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Comparative Analysis of Double Cover Single Bolted Butt Joint using ABS and PLA Material

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Abstract: ***Additive manufacturing is the process of generating the 3D model as a layer by layer formation using modeling software. Fused deposition modeling 3D printer uses an ABS (acrylonitrile butadiene styrene) and PLA (poly lactic acid) material for printing. In this experiment, analysis of ISO standard nut & bolt is proposed. Nut and bolt can be assembled in plates to create a double cover single bolted butt joint. ANSYS mechanical finite element software is used for simulation of double cover single bolted butt joint and bolts to analyze the mechanical behavior such as equivalent stress, total deformation and maximum principal stress. Comparative analysis of bolts designed with ABS and PLA material is carried out and the respective properties are calculated.***
Keywords: Additive manufacturing, ANSYS software, Finite element method, ABS, PLA.

I. INTRODUCTION

Additive manufacturing is a process of generating 3D model using CAD modeling software. Additive manufacturing process is carried out in a layer by layer manner starting from bottom and ending to the top. Cura software known as slicing software is used to create a G-code as per the STL file and required input parameter. According to numerically controlled mechanism the printer operates and creates a product in a 3D printer. After printing, testing and analysis is generally carried out on 3D printed product.

In this work, the comparative analysis of double cover single bolted butt joint of ABS and PLA material is carried out. Fused deposition modeling 3D printer is used to print bolted joint by ABS and PLA material. Analysis of 3D printed part using ANSYS software is carried out. ANSYS is finite element analysis software which is used for simulation of digital model to analyze the mechanical properties of product and how it can be operated in that condition. CATIA software has been used to design double cover single bolted butt joint.

However, the CAD file that initially designed is later resolved on ANSYS software. Equivalent stress is evaluated on bolted joint and bolt. Normal stress, maximum principal stress, shear stress, total deformation is evaluated on bolt. Maximum principal stress is evaluated on plates. Comparative analysis of bolts designed with ABS and PLA material is carried out and the respective properties are calculated.

II. METHODOLOGY

In this paper, analysis of 3D printed part using ANSYS software is carried out to determine the mechanical function of the 3D printed part. Fused deposition modeling method is used for printing of double cover single bolted butt joint using ABS and PLA material respectively. ANSYS software is used for simulation of computer generated CAD model to analyze the static structural analysis of 3D printed part. Firstly, CAD file is developed in CATIA software using ISO standard dimension of nut, bolt and plate etc. All those parts were assembled together and generated a double cover single bolted butt joint. Convert that CAD file into STEP file which is required for ANSYS software.

First step of ANSYS software is to input the engineering data as per the material required for the model. Second step is to import geometry which was created in CATIA software as a STEP file. Third step is model; in that workbench imported geometry model is shown for further analysis. Then fix the geometry by using fixed support and frictionless support. Apply the pretension load on bolts as a 350N. Mechanical behavioral properties which are required for evaluation of result that was then inserted in a solution. In this work, ISO standard bolt is selected for analysis of different properties and to determine the behavior of material. Equivalent stress is evaluated on bolted joint and bolt. Normal stress, maximum principal stress, shear stress, total deformation is evaluated on bolt. Maximum principal stress is evaluated on plates.

Comparative analysis of bolts designed with ABS and PLA material is carried out and the respective properties are calculated.

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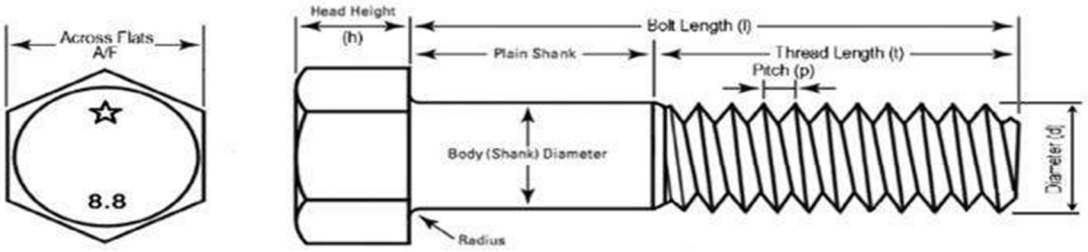

Fig1: cross section area of nut and bolt

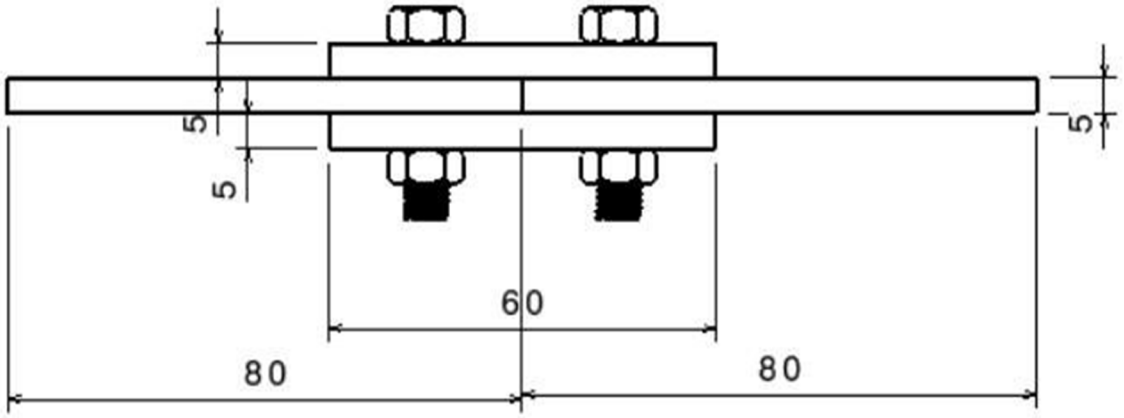

Fig2: design of double cover single bolted butt joint

Figure1 shows the cross section area of ISO standard nut and bolt. Figure2 shows the design of double cover single bolted butt joint in that bolt of M8 size is used.

III. CAD FILE

Firstly, CAD file is prepared using a CATIA software. Then that CAD file is converted to STEP file. This STEP file is then imported through import geometry function for analysis. Figure1 shows the CAD file of double-cover single bolted butt joint in designed in CATIA software.

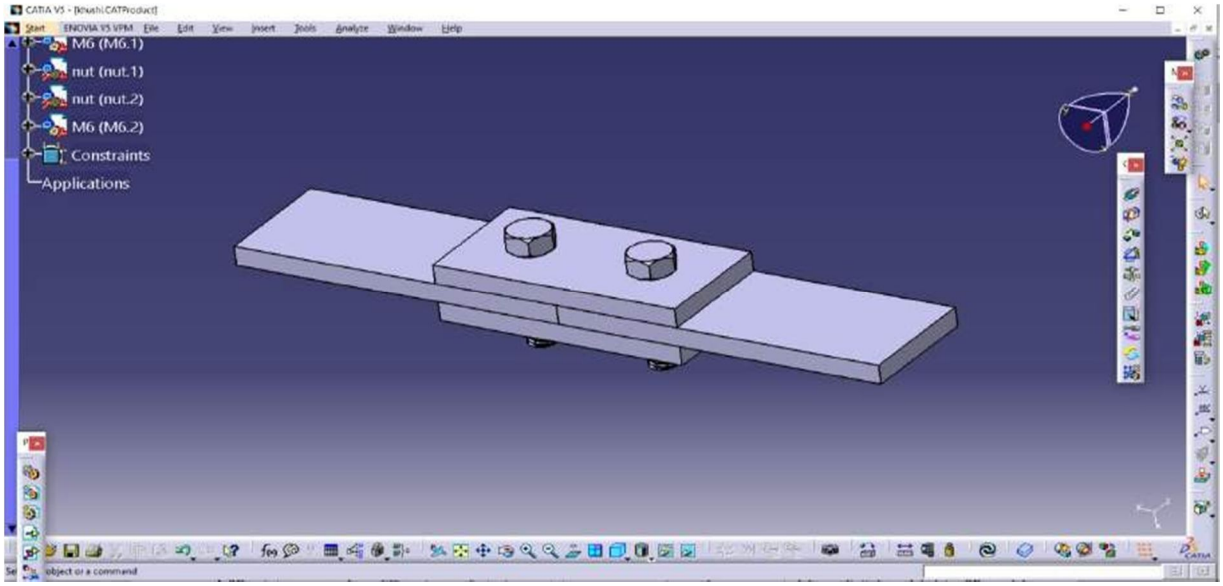

Fig3: CAD file of double-cover single bolted butt joint

IV. ANALYSIS

ANSYS is mechanical finite element analysis software which is used for simulation of computer models to analyze the mechanical properties of models. The behavior of the model without conducting physical tests can be determined by ANSYS software. The user may design the model in ANSYS itself or any other modeling software which can be later imported in ANSYS. Then we can add the engineering data as per the respective product and its material. In this research, ABS and PLA material is used for comparative analysis. Table 1 shows the engineering data required for ABS and PLA material.

Table 1: Engineering Data for ABS and PLA Material

Sr. No.	Properties	ABS	PLA
1.	Density	1300kg/m^3	1300kg/m^3
2.	Young's modulus	2600 MPa	3500 MPa
3.	Poisson's ratio	0.39	0.39
4.	Tensile yield strength	37.50 MPa	37.50 MPa
5.	Compressive yield strength	37.50 MPa	37.50 MPa
6.	Tensile ultimate strength	50 MPa	50 MPa
7.	Compressive ultimate strength	50 MPa	50 MPa

A. Analysis of Bolted Joint

Initial CAD file was converted in STEP file which is later imported in ANSYS software for further analysis. Figure1 shows the double cover single bolted butt joint in an ANSYS workbench. The static structural analysis of bolted joint was carried out with fixed support and frictionless support. Bolt pretension load was applied on a bolt. Figure 4 shows the bolted joint in ANSYS workbench.

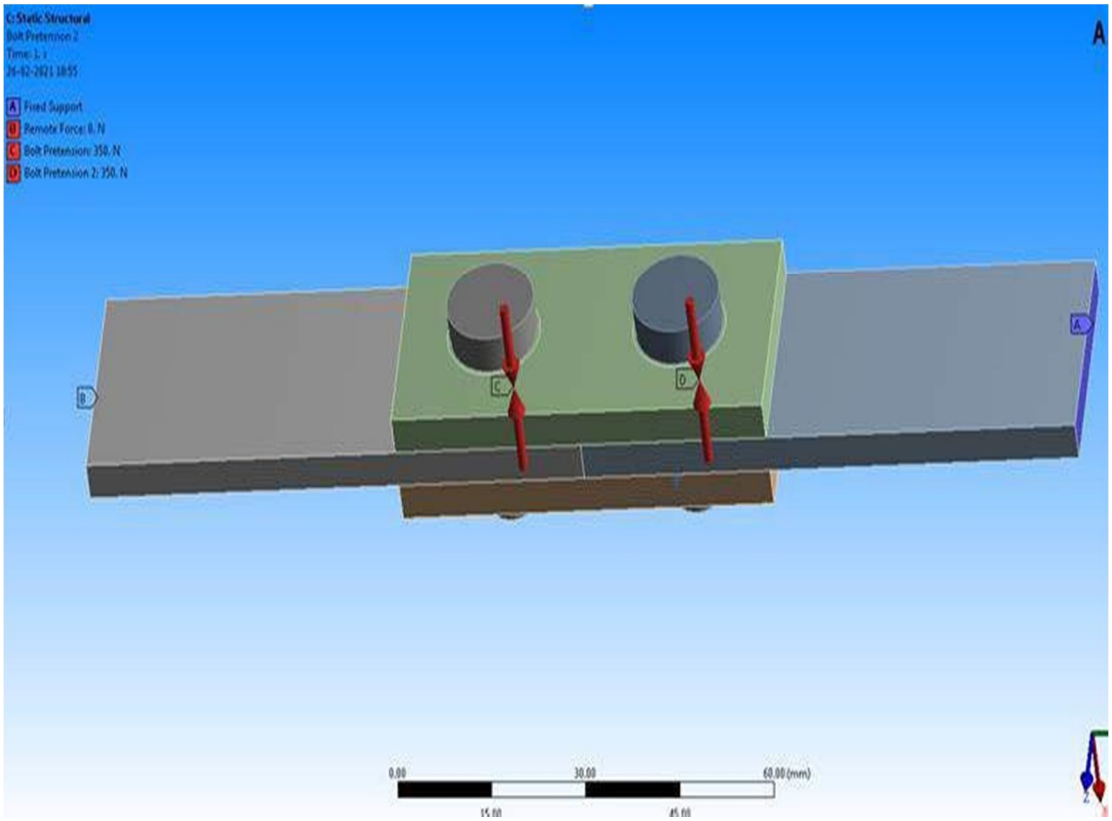

Fig4. Bolted Joint in ANSYS model

B. Comparative Analysis of Bolted joint

Figure 5 and 6 shows the equivalent stress in a bolted joint of ABS and PLA material. Comparative analysis of equivalent stress values of ABS and PLA material are 19.855 MPa and 20.021 MPa respectively.

1) Equivalent Stress in Bolted Joint

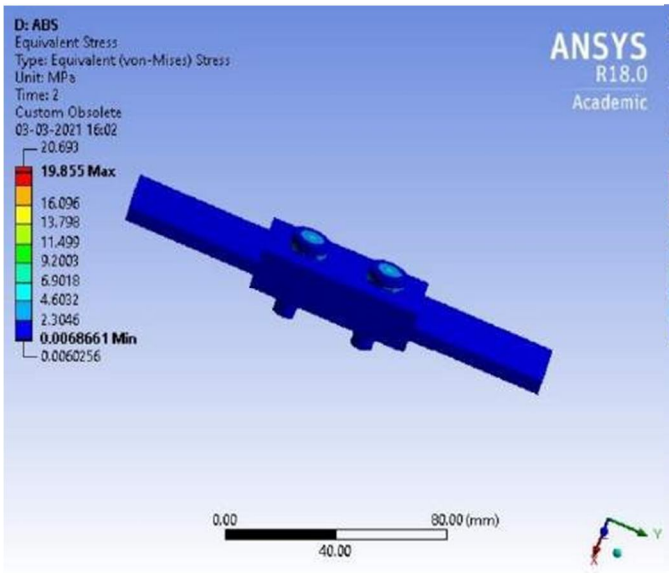

Fig5: Equivalent stress in ABS

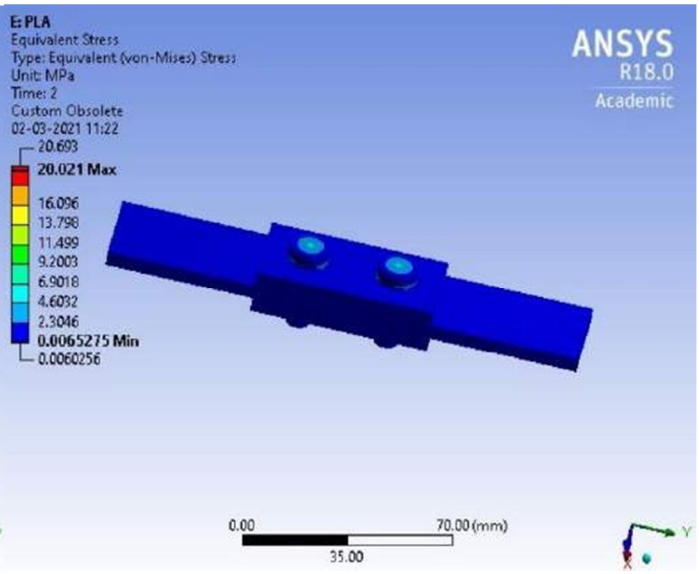

Fig6: Equivalent stress in PLA

C. Comparative Analysis of Bolt

Figure 7 and 8 shows the equivalent stress of bolt in ABS and PLA material. Comparative analysis of equivalent stress values of ABS and PLA material are 19.412 MPa and 19.384 MPa respectively. Figure 9 and 10 shows that maximum principal stress of a bolt in ABS and PLA material. Comparative analysis of maximum principal stress values of ABS and PLA material are 21.166 MPa and 21.327 MPa respectively. Figure 11 and 12 shows that normal stress of a bolt in ABS and PLA material. Comparative analysis of normal stress values of ABS and PLA material are 19.843 MPa and 19.996 MPa respectively. Figure 13 and 14 shows that shear stress of bolt in ABS and PLA material. Comparative analysis of maximum principal stress values of ABS and PLA material are 8.7054 MPa and 8.9935 MPa respectively. All these results of comparative analysis of bolt made of ABS and PLA material with pretension load 350N shows that the bolt made of PLA material has high stress value as compared to the bolt made of ABS material.

1) Equivalent Stress in Bolt

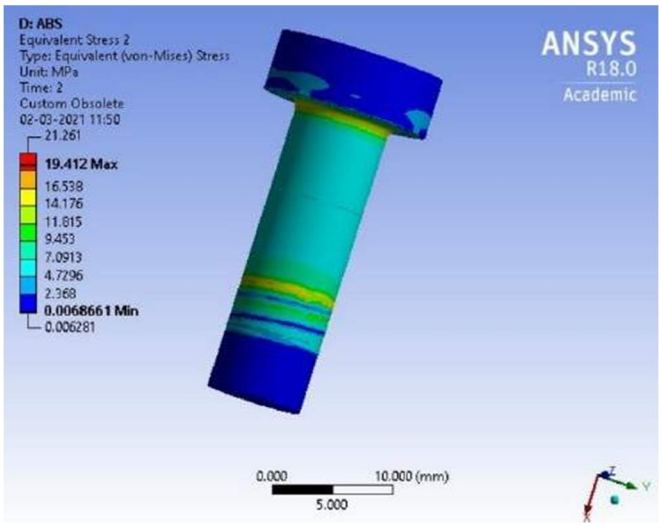

Fig 7: Equivalent stress in ABS

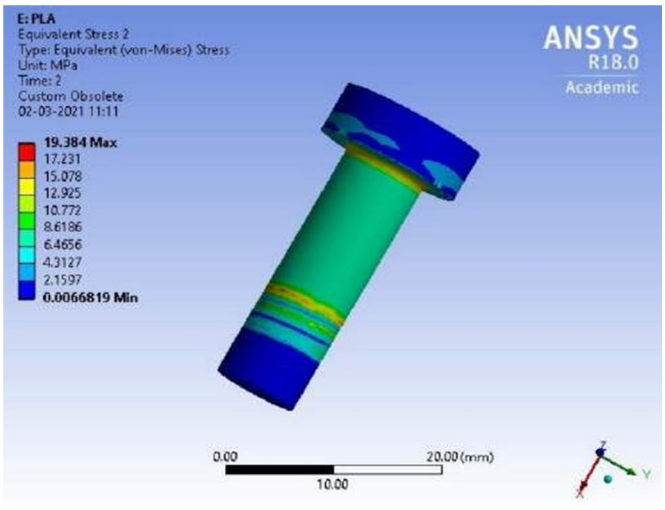

Fig 8: Equivalent stress in PLA

2) Maximum Principal Stress

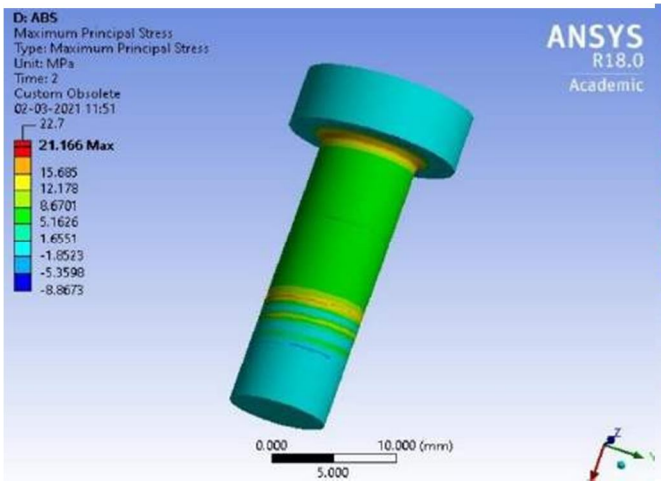

Fig 9: Maximum principal stress in ABS

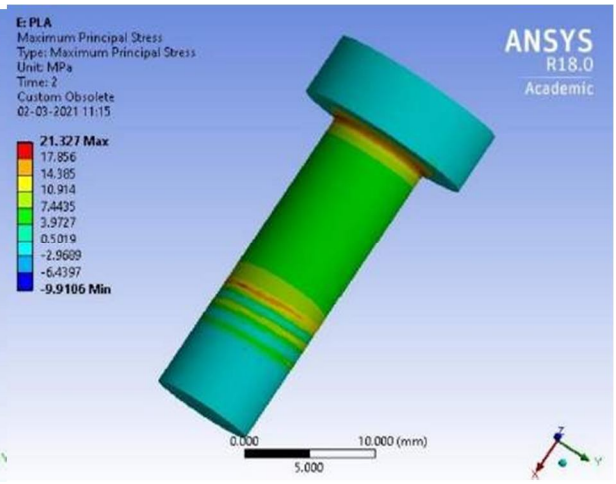

Fig 10: Maximum principal stress in PLA

3) Normal Stress

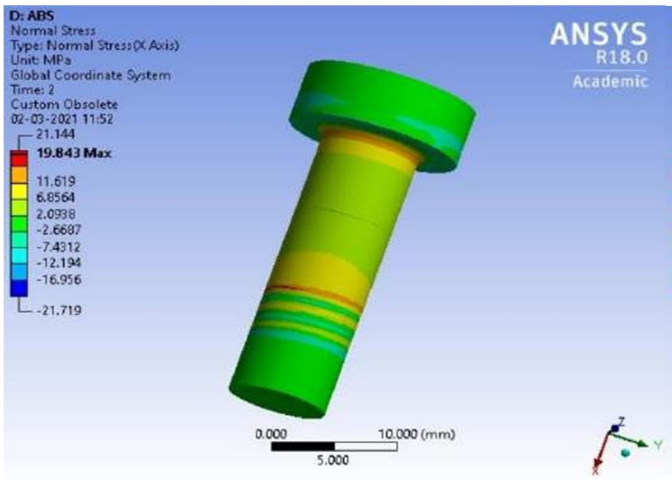

Fig 11: Normal stress in ABS

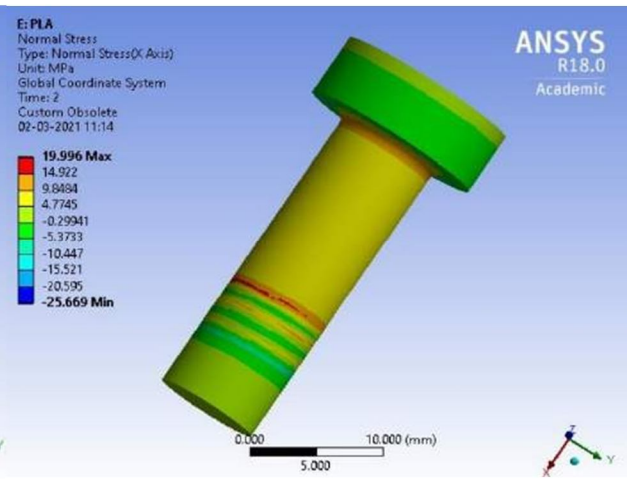

Fig 12: Normal stress in PLA

4) Shear stress

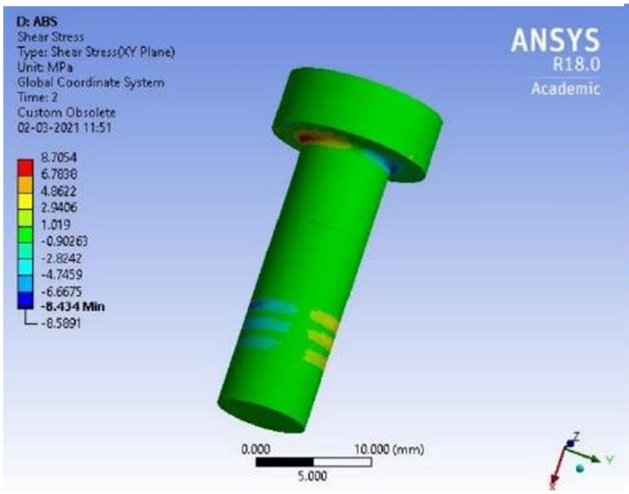

Fig 13: Shear stress in ABS

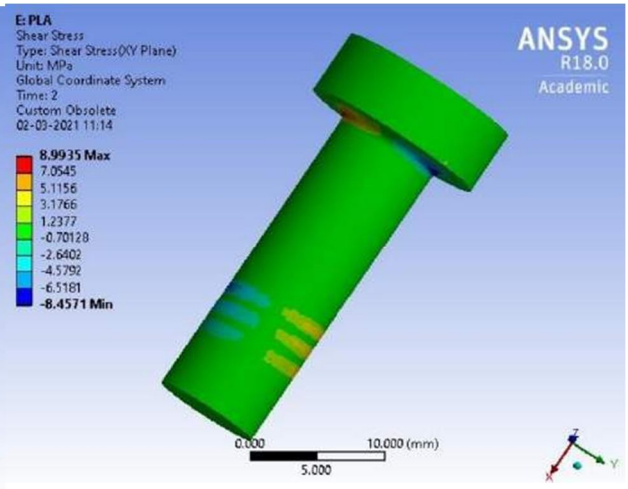

Fig14: Shear stress in PLA

D. Comparative Analysis of Plates

Figure15 and 16 shows that maximum principal stress values in ABS and PLA materials as 2.6209 MPa and 2.6211 MPa. Figure17 and 18 shows that maximum principal stress in middle plate of ABS and PLA materials which has stress values as 2.905MPa and 2. 9265 MPa respectively.

1) Maximum Principal Stress In Plates

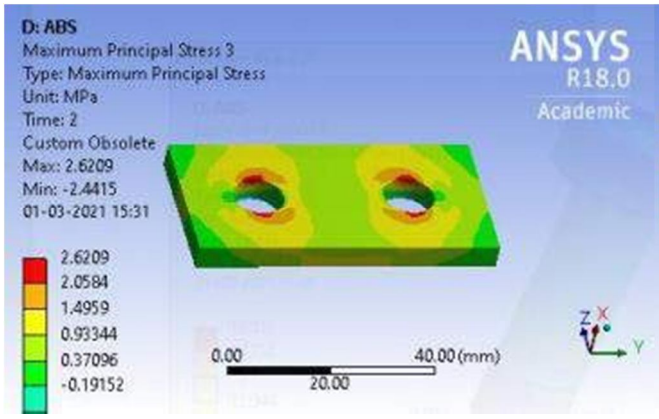

Fig 15: Maximum principal stress in ABS

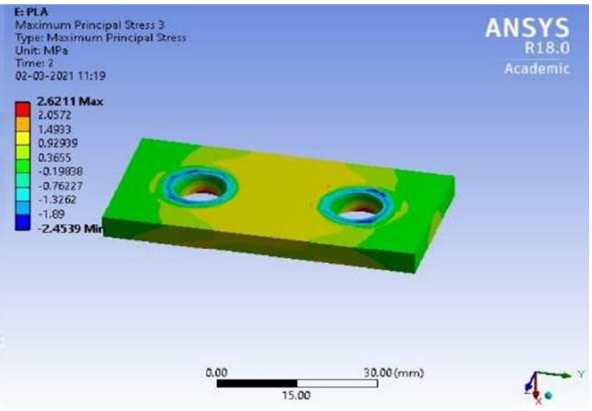

Fig 16: Maximum principal stress in PLA

2) Maximum Principal Stress In Middle Plates

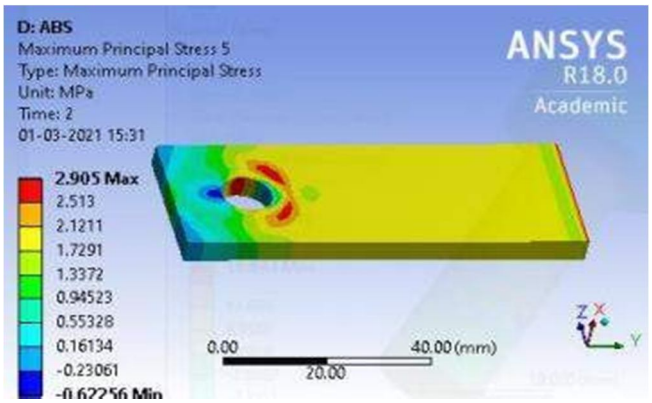

Fig 17: Maximum principal stress in ABS

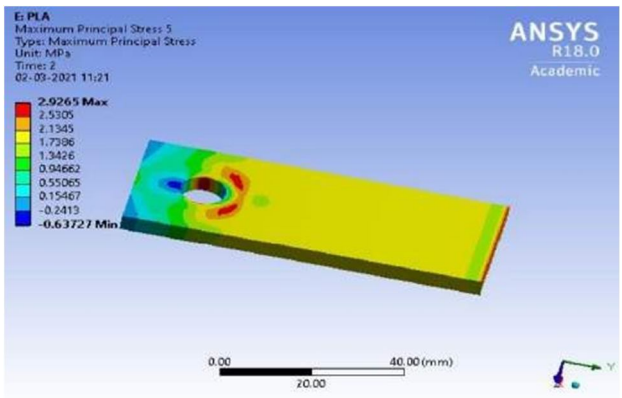

Fig 18: Maximum principal stress in PLA

E. Results of Analysis

Result obtained through the ANSYS software for the comparative analysis of bolted joints made of ABS and PLA material is as shown in table 2.

Table 2: Results of analysis

Sr. No.	Analysis results value	ABS	PLA
1.	Equivalent stress of bolted joint	19.412 MPa	20.021 MPa
2.	Total deformation of bolted joint	0.13797 mm	0.056146 mm
3.	Equivalent stress in bolt	19.412 MPa	19.384 MPa
4.	Normal stress in bolt	19.843 MPa	19.996 MPa
5.	Shear stress in bolt	8.7054 MPa	8.9935 MPa
6.	Maximum principal stress in bolt	21.166 MPa	21.327 MPa
7.	Maximum principal stress in plate	2.6209 MPa	2.6211 MPa
8.	Maximum principal stress in middle plate	2.9050 MPa	2.9265 MPa
9.	Total deformation of plate	0.087926 mm	0.056146mm
10.	Factor of safety	5.06	7.12

F. Tightening Torque

When the bolt has been properly tighten to the plates, it stretches the plates slightly, but not beyond its elastic limit. The joint preload which is known as the substrate materials to resist the compression for balancing the clamping pressure. The properly tightened bolt shares the preload with plates. Figure 19 shows that maximum tightening torque. In this, red zone is required maximum for sticking. If red zone is minimum it means the tightening torque is not sufficient.

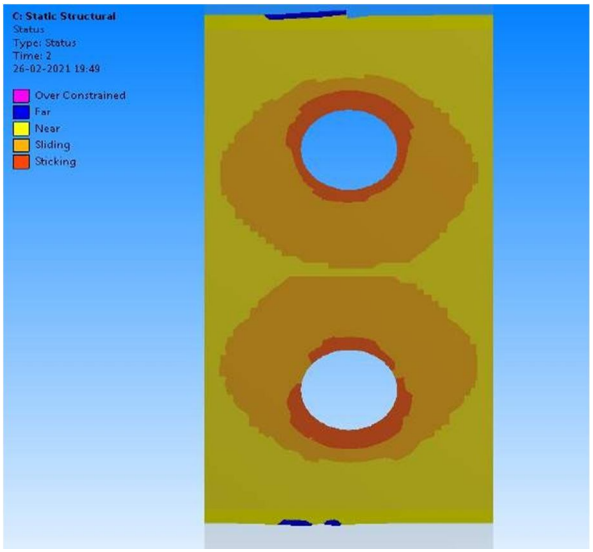

Fig 19: Maximum tightening torque

V.CONCLUSIONS

Analysis of double cover single bolted butt joint of ABS and PLA material is carried out in ANSYS software. Comparative analysis shows that equivalent stresses in PLA bolted joint are more as compared to ABS bolted joint. PLA bolt has higher stresses values as compared to ABS bolt and deformation of ABS plate is higher than PLA plate. All these result shows that ABS material is weaker as compared to PLA material.

VI. ACKNOWLEDGMENT

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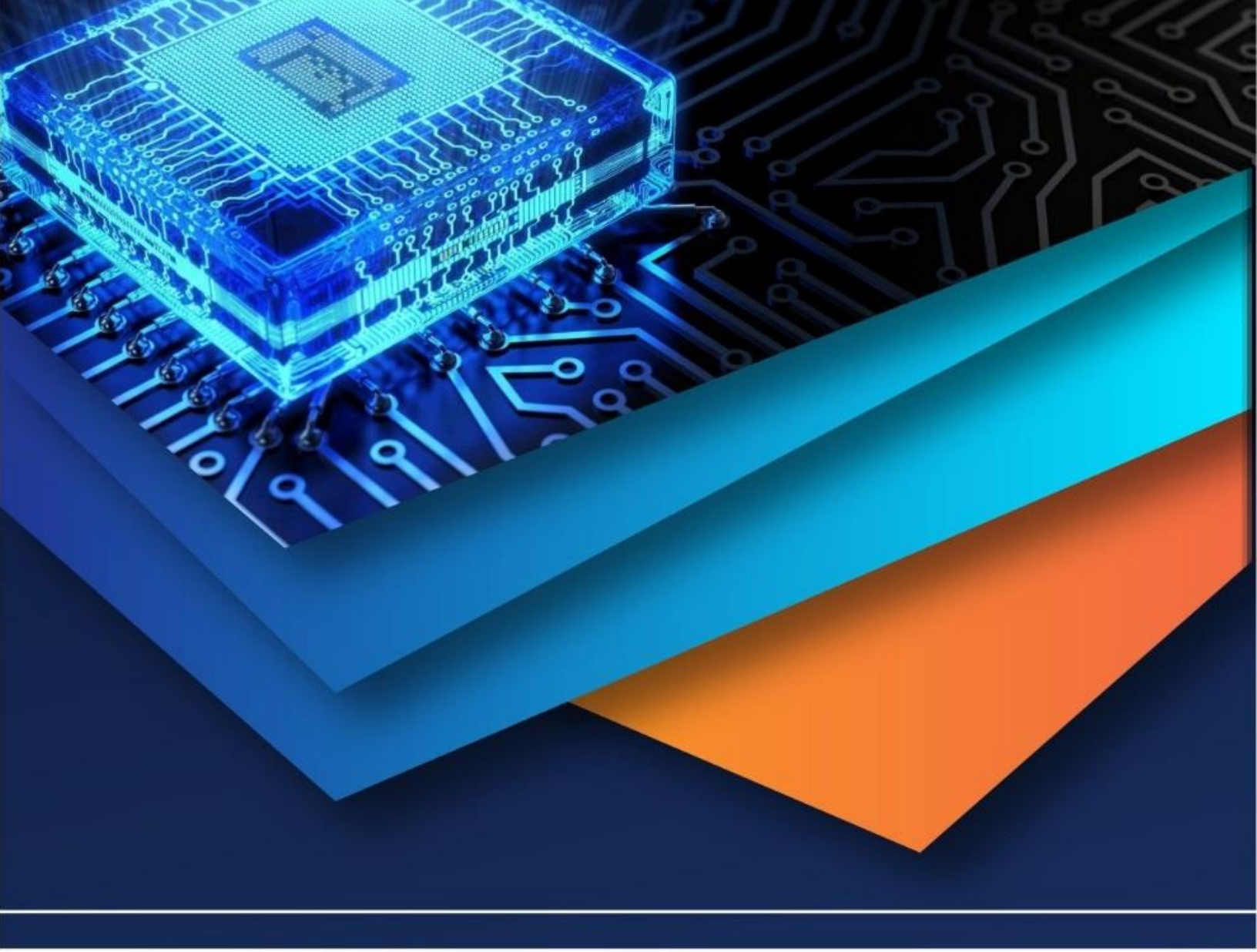

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