COMPRESSION TEST AND ANALYSIS OF TPU MATERIAL USING UTM & FEA

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***Abstract*: The automotive industry uses engineered polymer composites and plastics in a wide range of applications. Leading experts say there are four areas that require highest-priority research and development with plastics: *interior*, *body* and *exterior*, *powertrain* and *chassis*, *light weighting*. Polyurethanes (PUs) are a class of versatile materials with great potential for use in different applications, especially based on their structure–property relationships. Automotive interior parts such as gear knobs, instrument panels, or console parts have to meet the stringent requirements in terms of surface quality, aging, abrasion and scratch resistance, while being economical. A small specimen of Thermoplastic Polyurethane (TPU) material has dimension ($L \times W \times H$) $61 \times 50 \times 7$ and wall thickness 1mm are manufacturing by Fused Deposition Modelling. (FDM) The 3D model will be drawn with the help of CATIA V5 software and static analysis of specimen will be carried out with the help of ANSYS 19 software. The main aim of project is to study the effect of compression test on the TPU base material specimen.**

Index Terms: **Thermoplastic Polyurethane, FEA, UTM, FDM.**

I. INTRODUCTION

Thermoplastic polyurethane (TPU) is a melt-processable thermoplastic elastomer with high durability and flexibility. TPU provides a large number of physical and chemical property combinations for the most demanding applications such as automotive, wires and cables, breathable films for leisure, sports and textile coatings, weatherable, non-yellowing films etc. It has properties between the characteristics of plastic and rubber. Thanks to its thermoplastic nature, it has several benefits over other elastomers are unable to match, such as:
Excellent tensile strength, High elongation at break, and Good load bearing capacity .Polyurethanes (PUs) are a special group of polymeric materials that are in many ways different from most of the other plastic types. They can be incorporated into many different items, such as paints, liquid coatings, elastomers, insulators, elastic Fibers, foams, integral skins, etc
Thermoplastic polyurethanes (TPUs) reveal vast combinations of both physical properties and processing applications. Usually, they are flexible and elastic with good resistance to impact, abrasion and weather. With TPUs, there is the possibility for coloring as well fabrication using a wide range of techniques. The incorporation of TPUs could therefore improve the overall durability of many products .TPUs are melt processable, like other thermoplastic elastomers. They may be fabricated using extrusion, blow, compression and injection moulding equipment. They may also be solution-coated or vacuum-formed, which makes them suitable to be made by a large range of fabrication techniques. The several property combinations of TPUs makes them suitable for many applications, such as in automotive, footwear and construction

II. LITERATURE REVIEW

[1] Tomasz Wierzbicki et al.(1983) A method for determining the crushing strength of hexagonal cell structures subjected to axial loading is given. The method is based on energy considerations in conjunction with a minimum principle in plasticity. The problem is shown to be equivalents to the analysis of a system of collapsing angle elements undergoing bending and extensional deformations. The theory is first developed for an arbitrary angle between panels and then is specified for the 120 ° angle, appropriate for the hexagonal cell structures. Simple formulas are derived relating the crushing force and the wavelength of the local folding wave to the wall thickness and diameter of the cell. The theoretical solution has been compared with experimental results published in the literature and an excellent correlation has been obtained for the wide range of geometrical parameters involved. This solution replaces the less accurate earlier analysis of the same problem due to McFarland. The purpose of this study was to provide a simple and rational means by which hexagonal cell structures can be designed for use as energy absorbers in impact or impulsive loading situations.

[2] Yeqiu Yu et al.(2018) This work investigates the quasi-static crush response and energy absorption of the layered composite circular tubes formed by matching thin-walled tubes with novel crochet-sintered mesh tubes (CSMTs). The matching effect existed between the CSMT and the thin-walled tube has been observed. The CSMTs are suitable for application as energy absorption components to improve the load-bearing capacity and energy absorption of thin-walled tubes. The load-carrying capacity, energy absorption, effective stroke ratio and crushing force efficiency of layered composite tubes all increases, compared to those of metal thin-walled tube. The increment scale of energy absorption can be reach 106%. The load-carrying capacity, energy absorption, crushing force efficiency and specific energy absorption of the three-layered structure are higher than those of the two-layered structures. These show that the former have better structure crashworthiness than the latter. The layered composite tubes show great potential for application as energy absorbers.

[3] Fangyun Lua et al.(2017) Quasi-static axial compression tests were conducted on two types of empty aluminum alloy tubes (circular and square) and five types of aluminum ex-situ foam filled tube structures (foam-filled single circular and square tubes, foam-filled double circular and square tubes, and corner-foam-filled square tube). The load-deformation characteristics, deformation mode and energy absorption ability of these structures were investigated. Several parameters related to their crashworthiness were compared, including the specific energy absorption, the energy-absorbing effectiveness factor, etc. The influence of physical dimension on the crashworthiness of these structures was explored. Dimensions of the inner tube were found to have significant influence on the structural crashworthiness of foam-filled double tubes. The averaged crush force, specific energy absorption, energy absorption per stroke and energy-absorbing effectiveness factor of thin-walled circular structures are higher than those of thin-walled square structures, respectively.

[4] Ben Youngc et al.(2018) This paper presents experimental and numerical investigations and design of concrete-filled double-skin aluminum stub columns with circular hollow sections (CHS) as both outer and inner skins. A series of tests was carried out to investigate the effects of the geometric dimension of the aluminum CHS and concrete strength on the behaviour and strength of the composite columns. The CHS tubes were fabricated by extrusion using 6061-T6 heat-treated aluminum alloy having nominal 0.2% proof stress of 240MPa. The structural performance of the composite columns was investigated using different nominal concrete cylinder strengths of 40, 70 and 100MPa. A non-linear finite element model is developed and verified against the experimental results. The test results and the composite column strengths predicted from the finite element analysis (FEA) were compared with the design strengths to evaluate the reliability of the design rules in the current American specifications for aluminum and concrete structures. Furthermore, design equations were proposed to consider the benefits of the composite columns due to the composite action between the aluminum tubes and concrete. The proposed design equations accurately predicted the ultimate strengths of the concrete-filled double-skin aluminum CHS stub columns.

[5] Ahmad Soman(2018) This article examines the effects of column slenderness and internal confinement on the behaviour of eccentrically-loaded circular RC columns strengthened with fiber reinforced polymer (FRP) sheets. Test parameters included column height, level of transverse reinforcing steel, and absence/presence of FRP jackets, fiber orientation and stiffness of the jacket. Tests proved that FRP wraps can be effectively used to enhance the strength, toughness, ductility and deformation capacities of eccentrically loaded-columns and that their efficiency decreases with increased slenderness. Tests showed that variations in internal confinement have a lower impact on column behaviour compared to the external FRP confinement. Negligible improvements in load-carrying capacities of columns confined with one hoop FRP sheet were encountered upon adding a longitudinal sheet. Conventional section analysis using material properties based on the stress–strain model adopted by the American Concrete Institute for FRP-confined concrete under combined axial compression and bending resulted in over estimation of axial column strengths.

III. Problem Statement

The automotive industry uses engineered polymer composites and plastics in a wide range of applications, as the second most common class of automotive materials after ferrous metals and alloys (cast iron, steel, nickel) which represent 68% by weight. The plastics contents of commercial vehicles comprise about 50 % of all interior components, including safety subsystems, door and seat assemblies. so there is an equally impotents of safety so analytical and experimental work on Thermoplastic polyurethanes material parts.

IV. OBJECTIVES

1. The Objective of our project is to study Compression behaviour of TPU material.
2. To prepare CAD design of TPU specimen using CATIA V5.
3. To study 3D printing manufacturing process.
4. Selection of 3D printing method for manufacturing Thermoplastic Polyurethane base specimen.
5. To perform static analysis of TPU specimen by using FEA.
6. Compression test of manufactured specimen by using UTM.
7. Validation of analytical and experimental work.

V. APPLICATIONS

BASF materials and expertise have helped BOSCH Automotive Products (Suzhou) Co Ltd. to produce it's groundbreaking BOSCH Intelligent Glove (BIG) faster and more efficiently, to meet growing demand in China's manufacturing sector. The BIG, made with thermoplastic polyurethane (TPU) from BASF,is a milestone in connected manufacturing that provides connectivity and transperency for the workforce. It will be launched in China in second half of 2019.

VI. METHODOLOGY

Step 1: - I started the work of this project with literature survey. I gathered many research papers which are relevant to this topic. After going through these papers, I learnt about Compression test and analysis of TPU Material specimen/part using UTM and FEA

Step2: - After that the components which are required for my project are decided.

Step 3: - After deciding the components, the 3 D Model and drafting will be done with the help of CATIA software.

Step 4:- The Static Analysis will be carried out with the help of ANSYS software.

Step 5:- Manufacturing of Thermoplastic Polyurethane base specimen in by using 3D printing process.

Step 6:- The experimental observations will be taken on Universal Testing Machine.

Step 7:- Comparative analysis will be made between simulation and experimental results and then Results and conclusions will be drawn.

CATIA

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations.

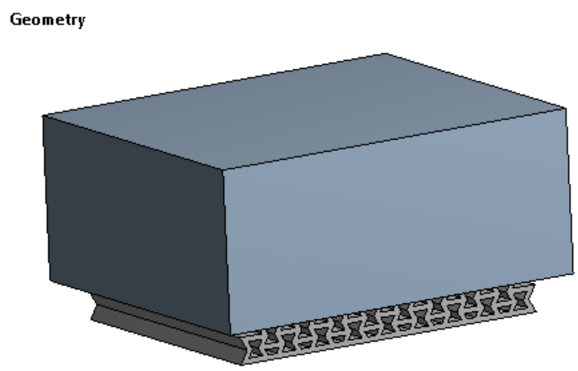
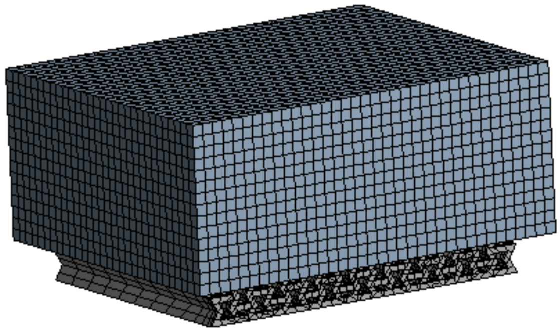


Fig.no.1 CATIA model

MESH

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient metaphysics 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.

Creating the most appropriate mesh is the foundation of engineering simulations. ANSYS Meshing is aware of the type of solutions that will be used in the project and has the appropriate criteria to create the best suited mesh. ANSYS Meshing is automatically integrated with each solver within the ANSYS Workbench environment. For a quick analysis or for the new and infrequent user, a usable mesh can be created with one click of the mouse. ANSYS Meshing chooses the most appropriate options based on the analysis type and the geometry of the model. Especially convenient is the ability of ANSYS Meshing to automatically take advantage of the available cores in the computer to use parallel processing and thus significantly reduce the time to create a mesh. Parallel meshing is available without any additional cost or license requirements.



Statistics	
Nodes	91667
Elements	19827

Fig. 2 Meshing of Model

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.

The main types of loading available in FEA include force, pressure and temperature. These can be applied to points, surfaces, edges, nodes and elements or remotely offset from a feature. The way that the model is constrained can significantly affect the results and requires special consideration. Over or under constrained models can give stress that is so inaccurate that it is worthless to the engineer. In an ideal world we could have massive assemblies of components all connected to each other with contact elements but this is beyond the budget and resource of most people. We can however, use the computing hardware we have available to its full potential and this means understanding how to apply realistic boundary conditions.

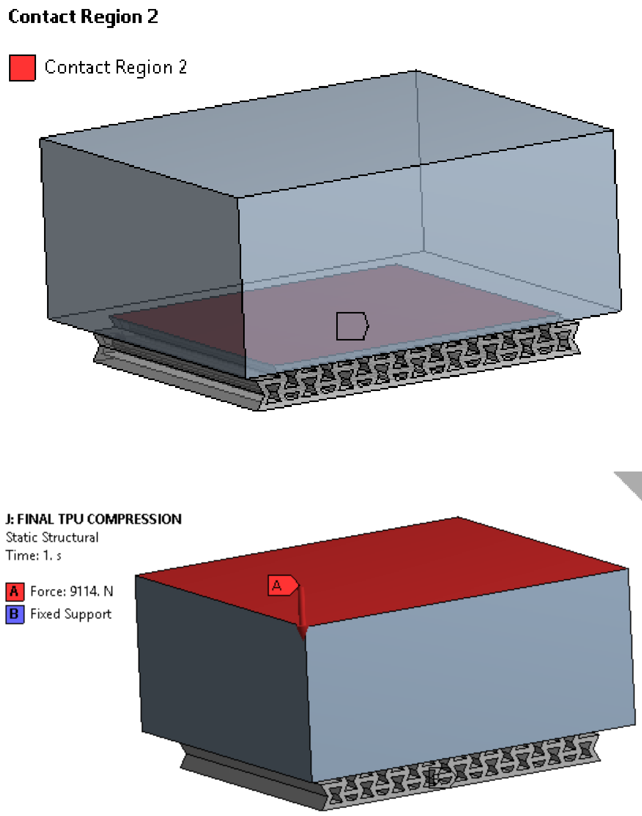


fig. 3. Boundary condition of model

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 vectors sum all directional displacements of the systems.

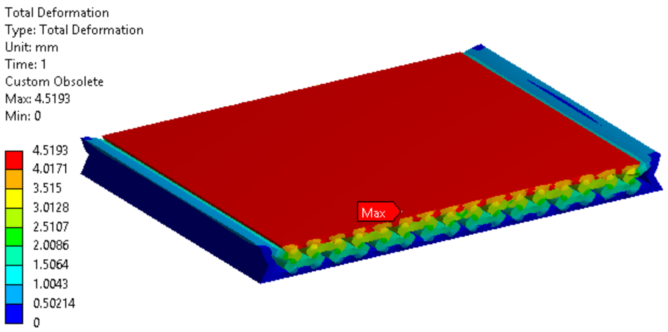


fig. 4 Total Deformation of Model

Maximum deformation of specimen after applying 9114N is 4.519 mm

Equivalent Stress

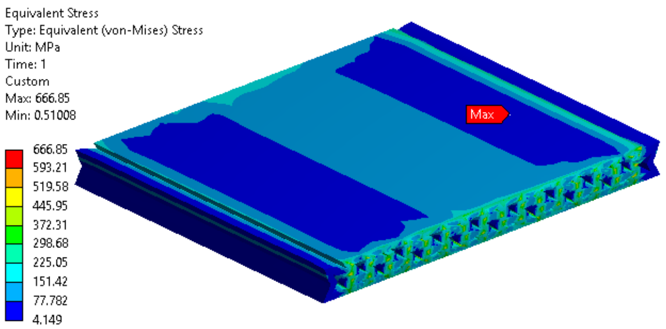


fig. 5. Equivalent Stress

Maximum Equivalent Stress of Thermoplastic Polyurethane base specimen is 666.85 MPa

Maximum Principal Stress

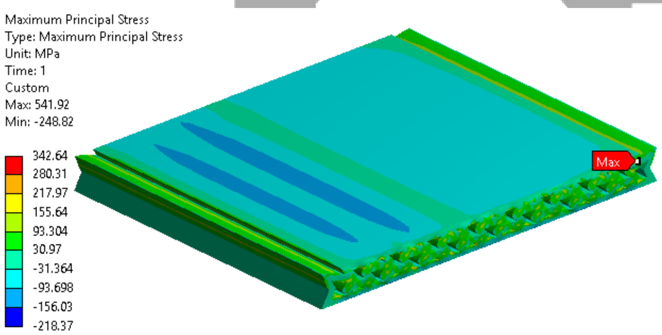


fig. 6. Maximum Principal Stress

Maximum Principal Stress of Thermoplastic Polyurethane base specimen is 541.92 MPa

Maximum shear stress

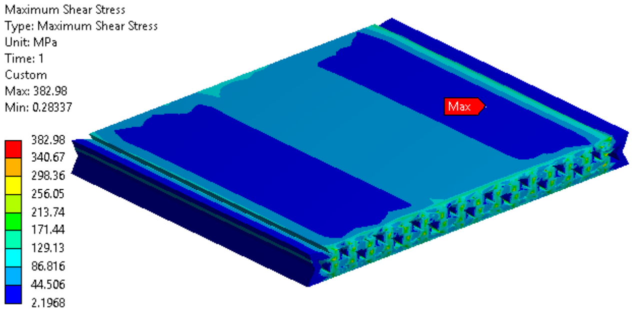


fig. 7. Maximum shear Stress

Maximum shear Stress of Thermoplastic Polyurethane base specimen is 382.98 MPa

VII. MANUFACTURING PROCESS

First 3D cad model of specimen of Thermoplastic Polyurethane (TPU) material has dimension ($L \times W \times H$) $61 \times 50 \times 7$ and wall thickness 1mm are design in Catia V5. after that file are 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.

The printer moves the extrusion head, laying down melted material at precise locations, where it cools and solidifies (like a very precise hot-glue gun). When a layer is finished, the build platform moves down and the process repeats until the part is complete.

After printing, the part is usually ready to use but it might require some post-processing, such as removal of the support structures or surface smoothing.

After printing / manufacturing specimen we perform experimental work

VIII. EXPERIMENTAL TESTING

A universal testing machine (UTM), it is also known as a universal tester, Materials testing machine or materials test frame, it is used to test the strength i.e. compressive strength and tensile strength of materials. An earlier name for a tensile testing machine is a tensometer. The "universal" name itself indicates that it can perform many standard compression and tensile tests on materials, components, and structures. A UTM machine, also known as a materials testing machine, universal tester or materials test frame, is used for testing the tensile strength as well as compressive strength of the materials. An earlier name for a tensile testing machine is a tensometer. The name "universal" reflects that it can perform many type of standard tensile as well as compression tests on materials, components & structures i.e in other words, that it is versatile machine.
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. it also have an advantage, If an extensometer is not fitted, the machine itself can record the displacement between its cross heads on which the specimen is held with help further for record. However, the other thing we have to keep in mind, this method not only records the change in length of the specimen but also all other extending / elastic part of the testing machine and its drive systems including any slipping of the part in the grips.
Once the machine is started it starts to apply an increasing load on the specimen. Throughout the tests the control system and its associated software help us to record the load and expansion or compression of the specimen.

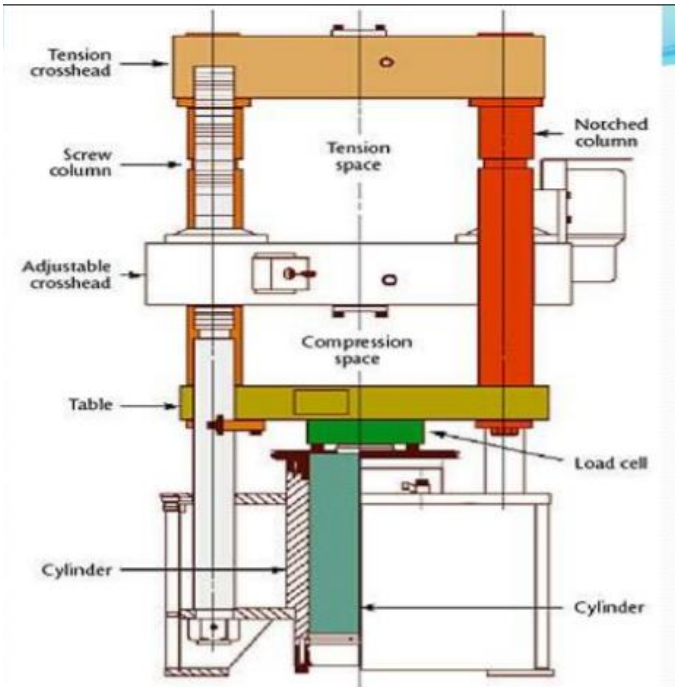


Fig. 8 Universal Testing Machine

Table no. 1 Specification of UTM

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

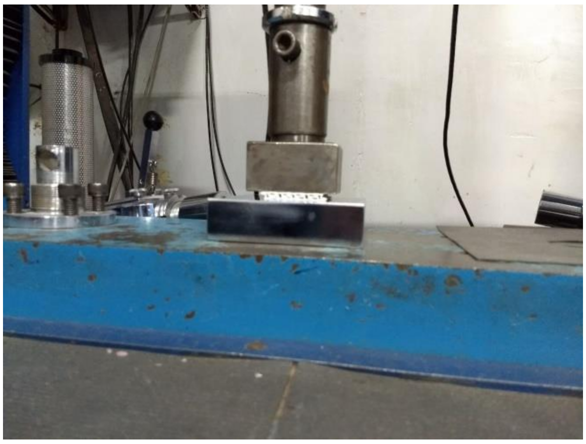
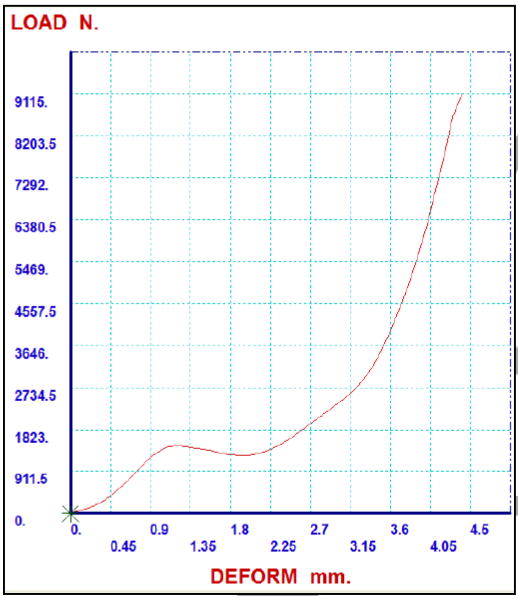


Fig. 9. Experimental testing



Graph 1 Compression test (load VS deformation).

IX. CONCLUSION

- The TPU material is used. This material has high strength to weight ratio.
- Total Deformation of Specimen by using FE analysis is 4.519mm.
- From compression test conclude that total deformation in specimen is 4.5mm.
- .And this both result value are nearly equal. So Validation of analytical and experimental work of project done .

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