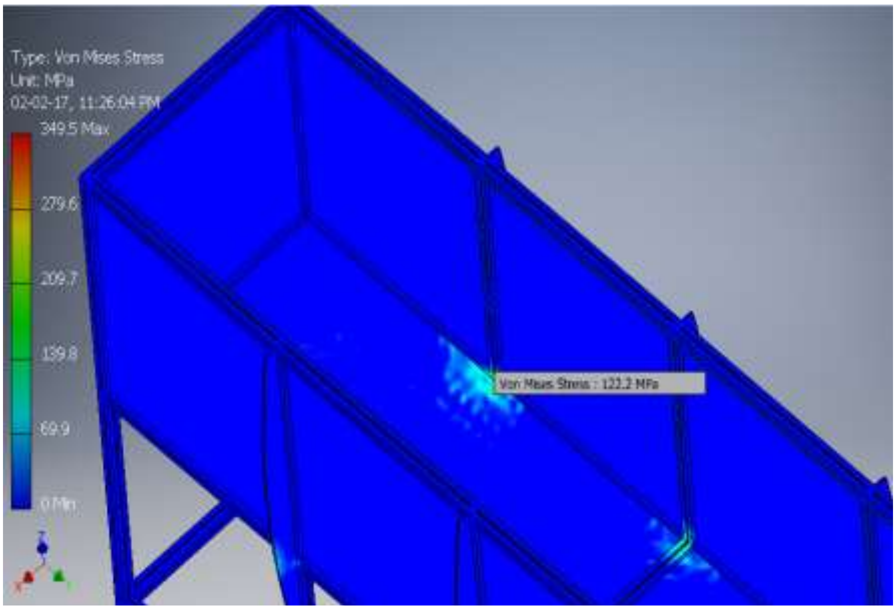


Fig. (11) Von Mises stress distribution of vertical stiffened tank

Fig. (11) also illustrate the stress distribution of the acrylic panel which shown in the order of about 50MPa.

Case 3: horizontal stiffened tank

Finite element analysis is carried out for a horizontal stiffened tank and the displacement plot is shown in Fig. (12). As shown in the figure the maximum displacement is about 8 mm and the displacement at three reference points shows to be 5.65mm, 4.9mm and 1.38mm. Displacement at the middle of the acrylic panel is in the order of 7mm.

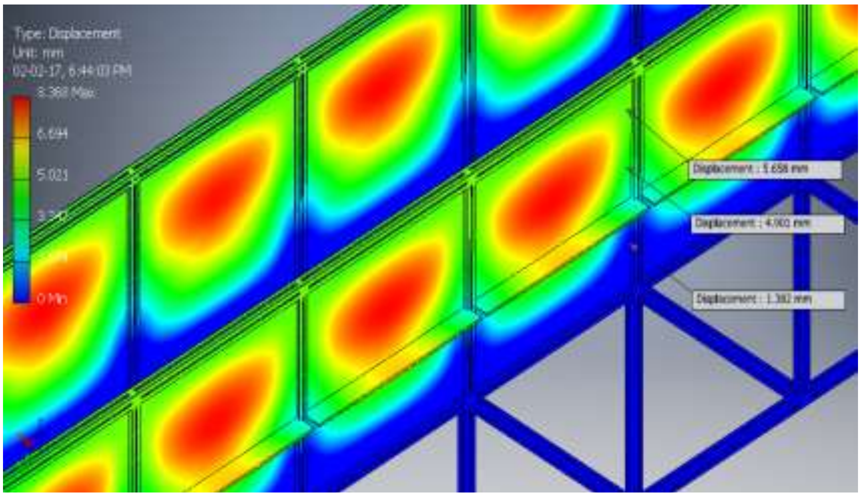


Fig. (12) Displacement plot of horizontal stiffened tank

Von-Mises stresses is illustrated in Fig. (13). As shown in the figure, stress at a reference point in the frame structure connection is about 103 MPa

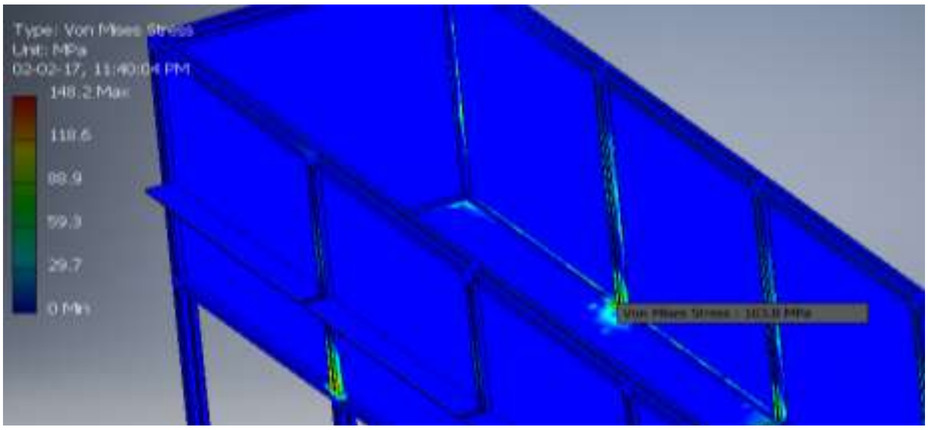


Fig. (13) Von Mises stress distribution of horizontal stiffened tank

Fig. (13) also illustrate the stress distribution of the acrylic panel which shown in the order of about 25 MPa.
Case 4: combined stiffened tank

Finite element analysis is carried out for a combined stiffened tank and the displacement plot is shown in Fig. (14). As shown in the figure the maximum displacement is about 8 mm and the displacement at three reference points shows to be 4.7mm, 2.8mm and 1.1mm. Displacement at the middle of the acrylic panel is in the order of 7mm.

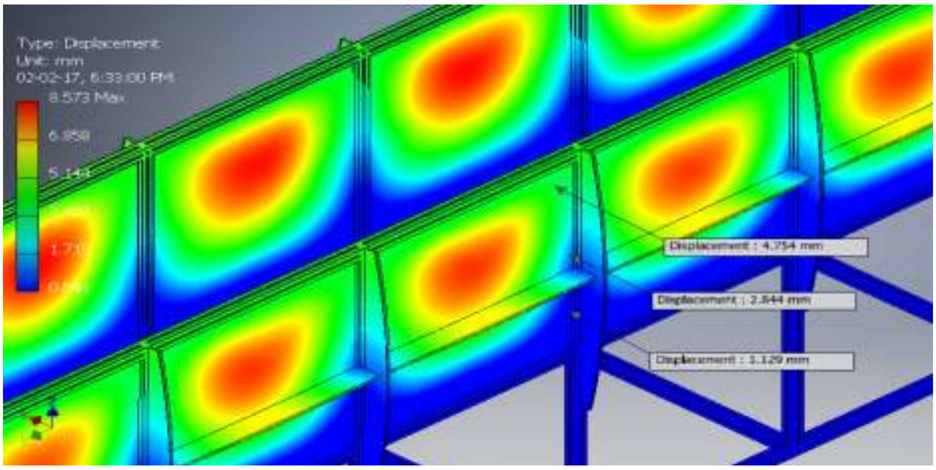


Fig. (14) Displacement plot of combined stiffened tank

Von-Mises stresses is illustrated in Fig. (15). As shown in the figure, stress at a reference point in the frame structure connection is about 62 MPa

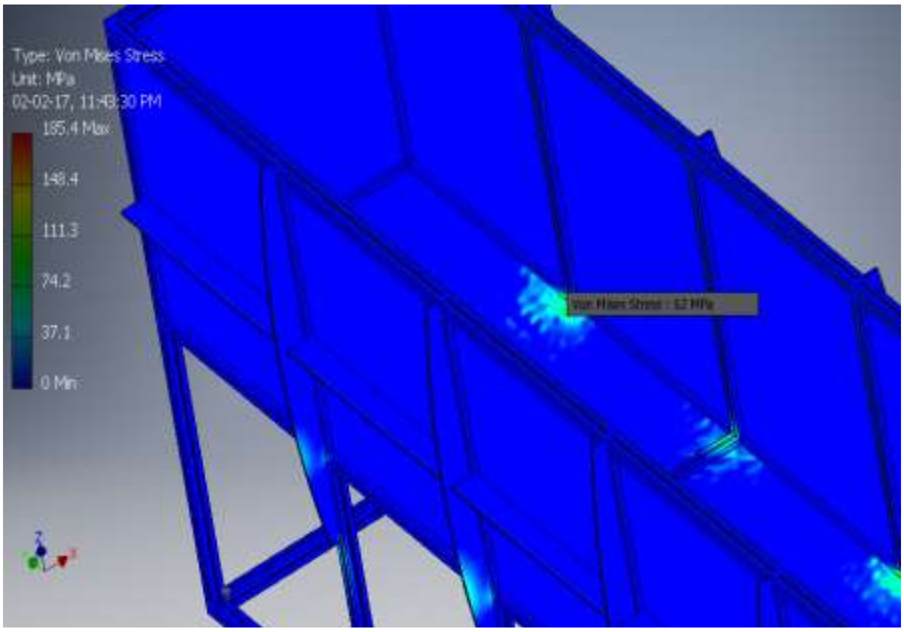


Fig. (15) Von Mises stress distribution of combined stiffened tank

Fig. (15) also illustrate the stress distribution of the acrylic panel which shown in the order of about 15 MPa.

V. CONCLUSION

Four stiffeners cases of a rectangulartowing tank with acrylic panel were analyzed in this study; non-stiffened, vertical stiffened, horizontal stiffened, and combined stiffened (horizontal and vertical stiffened). Deflection and stresses exerts from water pressure over tank frame structure and acrylic panels are calculated using finite element method. Three selected reference points were used to compare different stiffening cases. Results shows that non-stiffened tank in not safe from both deflection and strength points of view. While tank wall deflection with vertical stiffener is lower than that with horizontal stiffener, stresses on tank frame structure with vertical stiffener is higher than that with horizontal stiffener. Combined tank stiffener case using horizontal and vertical stiffener shows lower tank wall deflection and lower stresses of tank frame structure. Decrease tank wall deflection increases the reliability of sealing material and increase tank sustainability.

REFERENCE

[1]. Ivan Klučka, Richard Nekvasil, Stress Analysis of Deformed Storage Tank Shell, Chemical Engineering Transactions,52, 2016, 853-858
[2]. Marks, Standard Handbook for Mechanical Engineers -Tenth Edition (McGRAW-HILL,1996)
[3]. Rules For Classification Underwater technology, Part 4, Machinery and systems, Chapter 7 Pressure Vessels, 2015
[4]. Miroslav T.,Natasa Mrda, et al, Dimensioning Steel Structure of Rectangular Tank According to the Eurocode, Journal of Faculty of Civil Engineering, 28, 2015, 7-22
[5]. Pavol Lengvarsky, Miroslav Pástor, Jozef Bocko, Static Structural Analysis of Water Tank,American Journal of Mechanical Engineering, 3 (2), 2015, 230-234
[6]. Ranjitha. E, G. Dinesh Kumar, Parthiban. S.,Modelling of Liquid Propellant Slosh in a Rectangular Tank by Varying Baffle Heights,International Journal of Advanced Research, 4(4), 2016, 968-972