Experimental and FEA analysis of 3D printed TPU material Auxetic structure

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Abstract- These characteristics make TPU extraordinarily notable over an extent of business parts and applications. There are three principal mixture classes of TPU: polyester, polyether and a humbler class known as polycaprolactone. It has properties between the qualities of plastic and versatile. In light of its thermoplastic nature, it has a couple of points of interest over various elastomers, for instance, astounding flexibility, high augmentation at break, and extraordinary weight bearing cutoff. Errand work deal with the utilization of Thermoplastic polyurethane material for decreasing the largeness of the vehicle with the objective that it gets lighter and makes it dynamically viable. PC upheld plan (CAD) is the use of PC systems (or workstations) to help in the creation, modification, assessment, or improvement of a structure. PC helped configuration yield is every now and again as electronic records for print, machining, or other amassing movement. In present examination two auxetic structure of 1 and 1.5 mm is been planned and 3D printed to assess the best execution for explicit applications. The printer moves the ejection head, setting down disintegrated material at accurate zones, where it cools and sets (like a definite warmed paste gun). Exactly when a layer is done, the amass stage goes down and the method repeats until the part is done.

Keywords—TPU, CATIA,FEA,ANSYS

INTRODUCTION

Thermoplastic polyurethanes (TPUs) reveal colossal blends of both physical properties and planning applications. Commonly, they are versatile and adaptable with incredible assurance from impact, scratched territory, and atmosphere. With TPUs, there is the opportunity of concealing similarly as assembling using a wide extent of techniques. The union of TPUs could, along these lines, improve the overall durability of various things. They may be made using removal, blow, weight and mixture molding gear. They may in like manner be course of action secured or vacuum-encircled, which makes them suitable to be made by a tremendous extent of creation methodology. Different properties of TPUs make them suitable for certain applications, for instance, vehicle, footwear and advancement. Thermoplastic polyurethane (TPU) is a stand-out class of plastic made when a polyaddition reaction occurs between a diisocyanate and at any rate one diols. Polyether TPUs are possibly lower in express gravity than polyester and polycaprolactone grades. They offer low-temperature flexibility and extraordinary scratched region and tear adaptability. They are moreover solid against microbial attack and give sensational hydrolysis hindrance – making them suitable for applications where water is an idea. Polycaprolactone TPUs have the natural quality and resistance of polyester-basedTPUs got together with low-temperature execution and reasonably high assurance from hydrolysis. They are an ideal unrefined material for pressure driven and pneumatic seals.

LITERATURE REVIEW

John O. Akindoyo et al [1],explained in their paper named "Polyurethane types, amalgamation and application-a review", the different sorts of polyurethane. Their unequivocal mechanical, physical, common, and substance properties are attracting enormous investigation thought with respect to fitting PUs for use in different applications. Redesign of the properties and execution of PU-based materials may be cultivated through changes to the creation technique or the unrefined materials used in their production or by methods for the usage of bleeding edge depiction methodologies. The current assessment intends to uncover understanding into the science, types, and mix of different kinds of PUs. A part of the huge assessment considers relating to PUs, including their amalgamation technique, depiction systems, and investigation revelations, are totally discussed. In this way, progressing propels in new kinds of PUs and their mix for various applications are also presented. In addition, information is given on the common pleasantness of the PUs, with a specific highlight on their recyclability and recoverability.

Simon R.G. Bateset al. [2]portrayed in their assessment work 'Compressive direct of 3D printed thermoplastic Polyurethane honeycombs with ground densities', that the joined filament production of thermoplastic polyurethanes (TPUs) offers an ability to manufacture tailorable, flexible honeycomb structures which can be updated for essentialness holding applications. This work researches the effect of an extent of checking on procedures on the essentialness fascinating and damping behavior of flexible TPU honeycomb structures. By applying thickness checking on, the imperativeness holding and damping virtuoso files are significantly modified from the uniform thickness indistinguishable. A 3D-printing technique was made which allowed the amassing of first class structures, which

experienced cyclic stacking to densification without frustration. Assessed honeycomb plans had an ordinary relative thickness of 0.375 ±0.05. After semi static testing, shows were presented to sinusoidal weight over an extent of amplitudes at 0.5 Hz. By surveying the helper thickness in different habits, mechanical damping was modified. Cyclic compressive testing in like manner demonstrated how strain-unwinding of the TPU parent material could provoke decreased damping through the range of 50 cycles. Tests were presented to influence stacking at strain-paces of up to 51 s-1 and specific influence energies of up to 270 mJ/cm3. Lower top weights were moved for assessed tests for the most genuine impact cases. This lead reveals the capacity of thickness assessing of TPU structures to give unparalleled impact protection in ludicrous environmental conditions.

Steven T. Patton et al. [3] from this paper we get some answers concerning included substance amassing of TPU material. Electromechanical, bond, and viscoelastic properties of polymers and polymer Nano composites (PNCs) are of excitement for included substance creating (AM) and versatile equipment. Exactly when it all abot improvement/upgrade of inks for AM is amazing, expensive, and substrate/interface subordinate. In these paper pros explores properties of disconnected motion pictures of a thermoplastic polyurethane (TPU) polymer and an Ag–carbon dull (Ag-CB) TPU PNC in a gently stacked low strain contact as a horrendous extent of their suitability for AM. The TPU demonstrated high hysteresis and weight a colossal viscoelastic response, and satisfactory stay time was required for polymer chain loosening up and quantifiable grasp. Another disclosure is that immense enough contact zone is relied upon to allow longer time consistent polymer mentioning in the contact that incited higher connection and better execution/trustworthiness.

KanchanVarankaret al. [4]in this paper they talk about materials used in vehicle. The vehicle business uses planned polymer composites and plastics in a wide extent of uses. Authorities in vehicle organizations express that there are four regions that require most significant need inventive work with plastics: inside, body and outside, powertrain and outline, light weighting. Polyurethanes (PUs) is a versatile materials. It has amazing potential for use in different applications, especially subject to their structure–property associations.

Joyeeta Duttaet al,[5]In this paper maker look at about different extent of Thermoplastic Polyurethane. Novel blends reliant on Ethylene vinyl acidic corrosive induction/Thermoplastic Polyurethane(EVA/TPU) at different extents were prepared by methods for break down blending methodology. They do the Scanning electron microscopy (SEM) study which reveale that two phase morphology wherein the minor TPU stage was dissipated in the major endless EVA lattice. Exactly when the extent is 50/50 blend EVA and TPU appear as co-relentless stage. They look at the effect of blend extent on mechanical properties and hardness. to show perfect unbending nature and prolongation at breakwas saw when blend extent is 80/20 EVA/TPU.

PROBLEM STATEMENT

This project aims to check the Stress, Strain, and Deformation of Thermoplastic Polyurethane by compression test using ANSYS and Universal Testing Machine.

I. OBJECTIVES

- To prepare CAD design of TPU specimen using CATIA V5.
- To study the 3D printing manufacturing process.
- Selection of 3D printing method for manufacturing Thermoplastic Polyurethane base specimen.
- Strenth Compariosion between 1mm &1.5mm thickness.
- To perform a static analysis of the TPU specimen by using FEA.
- Compression test of the manufactured specimen by using UTM.
- Validation of analytical and experimental work.

II. METHODOLOGY

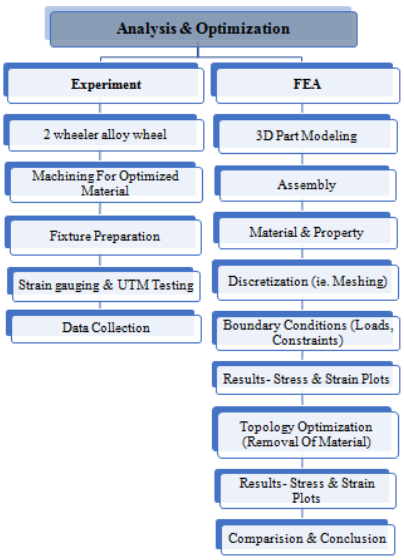
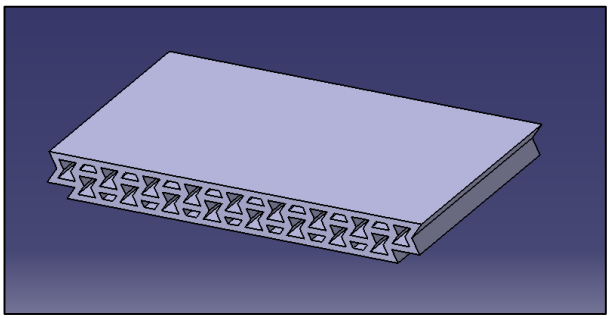


Fig.No.2 Flowchart for the Methodology

III. CAD MODEL



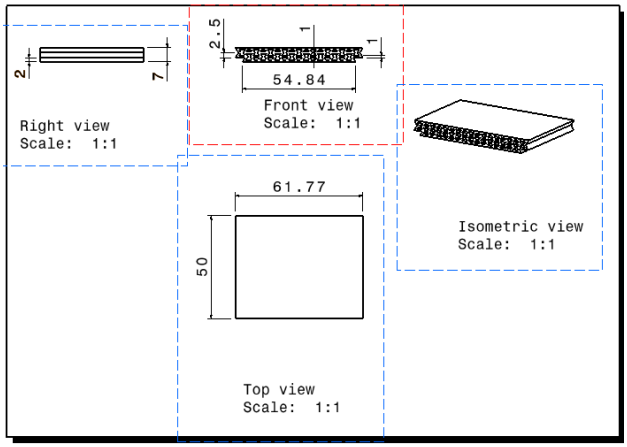
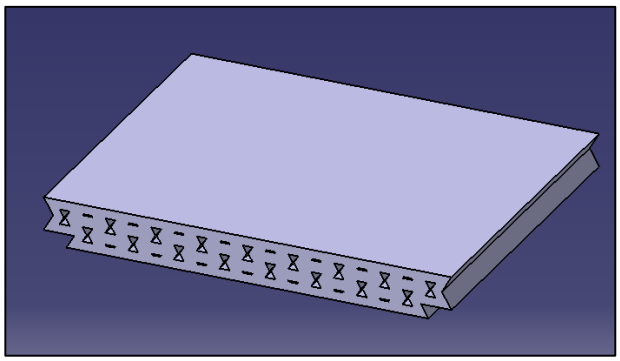


Fig. CATIA and drafting of 1 mm auxetic structure



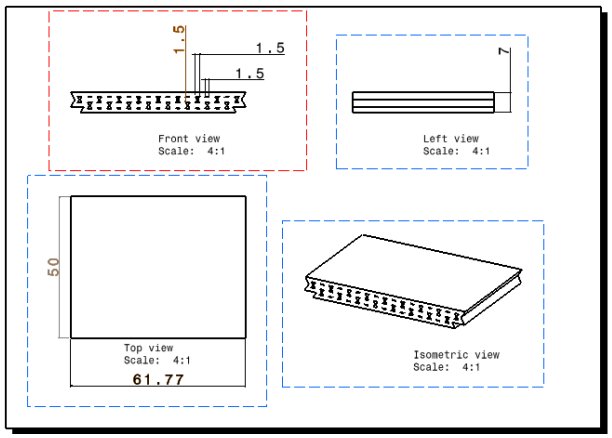


Fig. CATIA and drafting of 1.5 mm auxetic structure

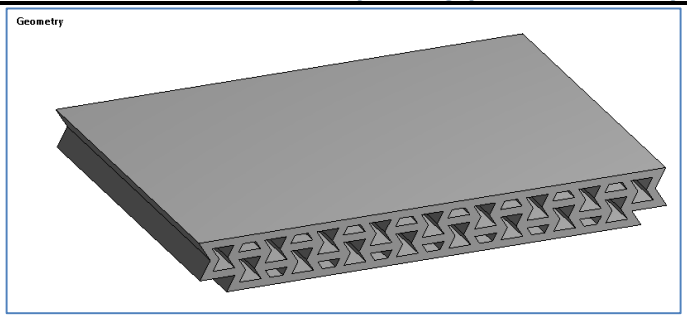
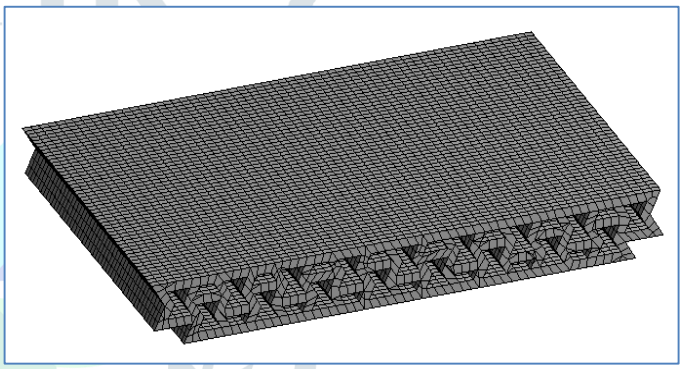


Fig. 3 CATIA model of TPU

IV. MESH

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient multiphasic solutions. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time you have to wait for mesh generation.



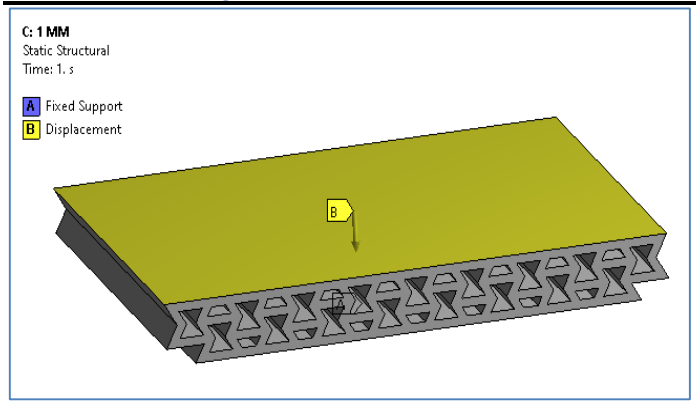
Statistics	
Nodes	105214
Elements	18150

Details of "Body Sizing" - Sizing	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Body
Definition	
Suppressed	No
Type	Element Size
Element Size	1.0 mm

Fig. 4 Meshing of model

V. BOUNDARY CONDITION

A boundary condition for the model is the setting of a known value for a displacement or an associated load. For a particular node you can set either the load or the displacement but not both.



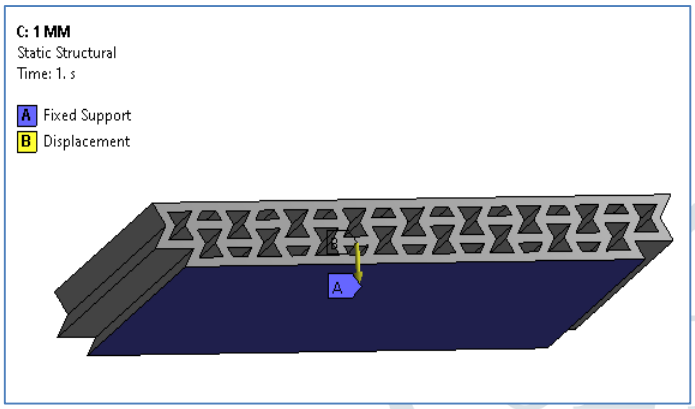


Fig. 5 The boundary condition of the model

Details of "Displacement"	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Type	Displacement
Define By	Components
Coordinate System	Coordinate System
X Component	0. mm (ramped)
Y Component	0. mm (ramped)
Z Component	-3. mm (ramped)

Fig.6 Detail of displacement

VI. STRUCTURAL ANALYSIS

Total Deformation

The total deformation & directional deformation are general terms in finite element methods irrespective of software being used. Directional deformation can be put as the displacement of the system in a particular axis or user defined direction. Total deformation is the vector sums all directional displacements of the systems.

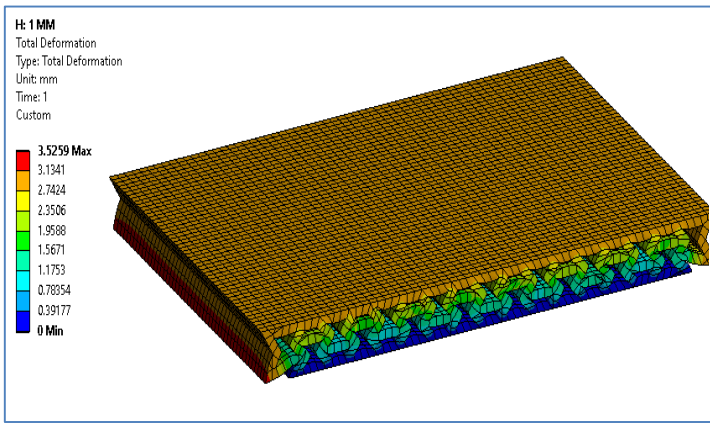


Fig.No.7 Deformation results TPU

Stresses on model

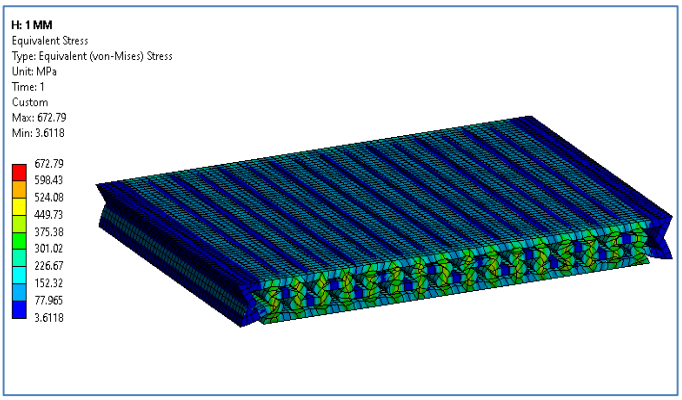


Fig. 8 Equivalent stress of model

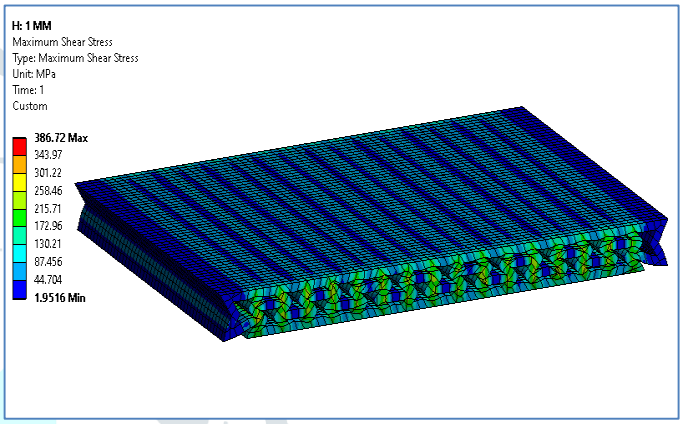
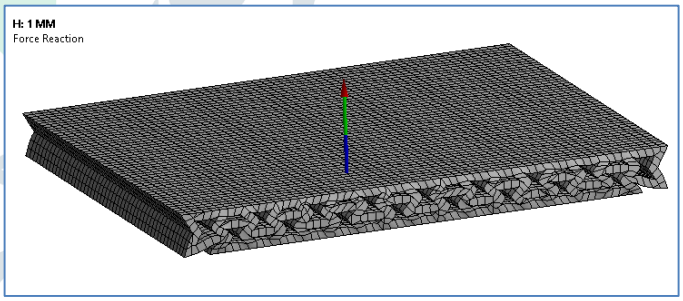


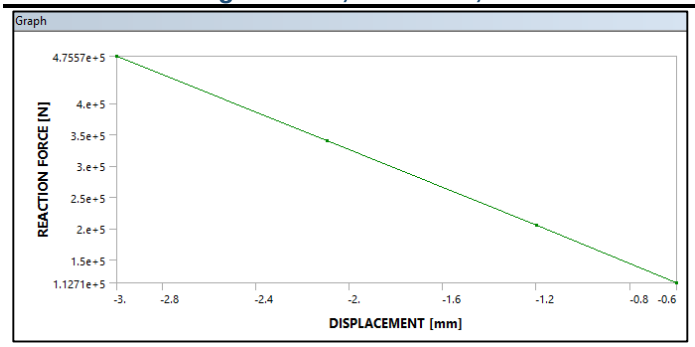
Fig.9 Maximum shear stress

VII. FORCE REACTION

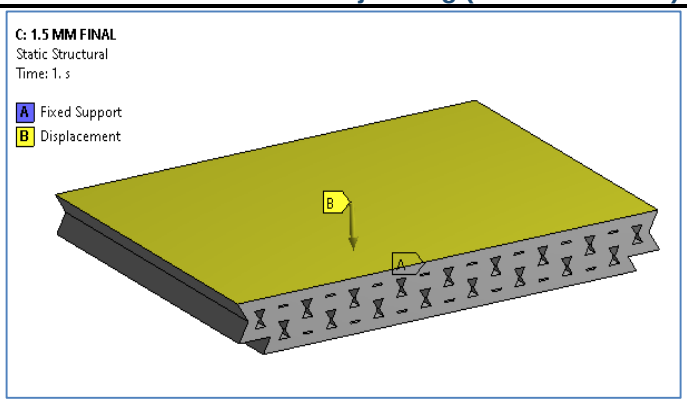


Maximum Value Over Time	
X Axis	-7.2147e-007 N
Y Axis	568.57 N
Z Axis	1.8917e+005 N
Total	1.8917e+005 N

Fig.10 Force reaction of TPU



Graph. Reaction force vs displacement



TPU 1.5 MM FEA ANALYSIS

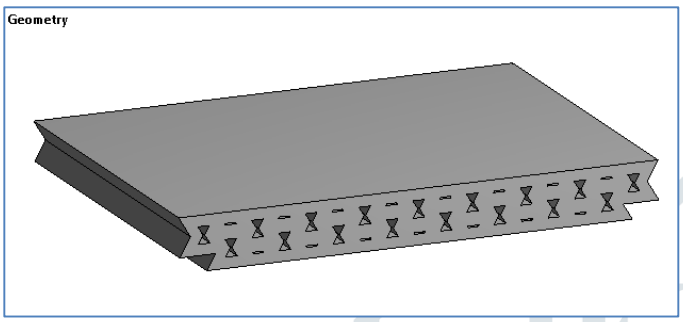


Fig.11 Cad model imported in ANSYS

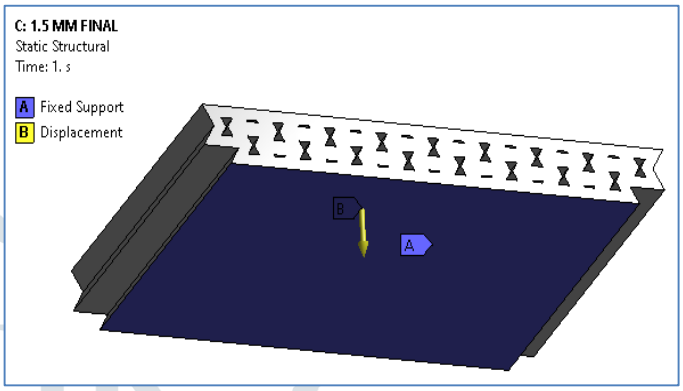


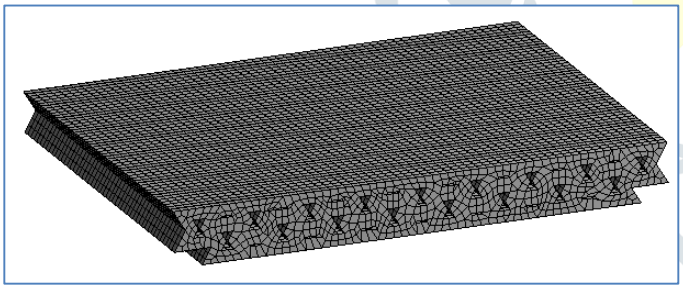
Fig.14 Boundary condition

Properties of Outline Row 4: PLA NEW			
	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	1.24E-09	tonne mm^-3
4	Isotropic Elasticity		
5	Derive from	Young's Modulus and Poiss...	
6	Young's Modulus	2000	MPa
7	Poisson's Ratio	0.35	
8	Bulk Modulus	2222.2	MPa
9	Shear Modulus	740.74	MPa
10	Bilinear Isotropic Hardening		
11	Yield Strength	42	MPa
12	Tangent Modulus	960	MPa

fig.12 Material properties

Details of "Displacement"	
Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Type	Displacement
Define By	Components
Coordinate System	Coordinate System
X Component	0. mm (ramped)
Y Component	0. mm (ramped)
Z Component	-3. mm (ramped)

Fig.15 Detail of displacement



Statistics	
Nodes	39525
Elements	29600

Fig.13 Meshing

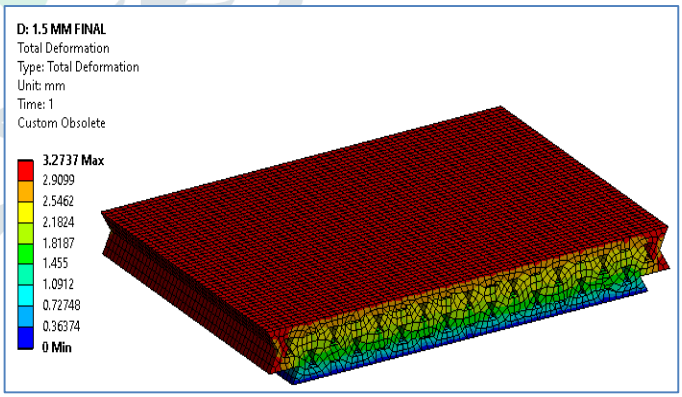


Fig.16 Total deformation

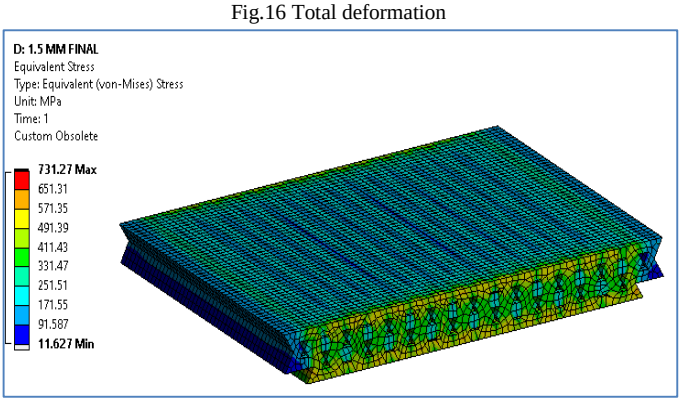


Fig.17 Equivalent stress

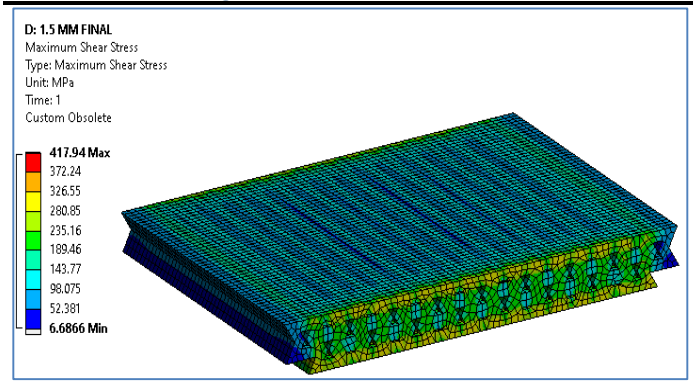
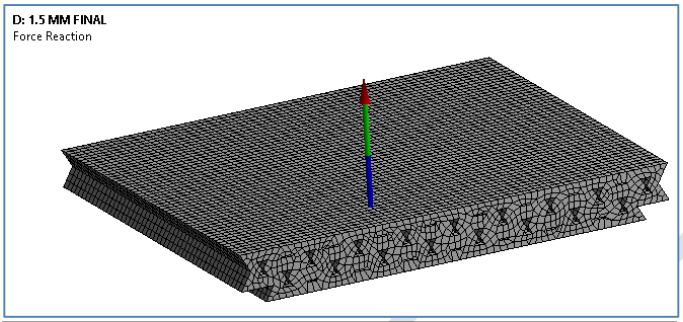


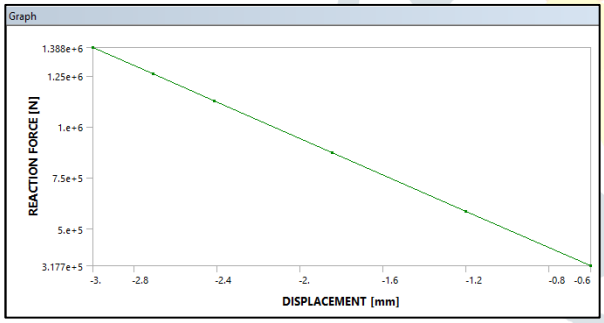
Fig.18 Maximum shear stress



Maximum Value Over Time	
X Axis	1.1058e-004 N
Y Axis	-9.0626 N
Z Axis	3.9819e+005 N
Total	3.9819e+005 N

Fig.19 Reaction force

It is observed that auxetic structure with 1.5 mm have more strength (force reaction) compared to 1 mm structure.



Graph.20 Reaction force vs displacement

VIII. Rapid Prototyping

Rapid prototyping is a group of techniques used to quickly fabricate a scale model of a physical part or assembly using three-dimensional computer aided design (CAD) data. Construction of the part or assembly is usually done using 3D printing or "additive layer manufacturing" technology.Rapid prototyping is a modelling technique that can speed up and improve new product development. Manufacturers, component suppliers and product designers use computer-aided design tools and rapid prototyping techniques such as three-dimensional printing or stereo lithography to create physical scale models of products for analysis and production tooling.

Auxetic Honeycomb Structure

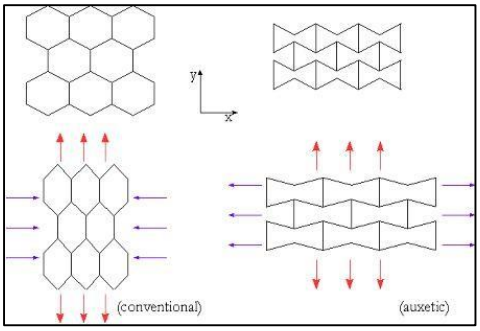


Fig. 12 Conventional and Auxetic Honeycomb Pattern

Auxetic materials and structures are a novel class of materials which have negative Poisson's ratio. They have improved mechanical properties such as fracture toughness, indentation resistance, etc.

Poisson's ratio () of a material is the ratio of the lateral contractile strain to the longitudinal tensile strain for a material undergoing tension in the longitudinal direction; that is, it shows how much a material becomes thinner when it is stretched. Therefore, most of the materials have a positive. In case of counterintuitive behavior of auxetic material, it undergoes lateral expansion when stretched longitudinally and becomes thinner when compressed.

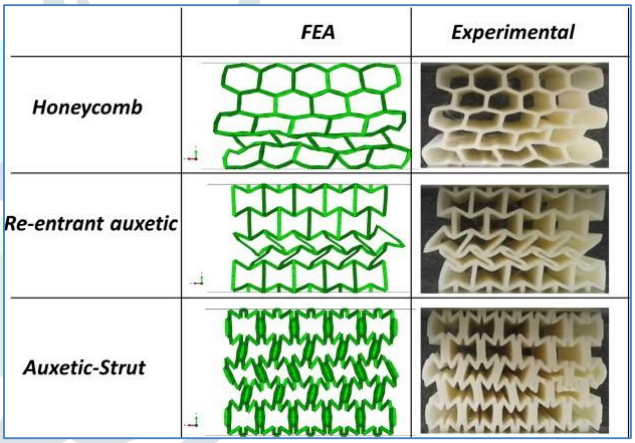


Fig.22 Auxetic and hybrid honeycomb structure.

IX. Manufacturing Process

First 3D CAD model of the specimen of Thermoplastic Polyurethane (TPU) material has a dimension ($L \times W \times H$) $50 \times 50 \times 3$ and wall thickness 1mm are designed in Catia V5. after that file is load into FDM machine for printing specimen.

In FDM, a spool of (Thermoplastic Polyurethane (TPU)) filament is loaded into the printer and then fed to the extrusion head, which is equipped with a heated nozzle. Once the nozzle reaches the desired temperature, a motor drives the filament through it, melting it.

EXPERIMENTAL SETUP

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials. An earlier name for a tensile testing machine is a tensometer. The "universal" part of the name

reflects that it can perform many standard tensile and compression tests on materials, components, and structures (in other words, that it is versatile). The set-up and usage are detailed in a test method, often published by a standards organization. This specifies the sample preparation, fixturing, gauge length (the length which is under study or observation), analysis, etc.The specimen is placed in the machine between the grips and an extensometer if required can automatically record the change in gauge length during the test. If an extensometer is not fitted, the machine itself can record the displacement between its cross heads on which the specimen is held. However, this method not only records the change in length of the specimen but also all other extending / elastic components of the testing machine and its drive systems including any slipping of the specimen in the grips.Once the machine is started it begins to apply an increasing load on specimen. Throughout the tests the control system and its associated software record the load and extension or compression of the specimen.

Specification of UTM

1	Max Capacity	400KN
2	Measuring range	0-400KN
3	Least Count	0.04KN
4	Clearance for Tensile Test	50-700 mm
5	Clearance for Compression Test	0- 700 mm
6	Clearance Between column	500 mm
7	Ram stroke	200 mm
8	Power supply	3 Phase , 440Volts , 50 cycle. A.C
9	Overall dimension of machine (L*W*H)	2100*800*2060
10	Weight	2300Kg

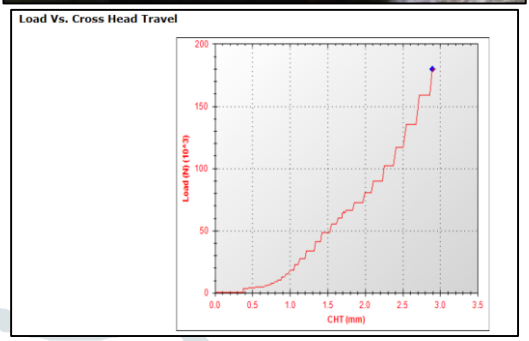


fig.23 Experimental testing for 1 mm thickness

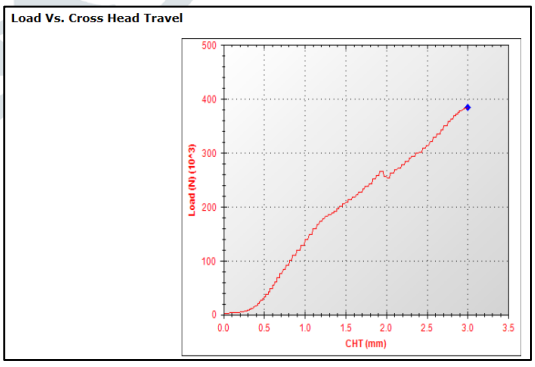


fig.24 Experimental testing for 1.5 mm thickness

EXPERIMENTAL TESTING FEA

For 1 mm thickness

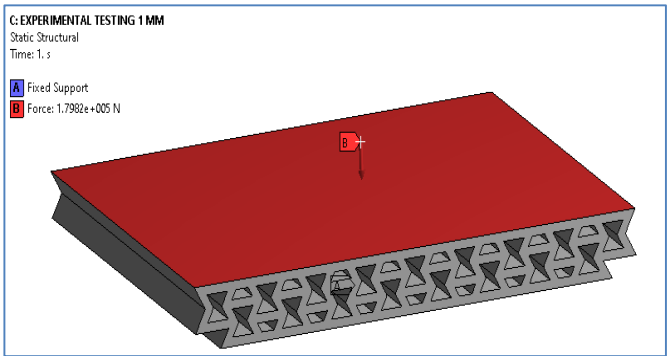


Fig.25 Boundary condition

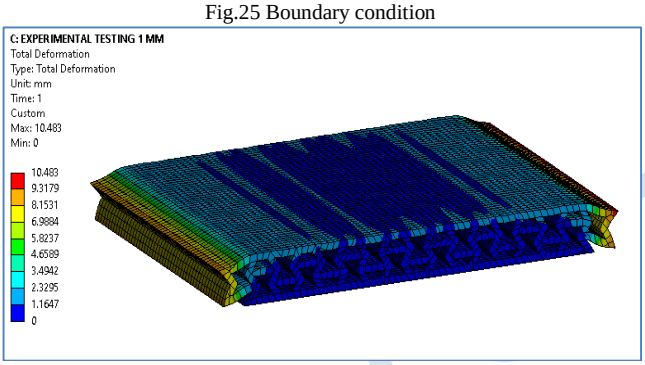


Fig.26 Total deformation

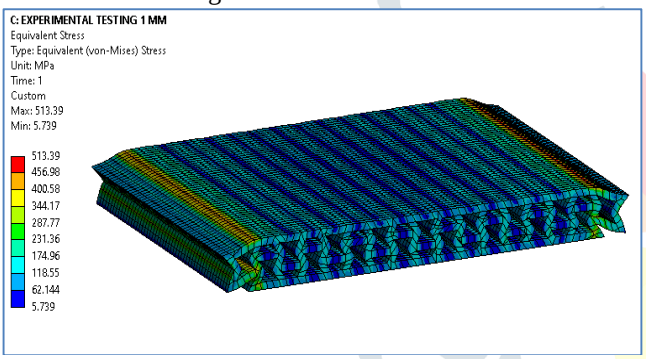


Fig.27 Equivalent stress

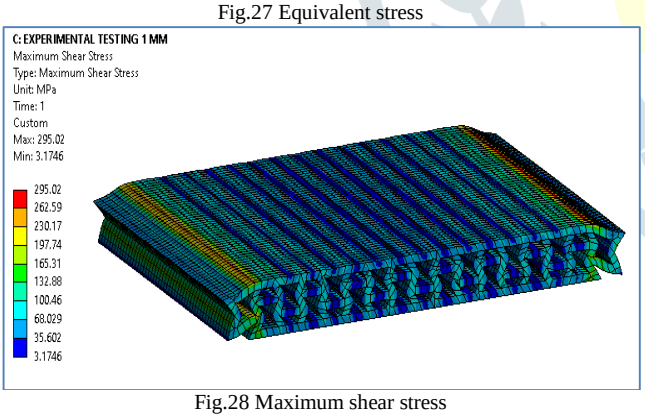


Fig.28 Maximum shear stress

It is observed that auxetic structure with 1.5 mm have more stress compared to 1 mm structure.

For 1.5 mm thickness

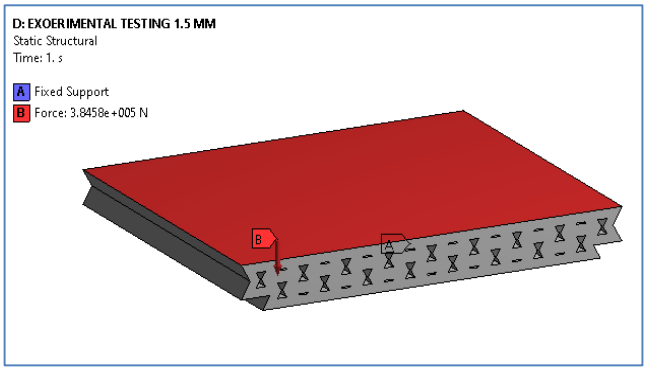


Fig.29 Boundary condition

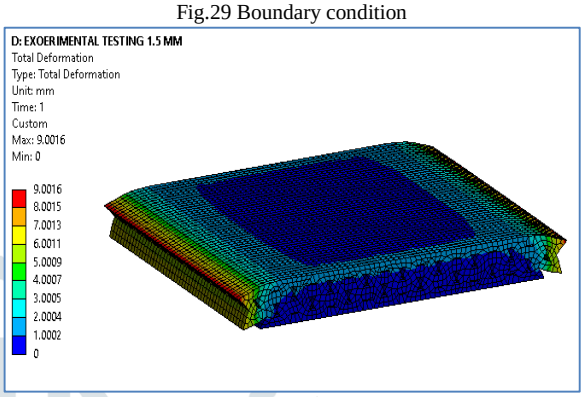


Fig.30 total deformation

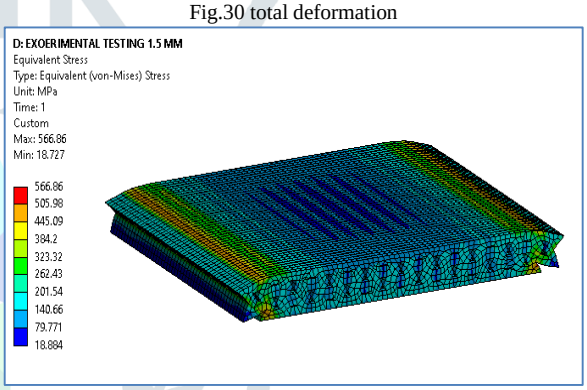


Fig.31 Equivalent stress

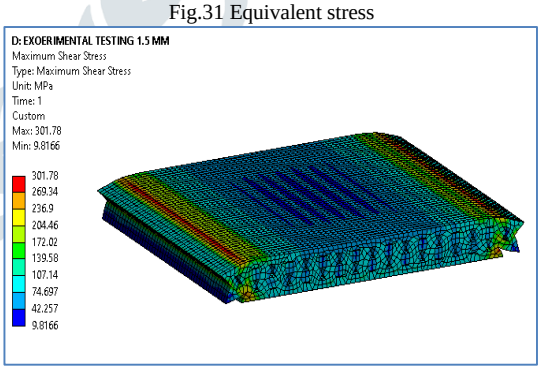


Fig.32 Maximum shear stress

RESULT AND DISCUSSION

FEA Analysis Result

In this project we utilization of Thermoplastic polyurethane material for reducing the weight of the automobile Auxetic structure material with 1mm & 1.5mm thickness.

FEA Analysis Result value is

1mm Thickness

Total force = 189170 N

1.5mm Thickness

Total force = 398190 N

Experimental Test Result for

1mm Thickness

Total force =179820 N

1.5mm Thickness

Total force =384580 N

Sr.No	FEA RESULT	EXPERIMENTAL RESULT	DIFFERENCE
1.(1mm thickness)	189170 N	179820 N	9350 N
2.(1.5mm thickness)	398190 N	384580 N	13610 N

Result of force reaction in FEA and UTM are matched with 10% error so experiment validation are complete

X. CONCLUSION

- Project work deal with the utilization of Thermoplastic polyurethane material for reducing the weight of the automobile so that it becomes lighter and makes it more efficient.
- The objective of this project is to analyze whether thermoplastic polyurethane is suitable for manufacturing interior parts of an automobile. The compression test on this material by using ANSYS and Universal Testing Machine is performed.
- During static analysis deformation, stress, shear stress plots are observed to visualize the stress level over surface.
- It is better to use auxetic structure of 1.5 mm in application purpose of its better strength and greater sustainability.

XI. REFERENCES

[1] John O. Akindoyo, M.D.H. Beg, Suriati Ghazali, M.R. Islam, NitthiyahJeyaratnam and A.R. Yuvraj Polyurethane types, synthesis and applications- a review; International Journal of Scientific & Engineering Research, Volume 5, Issue 1, January-2014; pp.: 1-31.

[2] Simon R.G. Bates, Ian R. Farrow and Richard; Compressive behaviour of 3D printed thermoplastic Polyurethane honeycombs with grated densities; Science Direct; ISSN: 0975-5462 Vol. 5 No.09 November 2018; pp.: 1-13.

[3] Siddharth Bhandari and B Regina; 3D printing and its application, International Journal of Computer Science and Information Technology Research, Volume 2 Issue 2, April-June 2014, pp.: 1-3.

[4] Mariam Mir, Murtaza Najabat Ali, Javaria Sami, and Umar Ansari, Review of Mechanics and applications of Auxetic Structures Kinetic, Volume 3, Issue 4; November 2014; pp.: 1-5.

[5] D. A. Pardo, G. E. Jabbour and N. Peyghambarian,"Application of screen printing in the fabrication oforganic light-emitting devices," Advance Materials, vol. 12, no. 17, p. 1249–1252, September 2000

[6] E. Tuncer, I. Sauers, D.R. James, A.R. Ellis,M.P. Paranthaman, A.Goyal, and K.L. More, "Enhancement of dielectric strength in nanocomposites," Nanotechnology, vol. 18, 325704, 2007.

[7] 7 T. B. V. H. P. R. L. U. L. S. Sari Merilampi, "Analysisof electrically conductive silver ink on stretchablesubstrates under tensile loading," MicroelectronicsReliability, vol. 50, no. 12, pp. 2001-2011,16 June 2010.

[8] Valentine, K.; Alojz, I. Mechanical characterization of polyurethane elastomer for biomedical applications. J. Mech. Behav. Biomed. Mater. 2010.

[9] Noel, A.; Faucheu, J.; Rieu, M.; Viricelle, J.P.; Bourgeat-Lami, E. Tunable architecture for flexibleconductive graphene-polymer composites. Compos. Sci. Technol. 2014, 95, 82–88.