NONLINEAR BUCKLING ANALYSIS OF STIFFENED PLATE

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Abstract - *A stiffened plate is an extension of the beam-column in which an effective width is added to the beam. Stiffeners are used to resist lateral loading of a plate & are usually made from the rolled shapes integrally welded to the plate. They are used as structural part of ships, submarines & bridges. This project deals with the nonlinear and linear analysis of stiffened plate using ANSYS. A stiffened plate has been analyzed to find out its ultimate strength. An experimental determination of ultimate strength of stiffened plate has also been done in this project. It also includes the linear buckling of stiffened plate without stiffener. The stiffened plate has been analyzed with and without stiffener to get to know about the importance of stiffener. Stiffeners are secondary plates or sections which are used to stiffen the primary elements. The economical design of plate can be obtained by using stiffeners instead of increasing thickness of plate. Also, plates with varying number of stiffeners and stiffened plate under transverse loading condition have also been considered in this project.*

***Key Words*:** Stiffened plate, Stiffeners, Lateral loading, Ultimate strength, Linear buckling, Transverse loading.

1. INTRODUCTION

The widespread usage of stiffened parts in engineering began in the nineteenth century and it was used in steel plates for the hull of ships, steel bridges and also in aircraft structures. Stiffeners are used to withstand the extremely directional loads, and it introduce different load ways which may provide protection against harm and crack growth beneath both the tensile and compressive loads. The greatest advantage of using stiffeners are the increased bending stiffness of the stiffened panel with a minimum of extra material which makes the structures perfect for out-of-plane loads and also for destabilizing the compressive loads. Usage of stiffened plate gives more benefits like less material usage, low cost, better performance etc. Nowadays, the importance for structures with high stiffness is increasing day by day. One amongst the easiest way of achieving it is by using the stiffeners. Innumerous mechanical structures are manufactured from stiffened plates. These structural parts may be outlined as the plates strengthened by one or a group of beams or ribs on one side or both aspects of the plate. Therefore the stiffened plate units are manufactured from plate parts, on to which the loadings area have been applied. The beam parts are connected to a distinct spacing in one or both directions. The fabric of the plate and also the filler may be same or totally different. Compared to the unstiffened plates, the advantage of using stiffened plate is their high stiffness to weight quantitative relation. Because of the rise in overall stiffness of the system, stability characteristics have been increased. Thus these structurally economical elements have the additional benefit of fabric savings as well as they are economic too.

Another advantage of exploitation of stiffened plate is that they can be manufactured through an easy and simple process. Hence, it's not a surprise that such structural elements found a wide-spread utilization within the trendy branches of civil, mechanical, structural and construction engineering. Stiffened plates are subjected to many forms of loading conditions in their operating surroundings. For instance, the stiffened plate is subjected to lateral or cross load within the case of bridge decks. On the opposite hand, the longitudinal bending of the ship hull exert a longitudinal in-plane axial compression on the plates. The loading conditions on an element may be of 2 types: static and dynamic. Static masses are invariant of time and dynamic masses varies with the time. So the designers should keep in mind these 2 aspects of loading while the designing process.

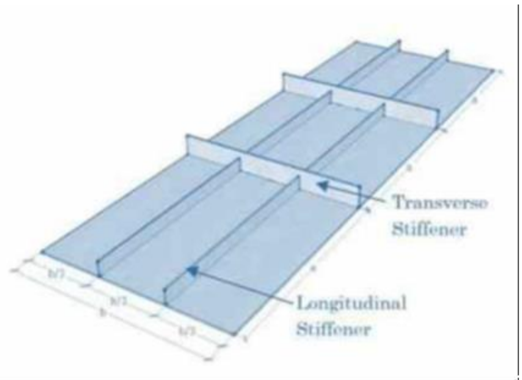

Fig -1: Stiffened plate

1.1 OBJECTIVES

The main objective of this study is:

- To analyze the stiffened plate.

- To apply the cases of loading and boundary conditions for a simply supported plate with stiffeners.
- To find out the ultimate strength of stiffened plate.

1.2 METHODOLOGY

- Review of literature
- Validation of ultimate strength of stiffened plate
- An experiment on ultimate strength of stiffened plate
- Linear buckling of stiffened plate without stiffener
- Analysis (linear) of stiffened plate with one stiffener
- Analysis of stiffened plate subjected to uniform transverse load
- Interpretation of results

2. LINEAR AND NONLINEAR ANALYSIS OF STIFFENED PLATE

The stiffened plate has been analyzed linearly and nonlinearly in order to find out the ultimate strength of the stiffened plate.

2.1 LINEAR ANALYSIS

- MATERIAL PROPERTIES
- The material used is aluminum alloy.
- Stiffened plate is of size 440*590 mm
- Dimension of stiffener – 590*28 mm
- Youngs modulus = 73700 MPa
- Tensile yield strength= 324 MPa.
- Compressive yield strength= 324 MPa.
- Tensile ultimate strength= 471 MPa.
- Compressive ultimate strength= 471 MPa.
- Initial yield strength = 299MPa.
- Mesh size given = 0.02m
- Poisson's ratio = 0.33
- Density of aluminum alloy = 2780kg/m^3
- Thickness of stiffened plate= 2.2mm
- Thickness of stiffener = 2.8mm
- Distance between stiffener = 167mm

2.1.1 MESHED MODEL

The model of stiffened plate is created using ANSYS software. In this study, the ultimate strength of stiffened plate is being carried out. Here, the thickness of stiffened plate is taken as 2.2mm and the thickness of stiffener is taken as 2.8mm. The mesh size of the model = 0.02m.

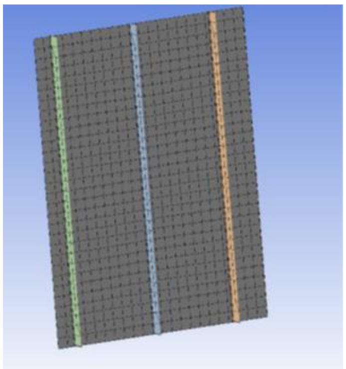

Fig -2: Meshed model

2.1.2 CONNECTIONS

The stiffened plate and stiffeners are connected by the bonded type of connection. It is done by using the manual contact region option found in ANSYS software. If the connection between the stiffeners and stiffened plate is not given, it surely affects the loadings given and thus we won't get the required deformation for the stiffened plate. So providing connection to both the geometries are very much important.

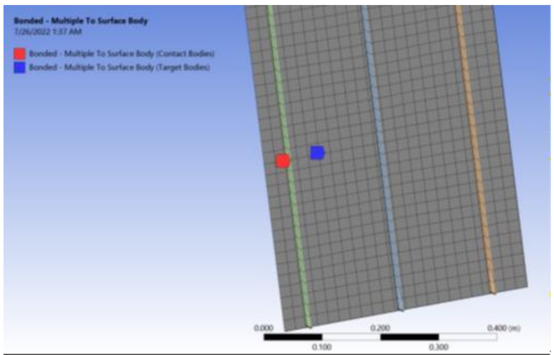

Fig -3: Connections

2.1.3 LOAD APPLIED

The load is given as a compressive load on both the edges of the stiffened plate. The load is applied on both the edges of stiffened plate as well as on the stiffeners. The load given is 100N/m.

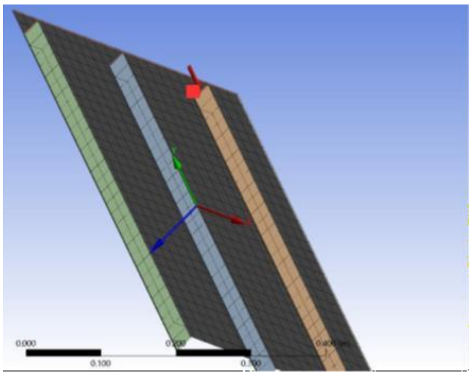

Fig -4: Load on top

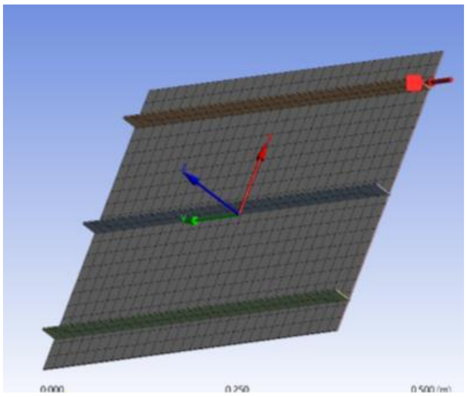

Fig -5: Load on bottom

2.1.4 RESULT

In this study, the total deformation was found out. In this case, linear analysis of stiffened plate was being carried out. The value of total deformation obtained is 0.059185m. The figure below shows the deformed model of stiffened plate with stiffener. On applying load, both the stiffened plate and stiffener are being deformed.

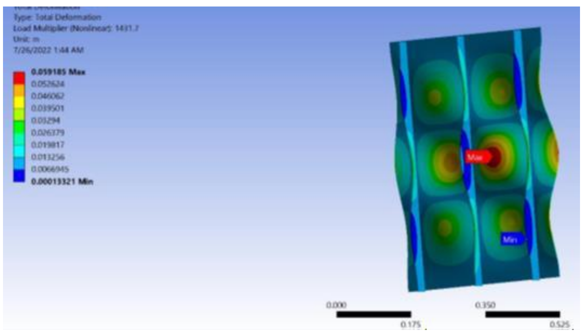

Fig -6: Total Deformation

2.2 NONLINEAR ANALYSIS

This is the nonlinear case of the validation. Here, same material properties and dimensions are used as in linear analysis. The only difference is that it is analyzed in nonlinear method. The figure below shows the force reaction applied to the stiffened plate.

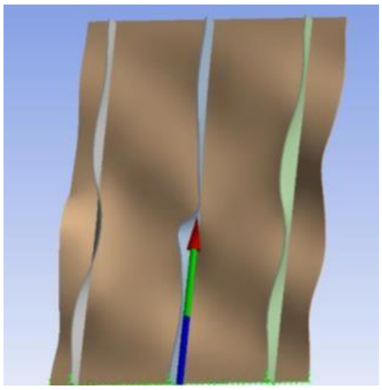

Fig -7: Force Reaction

2.2.1 RESULT

In this study, the total deformation was found out using nonlinear method here. In this case, nonlinear analysis of stiffened plate was being carried out. The value of total deformation obtained is 0.013893 m. The figure below shows the deformed model of stiffened plate with stiffener. On applying load, both the stiffened plate and stiffener are being deformed.

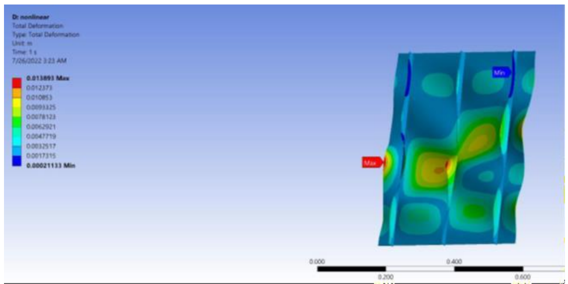

Fig -8: Total Deformation

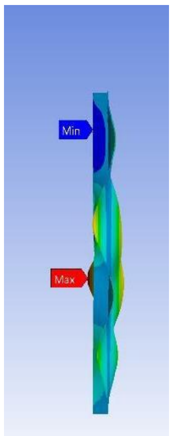

Fig -9: Deformed shape of stiffener

3. EXPERIMENT

MATERIAL PROPERTIES

- Material used: aluminum alloy
- Stiffened plate is of size 440*590 mm
- Dimension of stiffener – 590*28 mm
- Thickness of stiffened plate= 2.2mm
- Thickness of stiffener = 2.8mm
- Distance between stiffeners = 110mm

stiffened plate is of 440*590 mm and stiffener is of 590*28 mm.

Fig -10: Stiffened plate

Fig -11: Stiffened plate

3.1 LOAD APPLIED

The figure below is the stiffened plate made of aluminum. This stiffened plate is kept on a Universal Testing Machine (UTM). Then UDL of 36 kN/m was applied on top of stiffened plate and fixed support was given on the bottom portion of stiffened plate. The

Fig -12: Applying Load on UTM

3.2 RESULT

Fig -13: Deformation of stiffened plate

4. PARAMETRIC STUDIES

4.1 LINEAR BUCKLING OF STIFFENED PLATE WITHOUT STIFFENER

- MATERIAL PROPERTIES:
- Material used – Aluminum alloy
- Size of stiffened plate= 2500*1800 mm
- Ultimate tensile strength =537 MPa
- Ultimate yield strength =489 MPa
- Young's Modulus =72 GPa
- Poisson's ratio = 0.34
- Density =2795 kg/m

4.1.1 MESHED MODEL

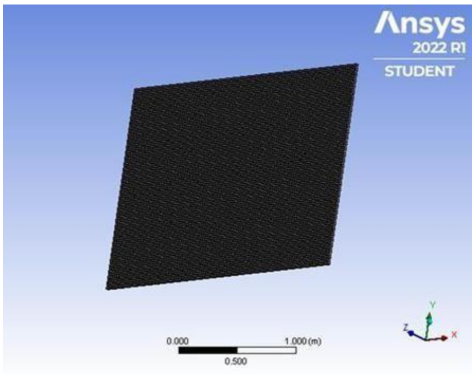

Fig -14: Meshed model

4.1.2 LOADS GIVEN

Here, the load is given on both edges of stiffened plate. A bare plate or a stiffened plate without stiffener is being considered here. Linear analysis is done in this study. The load given = 135 kN.

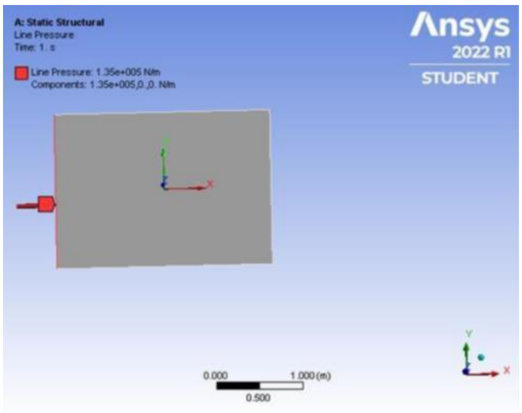

Fig -15: Loads Given

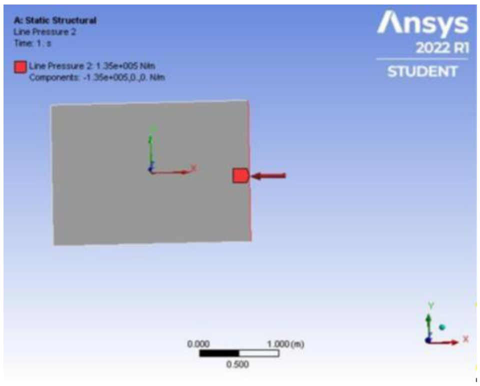

Fig -16: Loads Given

4.1.3 RESULT

The Value of deformation obtained (for plate having thickness 20mm) = 0.379m.

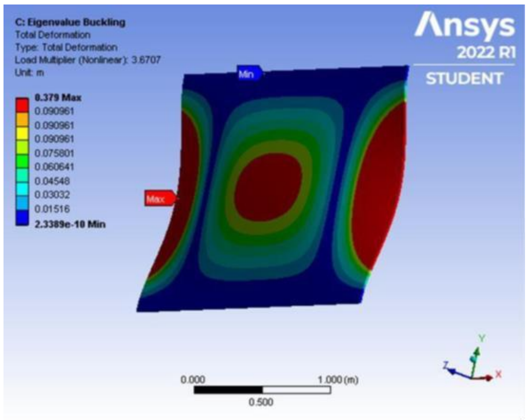

Fig -17: Total deformation

4.2 ANALYSIS OF STIFFENED PLATE WITH ONE STIFFENER

MATERIAL PROPERTIES:

- Material used – aluminum alloy
- Stiffened plate is of 440*590 mm
- Dimension of stiffener – 590*28 mm
- Young's modulus = 73700 MPa
- Tensile yield strength= 324 MPa.
- Compressive yield strength= 324 MPa.
- Tensile ultimate strength= 471 MPa.
- Compressive ultimate strength= 471 MPa.

- Initial yield strength = 299MPa.
- Mesh size= 0.02m
- Poisson's ratio = 0.33
- Density of aluminum alloy = 2780kg/m^3
- Thickness of stiffened plate= 2.2mm
- Thickness of stiffener = 2.8mm

4.2.1 MESHED MODEL

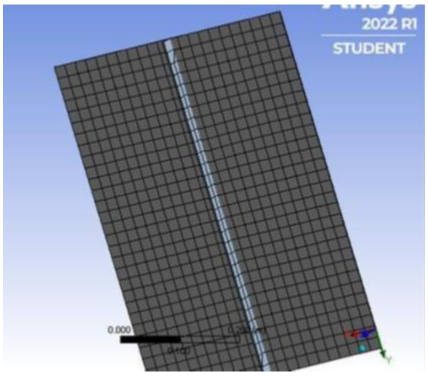

Fig -18: Meshed model

4.2.2 LOADS GIVEN

The load applied to the stiffened plate with one stiffener = 100 N/m.

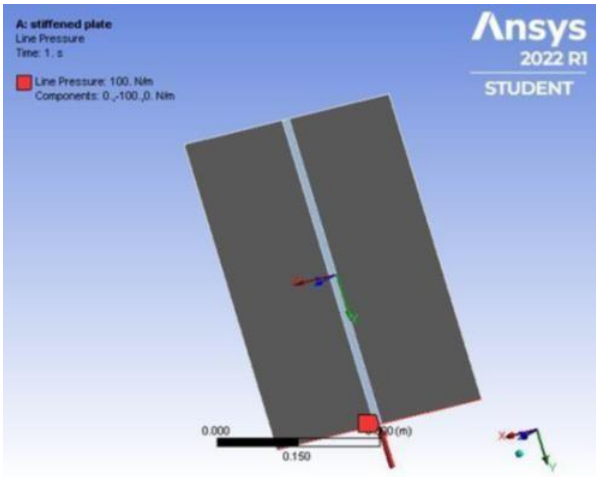

Fig -19: Load Given

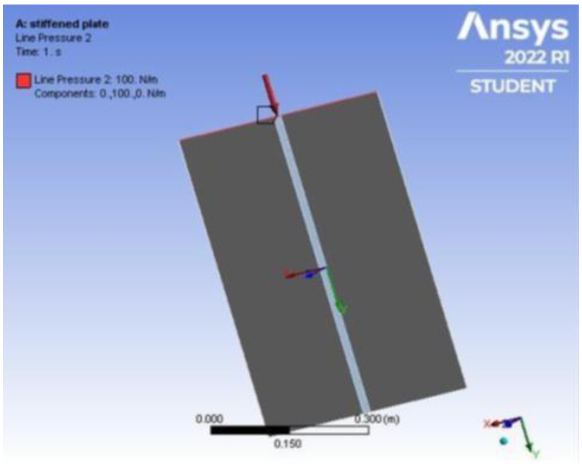

Fig -20: Load Given

4.2.3 RESULT

The value of total deformation obtained = 0.18285 m

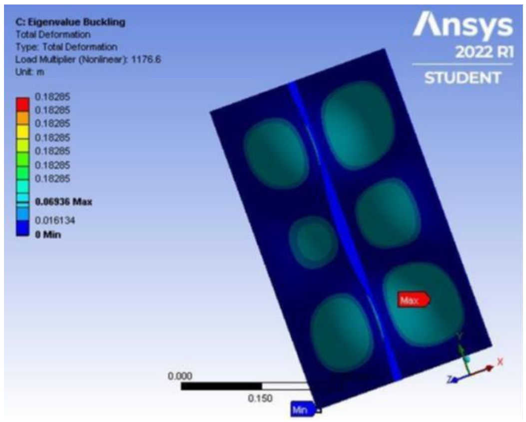

Fig -21: Load Given

4.3 ANALYSIS OF STIFFENED PLATE SUBJECTED TO UNIFORM TRANSVERSE LOAD

MATERIAL PROPERTIES:

- Material used – aluminum alloy
- Stiffened plate is of 440*590 mm
- Dimension of longitudinal stiffener – 590*28 mm
- Dimension of transverse stiffener – 440*28 mm
- Young's modulus = 73700 MPa
- Tensile yield strength= 324 MPa.
- Compressive yield strength= 324 MPa.

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- Tensile ultimate strength= 471 MPa.
- Compressive ultimate strength= 471 MPa.
- Initial yield strength = 299MPa.
- Mesh size= 0.02m
- Poisson's ratio = 0.33
- Density of aluminum alloy = 2780kg/m^3
- Thickness of stiffened plate= 2.2mm
- Thickness of stiffener = 2.8mm

4.3.1 MESHED MODEL

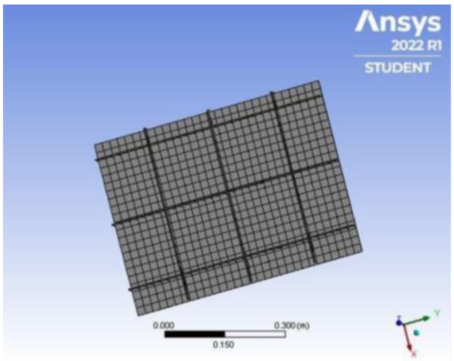

Fig -22: Meshed model

4.3.2 LOADS GIVEN

The Load applied to stiffened plate with longitudinal and transverse stiffener = 100 N/m.

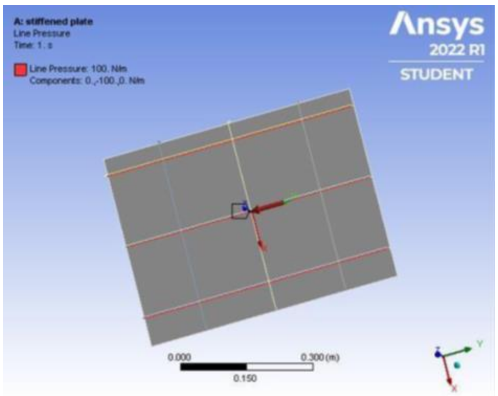

Fig -23: Loads Given

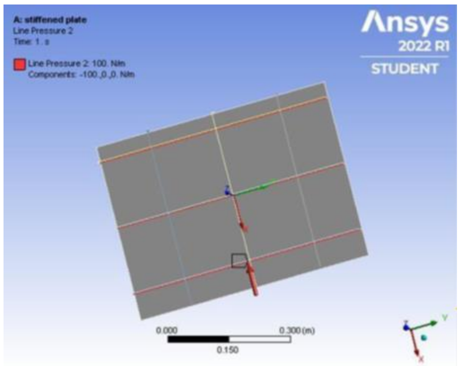

Fig -24: Loads Given

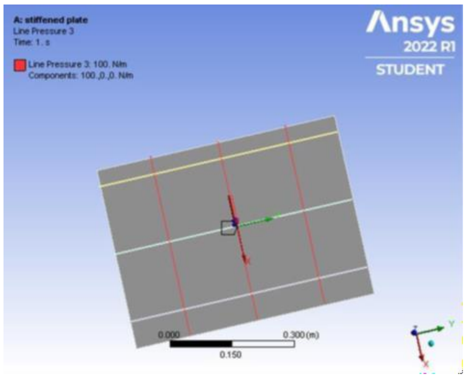

Fig -25: Loads Given

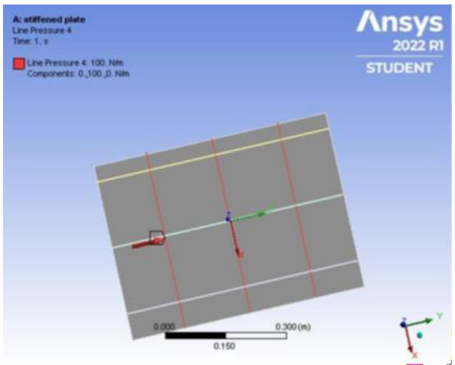

Fig -26: Loads Given

4.3.2 RESULT

The deformation value obtained for stiffened plate with longitudinal and transverse stiffeners = 1.5524e^{-7} m.

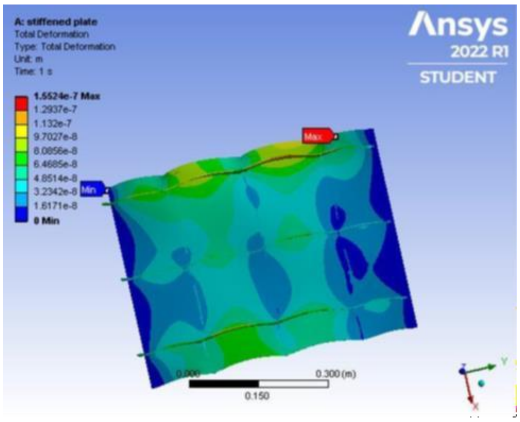

Fig -27: Total deformation

5. CONCLUSION

This project was conducted to find out the ultimate strength of stiffened plate with and without stiffener. So, it was found that adding stiffeners to the stiffened plate increases the strength and less amount of material is required for such plates when compared to plates with no reinforcement. Thus, it makes an economical structure. It also improves resistance and rigidity with respect to its weight. Therefore the economical style of plate will be obtained by using stiffeners rather than increasing the thickness of plate. Stiffeners facilitate in stiffening the first components. It absolutely was found that size of subpanel, form and size of filler and range of equi-spaced stiffeners affects the important buckling strength of stiffened plates having longitudinal stiffeners. By increasing the cross sectional moment of inertia, the rigidity of stiffeners will be raised.

In this study, stiffened plates with varying thicknesses were analyzed in ANSYS software. So it was found that stiffened plate having less thickness gives almost equal deformation when compared to a stiffened plate having greater thickness. That is, the strength characteristics of a stiffened plate is not dependent on thickness of plate. Also, analysis of stiffened plate with varying number of stiffeners were also conducted in this project. So it was found that the strengthening effect of stiffeners decreases as the number of stiffeners increases. As the number of stiffeners increases, the ultimate strength value decreases.

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