International Journal of Scientific Research and Engineering Development-– Volume 3 - Issue 4, July - Aug 2020

Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Experimental and FE Analysis of Modified 3d Printed Front Collision Bumper with Hexagonal Honeycomb Structure

Ms. Prachi R.Pagare PG Student*,

*(Mechanical engineering dept. of PDV VikhePatil College
Ahmednagar, Maharashtra
E-mail:Pagareprachi0@gmail.com)

Prof. Prashant Narwade**,

** (Mechanical engineering dept. of PDV VikhePatil College
Ahmednagar, Maharashtra
E-mail: narwadeprashant@gmail. com)

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Abstract:

The 3(D) printing or additive manufacturing could be a process of manufacturing a component or product layer by layer to finalized a product. Over recent couples of years The three-dimensional (3D) printing technology has experienced a lot of innovations and fastest growth in industry. It offers fastest product development cycles, low investment cost of starting up of production, on demand of production and local production. It can possible to hold a promise to create a component with highest rate and simultaneously low waste. The focus of this project work is to present a study of the mechanical behavior of 3D printed honeycomb structures beam using 3 D printing technology with the base material for comparison of existing design and material. Study is to Design of honeycomb structure with flexural strength to determine force reaction, stress and deformation for 3D front collision car bumper. Flexural tests are to be conducted to determine the mechanical properties their failure characteristics of 3 D printing with the change of materials. Depends on the analysis results of experiment, a graphical stress-strain relationship and a failure criterion based on the maximum stress criterion for 3 D printing materials are proposed for the structures of 3D printed material. Finally, a finite element analysis was conducted for a 3D printed honeycomb structure for front collision car bumper design , which shows that the parameters like printing direction has a significant influence on the load bearing capacity of the design of the application.

Keywords—FEA, collision bumper, Honeycomb structure, polyacetal ,bending test, UTM

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I. INTRODUCTION

3D printing is the process of constructing the desired product with the help up of a CAD model or a digital 3D model. It includes a variety of processes in which the selected material is deposited with layered configuration, joined, solidified under computer controlled to form a model of the component or a prototype model with a material being inserted together like as in liquid molecules or powder grains fused together typically layer by layer. in the 1980's this process is considered suitable only for production of aesthetic prototypes, functional purpose which is known for rapid prototyping process, nowadays in 2020 the precision work ,repeatability and the selection of material for the component has increased to the extent such that techniques are considered viable as an industrial production technology, where by this additive manufacturing process term can be used simultaneously with the 3D printing term. Its key advantages of printing that it can produce complex geometries or intricate shapes with the precised work which is not possible to manufacture with hand including hollow parts or parts which have a internal truss structure which reduced weight. 3D printing was first developed in the 1980's as sound system lithography (SL). The proposed work of this process was planned for disentangling the prototyping procedure by decreasing time associated with the product and cost related with customary techniques to reduces the wight. FDM is the most common process of 3d printing in use as of 2018 according to survey FDM has become the most famous and generally utilized AM strategy with one fourth of the machines in industrial sector being of this kind[1]-[3]. The use of FDM in 2018 was 46% than the other process is a material extrusion technique known as fused deposition modelling. While it is later developed than the other two popular technologies that is stereolithography and selective laser sintering. Which is most inexpensive of the other two by large margin, which causes its to become popular in process.3D printed models is generated with the catia design that is CAD design via 3D Scanner. It can generate the model with a very few errors than the other methods. The errors are corrected or identified before the component is printed 3D scanning is a technique of collecting digital data on the shape and appearance of the final object, which creates a digital model upon it[4]. The CAD model is saved in the stereolithography file format, a de facto file cad format for 3d printing that stored dada based on triangulations of the surface of catia models, a new one CAD file format that is additive manufacturing file format was innovated in 2011 to solve the problem associated with the STL file format which was non tailored for AM process which were generates large size of topology optimized parts and their lattice structure because of large numbers of surfaces involved in process. Before printing it should be tested for errors in STL file most of cad applications produce errors in output STL files of holes, self-interconnection, noise shells, faces normal, manifold errors. As the innovation in technology of FDM proceeded, the nature of parts created improved with the growth and development into a last assembling technique.There exists an different technology of added substance producing strategies, of which the most widely known incorporate Fused Deposition Modeling (FDM), Electron Beam Sintering (EBS) and Powdered Laser Sintering (PLS).PLS and EBS include utilizing a laser and an electron pillar individually to melt metal powder in bunches of even layers, constructing the model lateraly, while FDM melts and stores material layer by layer through a spout. Notwithstanding, the use of 3D printing and added substance fabricating in industry has developed also, as new strategies and research bring about upgrades version in the nature of prints. The most important circumstances of 3D printing and the explanation it has such a significant task to carry out in the assembling segment is on the grounds that it tends to be utilized to make segments which ordinary assembling can't make. This incorporates complex shapes or geometry which are difficult to manufacture , which costly to plant or machine, for example, structures with inward depressions or those which don't permit access to regions which need machining. It is perfect for lean creation, where parts are possibly delivered when required with the aim for no stock is kept. Also, squander is minimum as just the material required for the part is utilized during make.A bumper is a shape connected to or attached with the front and rear ends of a motor car, to take in impact in a minimum collision, ideally minimizing repair cost. Stiff metallic bumpers regarded on automobiles as early as 1904 that had a mainly decorative feature. Tremendous developments, enhancements in materials and technologies, as well as greater recognition on specifications for shielding car components and enhancing protection have modified bumpers over the years. Bumpers ideally limit height mismatches among motors and defend pedestrians from damage. Regulatory measures were enacted to minimise the vehicle repair costs and, more lately, impact on pedestrians. Bumpers are more and more being designed to reduce the damage to pedestrians struck by using automobiles, inclusive of via the usage of bumper covers fabricated from associated flexible materials. Front bumpers, specially, have been diminished and manufactured from softer materials, including foams and crushable plastics, to reduce the severity of impact on legs[4]-[7]. Some bumpers offer better safety than others. Plain and easy. Factors which can impact the effectiveness of your bumper encompass materials, design, integrated lighting fixtures, and the quantity of overhang your bumper has. While you could favour a sure bumper style, you must also don't forget your using habits. An aggressive metal bumper with a large amount of overhang might not be perfect for drivers who persist with paved roads, but should provide extraordinary protection on the path. Smaller and sleeker OEM bumpers generally raise your gas economy and offer ok safety in greater urban settings without stressing your front suspension

□. LITERATURE REVIEW

AMM Nazmulahsan et al.[1]In this research work it presents a novel grain-based division approach used for bended freestyle formed slim divider objects. The grain geometry is developed for most extreme consistency in their surface curvature and flow to lessen their manufacture unpredictability, bolster volume and creation time. When the grains are constructed, they are ideally arranged on the base plane to decrease the deviation brought about by the surface bend in the geometry. The grain is at that point decorated with variational hexagonal honeycomb sandwich core cells to catch useful variety. The approach of proposed is executed on two freestyle formed custom articles head protector and hand cast, and tried on industrially accessible printers for making. Depend on the quantity of grains, their Gathering time is to a great extent. With better get collected and basic soundness for example methodical grain to grain opening and connector can be utilized to facilitate the gathering procedure. It is observed that the thickness of cross section design remains stable inside each grain and shifts between grains. The proposed particular structure and assembling strategy will likewise be reasonable for appropriated assembling or network-based assembling coordinated effort for big sized parts.

KanygulChynybekovaet. al [2] In this article it focuses to make adaptable, stretchable, and lightweight delicate 3D printed questions by investigating their twisting reactions under pressure, pressure and flexure tests. The introduced look into thinks about delicate 3D printing, especially concentrating on the improvement of adaptable examples dependent on non-homogenous cross breed honeycombs for the inside of 3D printed articles to improve their adaptability and extra stretch ability including the lightweight inside. Through the examinations, we considered the effects of pressure, strain and flexure stacks on infill designs. It is observed that this investigation brings new developments into delicate 3D printing by giving these significant bits of knowledge into the plan procedure.

P Satya Lakshmiet al.[3] collision analysis of car bumper using steel material and the combination of composite material such that the weight of the vehicle is to reduce and ultimately for safety purpose to reduce the impact of collision over pedestrians so due to composite material properties weight of the vehicle and collision impact is reduced with the hand lay -up technique by doing the crash analysis he observed to that in composite honeycomb structure of car front collision bumper the impact of collision is reduced due to more energy gets absorbed than the existing one. A change of 25.62% less deformation in case of composite HC hybrid structure bumper than the existing one

Girish Kotwal et al.[4] Aluminium honeycomb panels are light in weight and absorb more energy they can bear pressure coming from the plates which provides the superior flat and rigidity if the plates are of large sizes. In sandwich panels of honeycomb structure aluminum is the core material used for honeycomb over that face plate or sole plate is stacked with the adhesive glue. This is free from environmental pollution , moisture proof so that it is clean and recyclable it is coated with the HVDF paint which is durable are free of mildew in damp environments. This material provides good strength to weight ratio, better toughness and good moisture and corrosion resistance for demanding application.

SudarshanGilakaraet al. [5] by using the 4 types of configurations of honeycomb structure vehicle car bumper analyzes that out of four tested configuration 3-3mm panels results obtained for this is best performing bumper and results greatly improved with existing bumper design. For the purpose of maintaining the aerodynamics and the aesthetics of the vehicle HC configured structure is assembled with the panels which looks like existing one he analyzes that by using this bumper design vehicle weight reduction is achieved with the reduced repair cost also he solves the problem faced by vehicle industry with the use of ordinary vehicle bumper design in the market overview.

Nitin S Motgiet al. [6]considered the change of size , shape and material properties of the vehicle bumper using the impact analysis test which is necessary in the safety point of view of the vehicle due to the increasing number of accidents on road there is need to check for the analysis over the structural parameters in terms of mentioned above.

Sumit Kumar Shuklaet al.[7] accordingly bumper is the most important part of the vehicle during collision so to absorb the energy are reduce impact to frontier solution over the accidents he suggest the material GFRP to improves the impact analysis of the front car bumper from the passenger safety point of view which improves the bumper design over the existing one which results in light in weight ultimately improves the fuel efficiency of the vehicle .He suggest the best material over the existing material.

. PROBLEM STATEMENT

After survey of literature review it is observed that use of 3 D printed components in day by day life is extensively used to replace existing solid body structure. Due to honeycomb structure load distribution and capability to sustain is greater. So, in present investigation 3 D printing material is used to understand the stress concentration and load carrying capacity along with low weight application e.g. space, aerospace and automobile.

.OBJECTIVES

- To investigate the effects of flexural strength and materials, manufacturing processes and length of span of honeycomb structure panel on existing front bumper.
- To Compare existing and modified design in FEA analysis.
- To perform static structural analysis of 3D printed material with the help of ANSYS 19 software.
- To determine reaction force for application of load/displacement on honeycomb structure panel.
- Manufacturing of 3D printed honeycomb panel to perform three-point bend test.
- Validation of experimental results of three-point bending test with FEM simulation.

. METHODOLOGY

Step 1:- Initially research paper gathered and are studied to find out research gap for project then necessary parameters are studied in detail. After going through these papers, we learnt about 3D printed honeycomb sandwich structure.
Step2:- Research gap is studied to understand new objectives for the decided project.
Step 3: - After deciding the application, the 3 D Model and drafting will be done with the help of software.
Step 4: - The components will be manufactured and then assembled with each other for three-point bend test.
Step 5: -The testing will be carried out and through testing the result and conclusion will be drawn.

. MATERIAL SELECTION

Here we have selected the polyacetal material as the material for the front collision bumper to increase the stiffness load bearing capacity and the reaction forces.

TABLE .
MATERIAL PROPERTIES

	Tensile strength (MPa)	Yield strength (Mpa)	Modulas of Elasticity(Gpa)	Density(Kg/m3)
Polyethylene	7.60-43	11-43	0.565-1.50	952-965
Polyacetal	5-70	43	0.586-11.7	1410

POM resins are extensively used inside the assembly of precision elements for packages annoying precise dimensional balance and sliding houses. Number of them include:

- Automotive
- Digital And Electrical
- Industrial
- Drug Delivery

The polymer serves as an another metals thanks to its its low friction and wear traits additionally to its exceptional stability of mechanical and chemical properties.
Reveal well-balanced homes ranging for mechanical to bodily and flammability performance. The key advantages of POM resins encompass:

- Excellent mechanical homes over a temperature variety upto one 100 forty°C, all the way right down to -40°C
- High tensile energy, rigidity and longevity (brief-time period)
- Low tendency to creep (compared to nylon) and fatigue (lengthy-time period). Not at risk of environmental pressure cracking
- High diploma of crystallinity and tremendous dimensional balance
- Excellent placed on resistance
- Low coefficient of friction
- Good resistance to organic solvents and chemicals (except phenols) at room temperature
- Low smoke emission
- High gloss surfaces

- Low moisture absorption

APPLICATION OF PROJECT

Pedestrians safety of view it is observed in 4-wheeler vehicle that front bumper are designed in either rectangular or circular shape with uniform cross section. But in present research to reinforce the shock absorbing resistance design is modified in hexagonal structure with varying flexural strength of hexagonal shape. To grasp and implicate the result in current design and future scope for innovative design implementation.

- **CATIA DESIGN OF ORIGINAL BUMPER**

The model is built up based on 80% overview of the planning from Honda car and for the simplicity of the manufacturing design point of view we have got constructed below showed model.

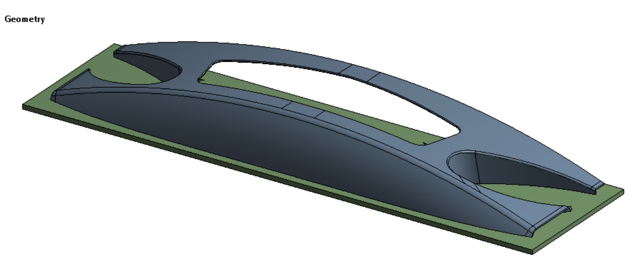


Fig.1 CATIA model imported in ANSYS without honeycomb structure

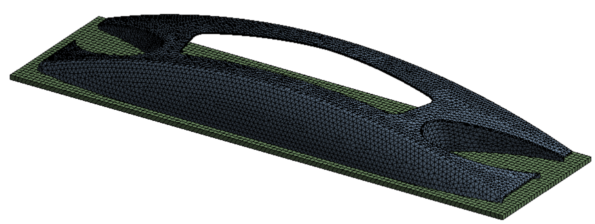
TABLE .□
MATERIAL PROPERTIES OF POLYETHYLENE

Properties of Outline Row 4: Polyethylene

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	950	kg m^-3
4	Isotropic Secant Coefficient of Thermal Expansion		
5	Coefficient of Thermal Expansion	0.00023	C^-1
6	Isotropic Elasticity		
7	Derive from	Young's Modulus and Pois...	
8	Young's Modulus	1.1E+09	Pa
9	Poisson's Ratio	0.42	
10	Bulk Modulus	2.2917E+09	Pa
11	Shear Modulus	3.8732E+08	Pa
12	Bilinear Isotropic Hardening		
13	Yield Strength	3.5E+07	Pa
14	Tangent Modulus	9.9E+08	Pa

Mesh

In ANSYS Mesh generation is a practice of generating a polygonal or polyhedral mesh which approximately mesh the geometric domain. Mesh-elements and nodes is commonly associated with the finite element method. This method of meshing is operated as similar to discretization process in FEA procedure in which it breaks whole product in small elements and nodes. So, in FE analysis boundary condition equation are solved at this nodes and elements. ANSYS Meshing is a general-purpose, automated high-performance, intelligent product. It produces the most appropriate and corrective mesh for accurate, efficient Multiphysics solutions. A mesh is well suited for a associated analysis can be created with a single mouse click of computer for all components in a model.



Statistics	
Nodes	78528
Elements	28646

Fig.2 Details of meshing

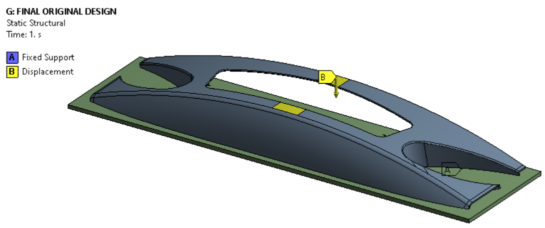


Fig.3 Boundary condition 1 of original design

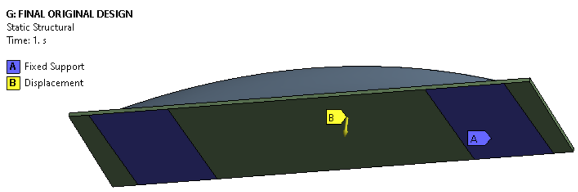


Fig.4 Boundary condition 2 of original design

Three-point bend test is performed with fixed support at base and displacement of 1 mm to determine reaction force.

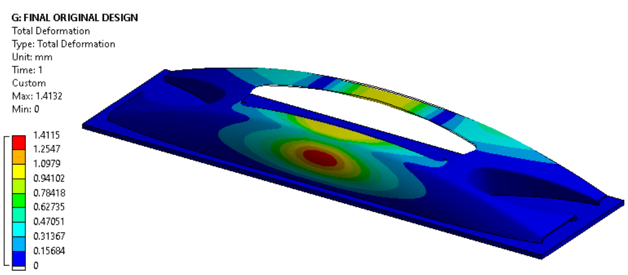


Fig.5 Deformation result of original design

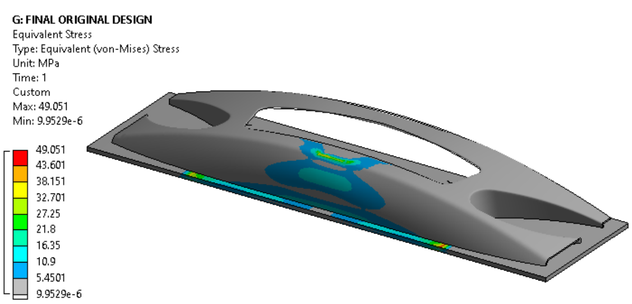


Fig.6 Equivalent stress results of original design

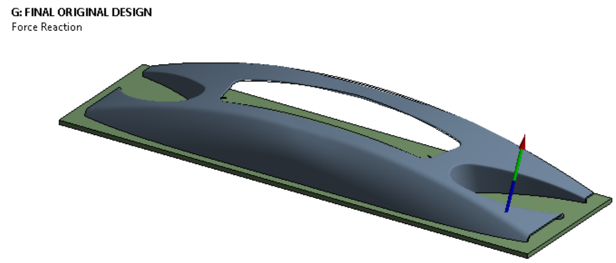


Fig.7 Force reaction result of original design

TABLE .

FORCE REACTION OF ORIGINAL DESIGN

Maximum Value Over Time	
X Axis	-0.54937 N
Y Axis	-15.193 N
Z Axis	40.423 N
Total	86.03 N

- **CATIA DESIGN OF ORIGINAL BUMPER WITH INTRODUCTION OF HONEYCOMB STRUCTURE**

The model is generated based on 80% of the design from Honda car with introduction of honeycomb structure and for the simplicity of the manufacturing design point of view we have constructed below showed model.

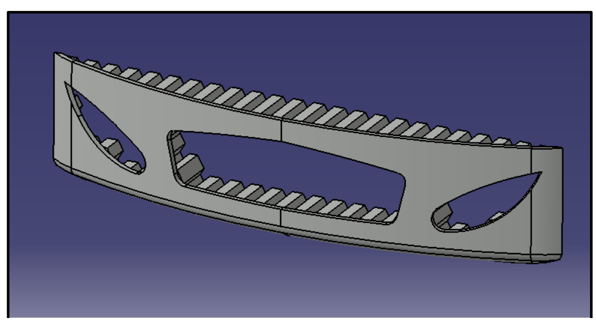


Fig.8 CAD design of honeycomb incorporated front collision bumper

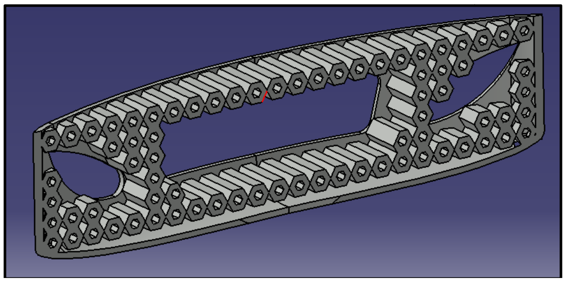


Fig. 9 Inside view of CATIA model of front bumper with honeycomb structure

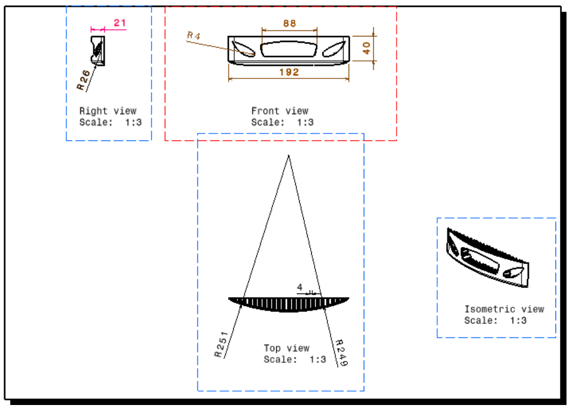


Fig.10 Drafting of front bumper with honeycomb structure

TABLE .
MATERIAL PROPERTIES OF POLYACETAL

Properties of Outline Row 3: POLYACETYL

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	1410	kg m^-3
4	Isotropic Elasticity		
5	Derive from	Young's Modulus and Poiss...	
6	Young's Modulus	3E+09	Pa
7	Poisson's Ratio	0.32	
8	Bulk Modulus	2.7778E+09	Pa
9	Shear Modulus	1.1364E+09	Pa
10	Bilinear Isotropic Hardening		
11	Yield Strength	4.2E+07	Pa
12	Tangent Modulus	9.6E+08	Pa

- **CATIA MODEL OF OPTIMIZED DESIGN FOR BUMPERWITH HONEYCOMB STRUCTURE**

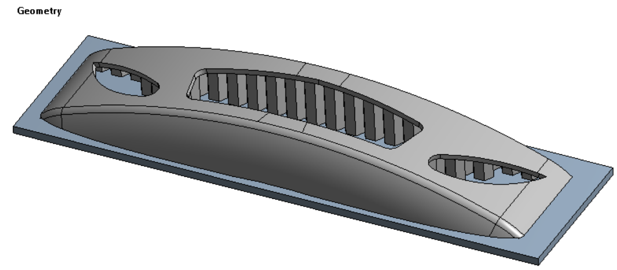


Fig. 11 Geometry of optimized front collision bumper with honeycomb structure

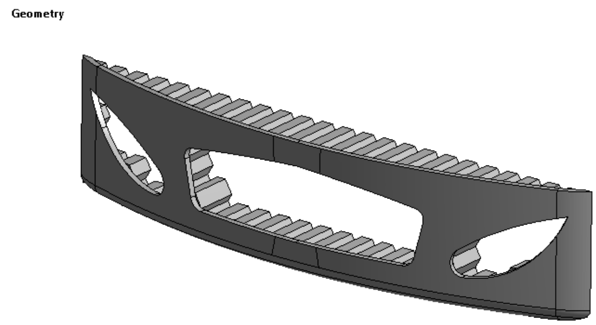
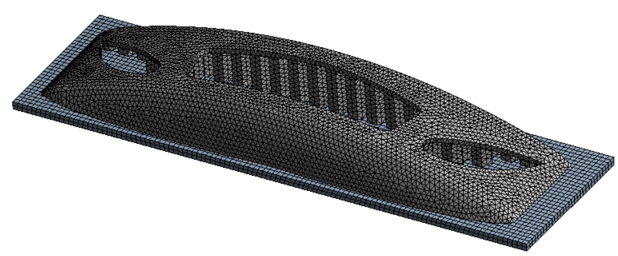


Fig.12 Another view of Geometry of modified front bumper with honeycomb structure



Statistics	
Nodes	135209
Elements	60280

Fig.13 Details of meshing of optimized design

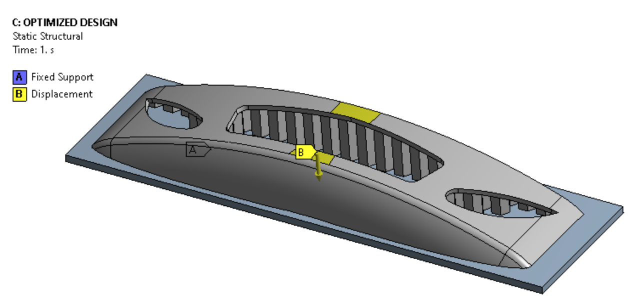


Fig.14 Boundary condition for optimized design

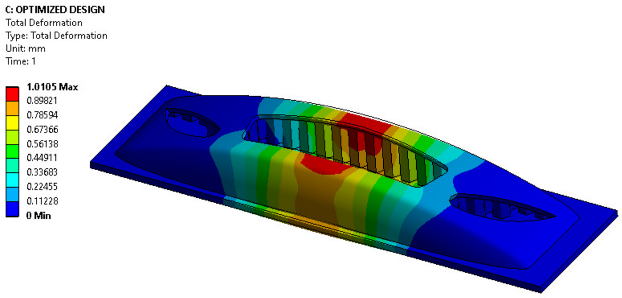


Fig.15 Total deformation result of optimized design

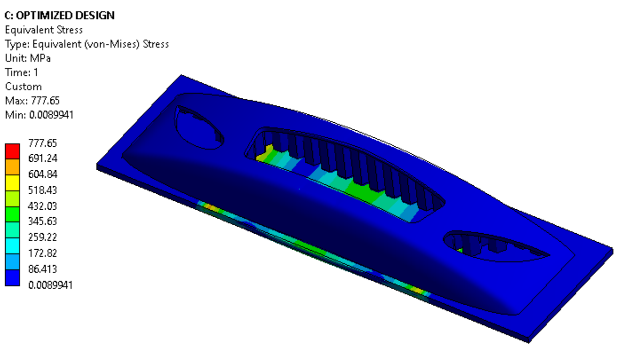


Fig.16 Equivalent stress result of optimized design

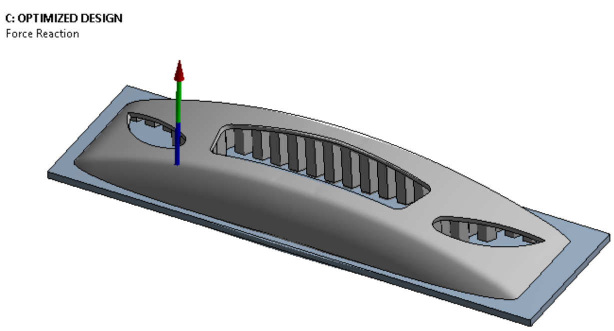


Fig.17 Force reaction result of optimized design

TABLE .□
FORCE REACTION RESULT

Maximum Value Over Time	
X Axis	227.19 N
Y Axis	-1666. N
Z Axis	678.56 N
Total	7974.5 N

It is observed from FEA result that modified design have greater reaction force than existing design.

□. EXPERIMENTAL SETUP

A universal testing machine (UTM), also known for a universal tester, materials testing machine or materials test frame, is empolyed to check the enduringness and compressive strength and bending strength of materials. An previous name for a tensile testing machine could be a tensiometers. The "universal" a part of name indicates that it can perform versatile operation on one unit as a many standard tensile and compression tests on materials, components, and structures (in other words, that its versatile). The usage and set-up are detailed in an exceedingly 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 within the machine between the grips and an extensometer if required can automatically record the change in gauge length during the test. If an extensometer isnt 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 long of the specimen but also all other extending / elastic components of the testing machine and its drive systems including any slipping of the specimen within the grips. Once the machine is started it begins to apply an increasing load on specimen. Throughout the tests the system and its associated software record the load and extension or compression of the specimen.

TABLE .□
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

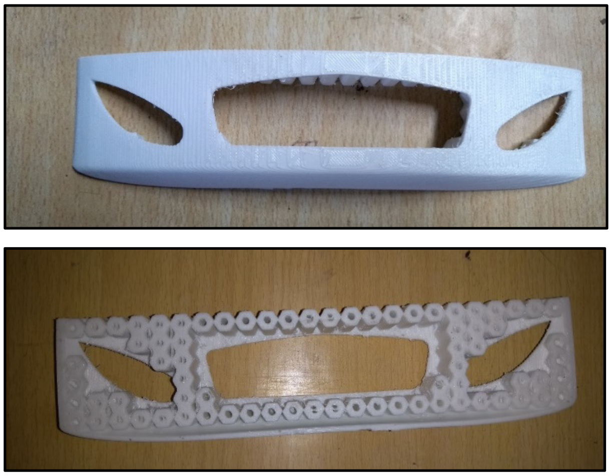


Fig 18.3d printed front collision bumper model of honeycomb structure

Fig.19. (3) point bending test set up view

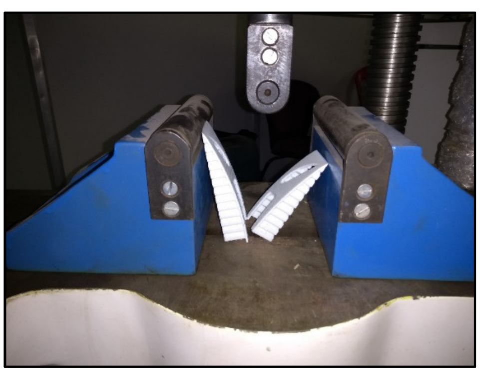


Fig.20 Experimental testing of front collision bumper

Fig.21 Failure of front collision bumper

After the resultant force value to observe the failure behaviour test bumper we are doing the reanalysis for the bumper.

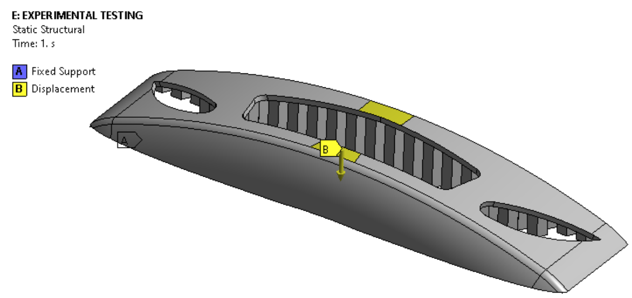


Fig 22. Design of optimized bumper for reanalysis to observe the behaviour of failure

TABLE .
DETAILS OF DISPLACEMENT

Details of "Displacement"	
Scope	
Scoping Method	Geometry Selection
Geometry	2 Faces
Definition	
Type	Displacement
Define By	Components
Coordinate System	Global Coordinate System
X Component	0. mm (ramped)
Y Component	7. mm (ramped)
Z Component	0. mm (ramped)

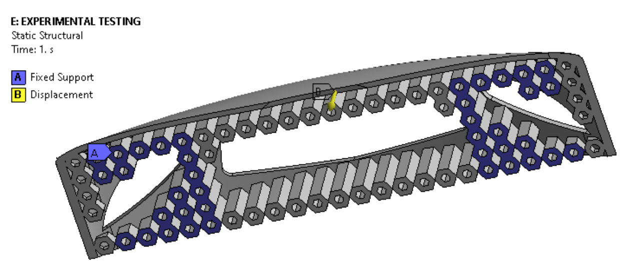


Fig.23 Boundary conditions from experimental setup

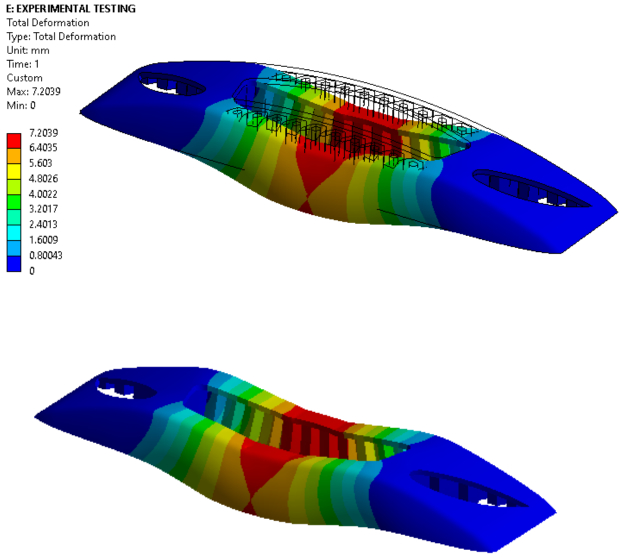


Fig. 24 Total deformation result for experimentalsetup

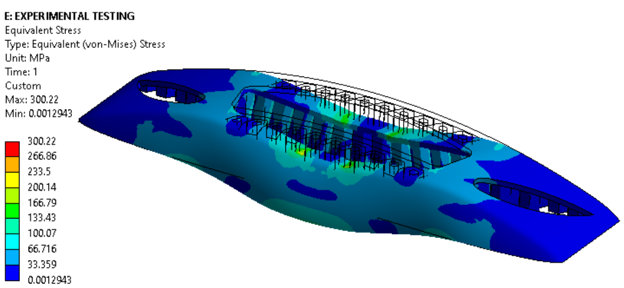


Fig. 25 Equivalent stress result for the experimental set up

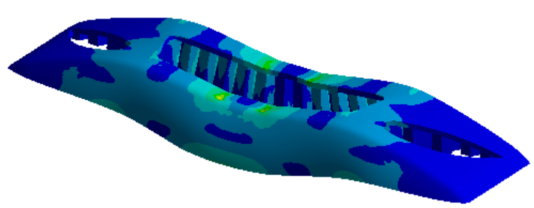


Fig.26 Equivalent stress result for the experimental set up

Through the analysis it can be observe that Equivalent stress has crossed the yield strength of material that is 43 MPa which leads to failure of component

□. RESULT AND DISCUSSION

TABLE .□
RESULT OF COMPARISON OF FE ANALYSIS PERFORMED

	Original design result in absence of honeycomb structure from analysis	Optimized design result in presence of honeycomb structure from analysis
Equivalent (Von-mises) stress(MPa)	49.051	777.65
Displacement(mm)	1.4132	1.0105
Force(N)	86.03	7974.5

From the result of FE analysis it can be observed that the Load or Force sustain by the optimized design result in presence of honeycomb structure is higher than the original design without honeycomb structure

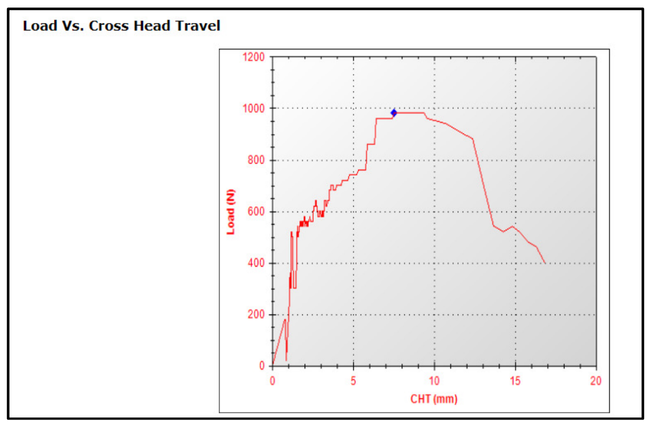


Fig.26 Experimental testing result

It is observed from experiment that in three-point bend test after displacement of 7 mm failure occurs and load is calculated around 980 N.

In FEA analysis with displacement of 7 mm is applied as per three-point bend test and failure conditions are observed.

TABLE .□
RESULT OF EXPERIMENTAL 3 POINT BEND TEST

	Force(N)	Displacement(mm)	Equivalent stress value(MPa)
1.	980	7	300.22

From the 3 point bend test we can observe that it can bear weight of around 980N And can deform at 7 mm .

. CONCLUSION

The goal of the thesis was to introduce the honeycomb structure as an alternative for the existing front collision bumper which ultimately reduce the risk of impact for the pedestrian . The hexagonal honeycomb structure model is computationally analysed by the Ansys software tested by simulation using finite element analysis.in this thesis the bumper model used for the analysis is 80% design from the Honda car which is modified with the design and also for the honeycomb structure and the changes in material that is polyacetal and then analysed for the strength, load bearing capacity, shock absorbing resistance. The following conclusions can be seen from the analysis . In present research existing front bumper design is modified to improved impact strength of front collision. Existing design is modified by considering hexagonal structure with 3D printing technique and the application of polyacetal material and also from FEA analysis it is observed that reaction force for scaled down model of honeycomb structured collision bumper is greater than existing design. From experimental testing under three-point bend test calculated experimental force is applied in ANSYS to observe the failure of component.

. FUTURE SCOPE

The following recommendations can be done for future scope study in this thesis

1. Improvement can be done in design of honeycomb structure beam, also changes in material used by varying their flexural strength

2. Impact analysis test can be done at testing station for measuring the crash test performance

3. Through the impact testing design modification can be done at core by filling with foam material which will absorb the shock resistance and ultimately can bear more load than the existing

4. Impact simulation can be done to understand energy absorbed due to impacts loads

5.Compression test can be done to further understand buckling behaviour or honeycomb structures and Auxetic structures can be investigated

. ACKNOWLEDGMENT

The authors acknowledge the research paper guide, HOD of department and the principal of the Vikhepatil college of engineering for the support provided during the work procedure of the research.

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