# COMPARISON BETWEEN ANALYTICAL AND EXPERIMENTAL RESULTS OF THERMOPLASTIC BATTERY BRACKET AND ITS VALIDATION

**MANDAR OMPRAKASH SHETE**[1]

Mechanical Engineer, Sinhgad College of Engineering, Vadgaon-Bk, Pune- 411 041, Maharashtra, India

**NIKHIL BHASKAR DHARMADHIKARI**[2]

Mechanical Engineer, Sinhgad College of Engineering, Vadgaon-Bk, Pune- 411 041, Maharashtra, India

***

**ABSTRACT:** 3D printing nowadays is emerging as a serious manufacturing technology because of its advantages such as weight reduction, availability and cost. It is time saving and simple. Because of this added advantages many automobile industries are replacing the metal components with 3D printed components. In automobile industry components such as supports, clips, brackets are manufactured with help of 3D printing technique. In this paper Sheet metal battery bracket is considered for analysis. Static and modal analysis of Sheet metal battery bracket and compatibility of polypropylene battery bracket with sheet metal battery bracket is referred from research paper: Mandar Shete, "Optimization of Sheet Metal Battery Bracket Using 3D Printing Technology" in IRJET, e- ISSN: 2395-0072, Volume 8, Issue 1 January 2021, India Static and Modal Analysis polypropylene battery bracket is done on ANSYS software. Experimental tensile testing is done on Universal Testing Machine. Experimental Modal Analysis is done on FFT setup. The results obtained from ANSYS software are then validated with the experimental results obtained from Universal Testing Machine and FFT analyzer.

Keywords: 3D Printing, Static and Modal, Analysis, UTM, FFT Analyzer, Battery Bracket

## 1. INTRODUCTION

Nowadays plastic materials and composites are helping to reduce the weight and increase the strength in modern vehicles. Additive manufacturing technology is advancing in automotive industry. 3D printing technology is now recognized as one of the serious manufacturing technologies. By reducing the weight fuel economy can be increased without compromising the strength of the automobile parts in growing fuel prices. A lot of automobile parts such as supports, clips, brackets are manufactured with help of 3D printing technology. In additive manufacturing technology different components can be manufactured only with the help of CAD model and manufacturing machine setup.

In this paper Sheet metal battery bracket is taken into consideration for comparative analysis. Similar kind of battery bracket is manufactured with thermoplastic material. Static and modal analysis is performed on both battery brackets on ANSYS software. Then a comparative analysis of analytical and experimental static and modal analysis results is done to validate the analytical results. The analytical results of Sheet Metal Battery bracket and thermoplastic (polypropylene) battery bracket are taken from research paper- Mandar Shete, "Optimization of Sheet Metal Battery Bracket Using 3D Printing Technology" in IRJET, e- ISSN: 2395-0072, Volume 8, Issue 1 January 2021, India.

## 2. LITERATURE SURVEY

**Merulla et.al [1]** In this paper the increasing importance of additive manufacturing is explained. It is also explained that the for the justified use of any additive manufactured material topology optimization is important. With the help of additive manufacturing technology it is possible to obtain parts with complex geometries and features, impossible to be produced by other processes. Additive manufacturing employs the layer-by-layer material deposition process. In building the new parameterized CAD model, the designer usually includes manufacturing considerations and constraints, which hamper the full exploitation of the optimization and can potentially lead to compromise solutions. In the case of AM, the great design freedom allows to remove extra-mass and to achieve the best benefits from the optimization process. This freedom is very advantageous from manufacturing point of view, as it will reduce the design time and it will thereby reduce the manufacturing cost.

**Melissa et.al [2]** The topology optimization exercise removes material from all locations where it is not necessary to support the specific loads or satisfy specific boundary conditions, resulting components often contain structures that are not constant in cross section and resemble tree branches or bones, and hence, are termed 'bionic' or 'organic'. Topology optimization is a "mathematical approach that, within a given design space, and a set of loads and boundary conditions, provides a solution that respects certain constraints and either minimizes or maximizes the objective variable. The fabrication of hollow structures, structures with internal cooling channels, organic, bionic shaped structures, and structures filled with lattice elements can now be made via Additive Manufacturing. Additive manufacturing employs the layer-by-layer material deposition process. Due to this layered approach, the engineering parts can be designed with great complexity. An important aspect of the topologically optimized design for Additive Manufacturing is to create self-supporting components, or when not possible, components with the minimal number of support structures. This will increase the stability and significantly reduce the overall weight.

**F.Brites et.al [3]** Among natural fillers, cork has been acknowledged as a suitable alternative of other cellular materials that are widely employed in engineering applications due to their low conductivity to heat, noise and vibration, high abrasion resistance and flexibility, high compressibility ratio, among other characteristics. The eco-friendly features of natural fillers-based composites make them a very promising and sustainable solution to large markets mainly if additive manufacturing technologies, such as 3D printing, are used. Through 3D printers, engineers, designers and architects can create design and decor products with a free complexity of geometry. In this research work, plastic matrices of HDPE – obtained from conventional suppliers – were reinforced with different ratios of cork waste and natural cork powders – obtained from cork transformation industries – to find the optimum mixture for 3D printing. The effects of cork powders content in the plastic on the morphological, physical and mechanical properties of the composites were investigated through the density, optical microscopy, wettability, thermal analysis and tensile testing. Cork-based composites were processed by an extrusion system, and the mixture of polymer, adhesive and fillers is discussed. The results show that the addition of pure cork and cork waste can be processed with polymers such as HDPE, having adequate physical and mechanical properties.

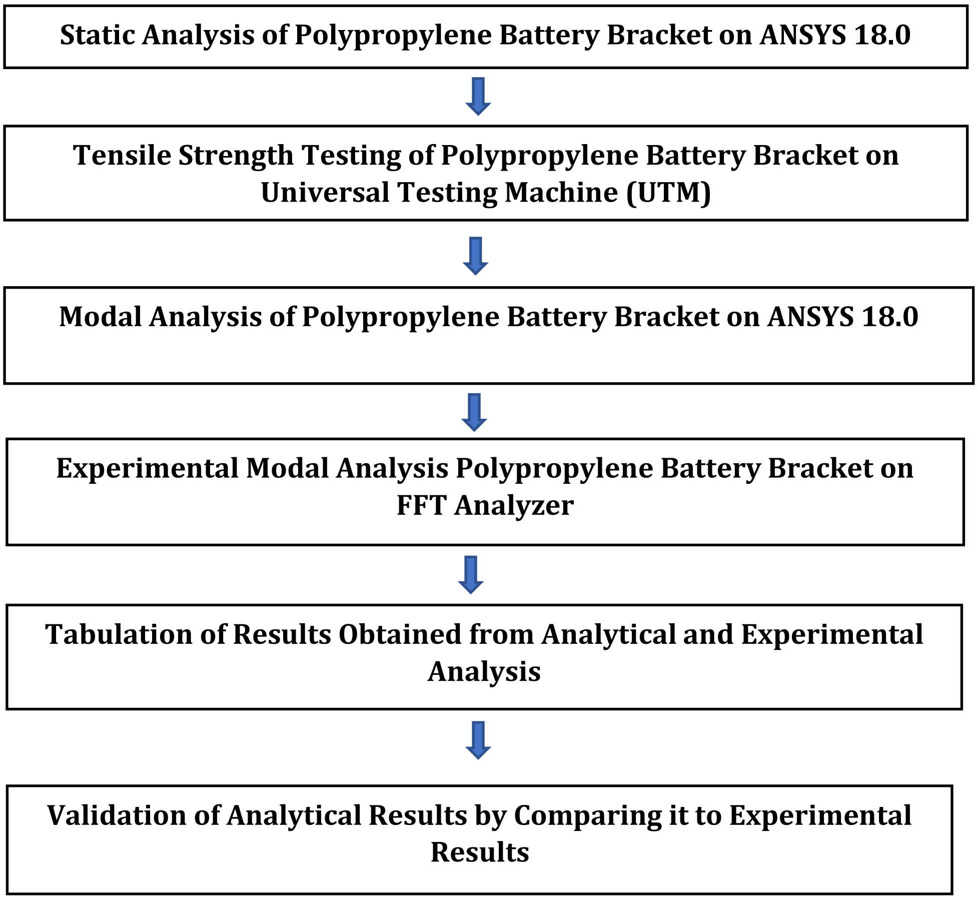
**Karjol et.al [4]** In this paper the replacement of the existing sheet metal electronic unit bracket is replaced with the help of polypropylene material. Modal analysis is done to achieve the required natural frequency targets so as to avoid resonance and the part is also checked for the load cases to check its structural integrity. Topology optimization is done to find out the required thickness of the replaced bracket so as to match the required frequency ranges. Maximum thickness is selected so as to give the required stiffness. Ribs addition is also done according to experience based on previous designs. The main motive is to reduce the weight of the vehicle so as to increase the fuel economy.

**Yongsheng Ma et.al [5]** In this paper has explained that the interpolation of nodal or point wise densities with material properties is an effective approach compared to direct density optimization. It has contributed to achieving the manufacturing-oriented topology design. Manufacturing rule violations are very common in topology optimization based conceptual design solutions, which negatively impact the manufacturability and even make them non-manufacture. With the help of additive manufacturing those metal components which previously were non-manufacture can be easily manufactured.

**Aubrey L. Woern et.al [6]** In order to assist researchers explore the full potential of distributed recycling of post-consumer polymer waste, this article describes a recyclebot, which is a waste plastic extruder capable of making commercial quality 3-D printing filament. The device design takes advantage of both the open source hardware methodology and the paradigm developed by the open source self-replicating rapid prototype (RepRap) 3-D printer community. Specifically, this paper describes the design, fabrication and operation of a RepRapableRecyclebot, which refers to the Recyclebot's ability to provide the filament needed to largely replicate the parts for the Recyclebot on any type of RepRap 3-D printer. The device costs less than $700 in mate rials and can be fabricated in about 24 h. Filament is produced at 0.4 kg/h using 0.24 kWh/kg with a diameter ±4.6%. Thus, filament can be manufactured from commercial pellets for printing.

**Tianyun Yao et.al [7]** 3D Printing is widely used in scientific researches and engineering applications, ranging from aerospace to biomedicine. However, little is known about the mechanical properties of 3D printing materials. In order to promote the mechanical analysis and design of 3D printing structures, the ultimate tensile strength of FDM PLA materials with different printing angles were studied theoretically and experimentally. A theoretical model was firstly established to predict the ultimate tensile strength of FDM PLA materials based on transverse isotropic hypothesis, classical lamination theory and Hill-Tsai anisotropic yield criterion, and then verified by tensile experiments. Compared with previous models, this model provided two kinds of in-plane shear modulus calculation methods, so the calculation results were more reliable. The specimens, designed according to the current plastic-multipurpose test specimens standard ISO 527-2-2012, were printed in seven different angles ($0^0$, $15^0$ , $30^0$ , $45^0$ , $60^0$ , $75^0$ , $90^0$) with three layer thicknesses (0.1 mm, 0.2 mm, 0.3 mm) for each angle. The relative residual sum of squares between theoretical data and experimental data were all close to zero, so the results that the theoretical model can accurately predict the ultimate tensile strength of FDM materials for all angles and thicknesses were confirmed. It was also found that the ultimate tensile strength decreased as the printing angle becomes smaller or the layer becomes thicker. This theoretical model and experimental method can also be applied to other 3D printing materials fabricated by FDM or SLA techniques.

## 3. METHODOLOGY



## 4. Static Analysis of Polypropylene Battery Bracket on ANSYS 19

The static analysis is done on ANSYS 18 software for polypropylene battery bracket to check the stress values in given loading conditions. The weight of the battery bracket is approximately 10 KG. acting at center of gravity. This load is taken as a point load acting vertically downwards with four corners fixed for static analysis. The load is rounded off to 100 N considering some factor of safety.

The maximum stress value is less than that of sheet metal battery bracket. The added thickness in polypropylene battery bracket increases the stiffness without sacrificing its weight. Total deformation of the Polypropylene Battery Bracket is 1.74 mm.

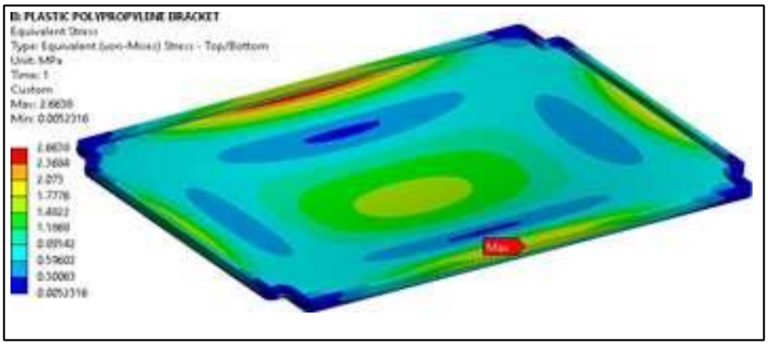


Fig. 1 Equivalent Stress on Plastic Polypropylene Bracket

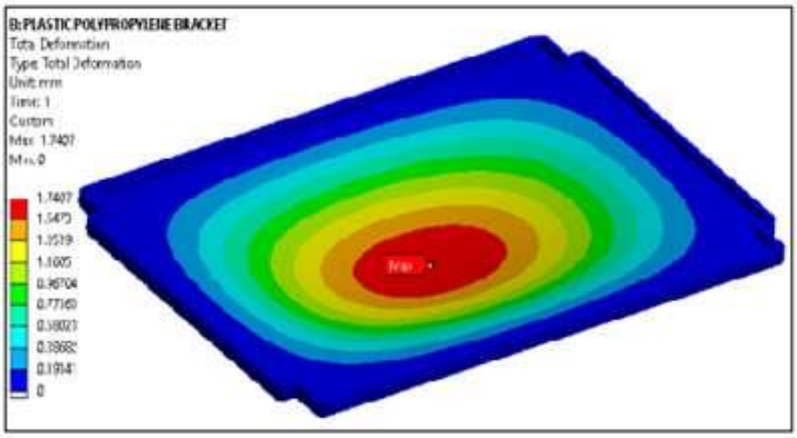


Fig. 2 Total Deformation of plastic polypropylene bracket

## 5. Tensile Strength Testing of Polypropylene Battery Bracket on Universal Testing Machine ( UTM)

To validate the results obtained from analytical analysis from ANSYS software the tensile strength testing is done on Universal testing machine. In this testing a variable tensile load is applied on polypropylene battery bracket until its fracture to find out its ultimate tensile strength. The component is clamped on the testing setup and load is varies with the help of knob. The Stress-Strain curve is simultaneously plotted on the computer screen and when component breaks plot shows a fracture point, which is known as Ultimate Tensile Strength.

The following pictures shows Universal Testing Machine setup.

Fig. 3 Picture of Universal Testing Machine Setup

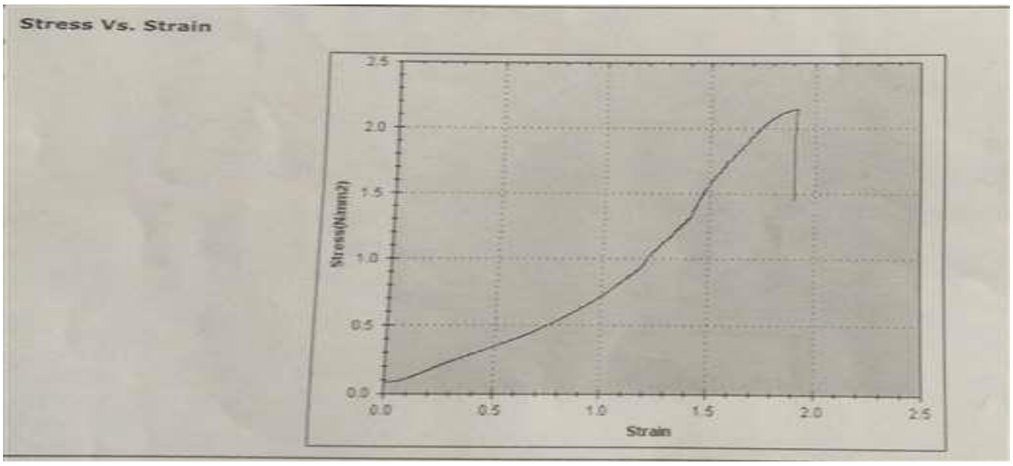


Fig. 4 Stress- Strain Curve of Plastic Polypropylene Bracket

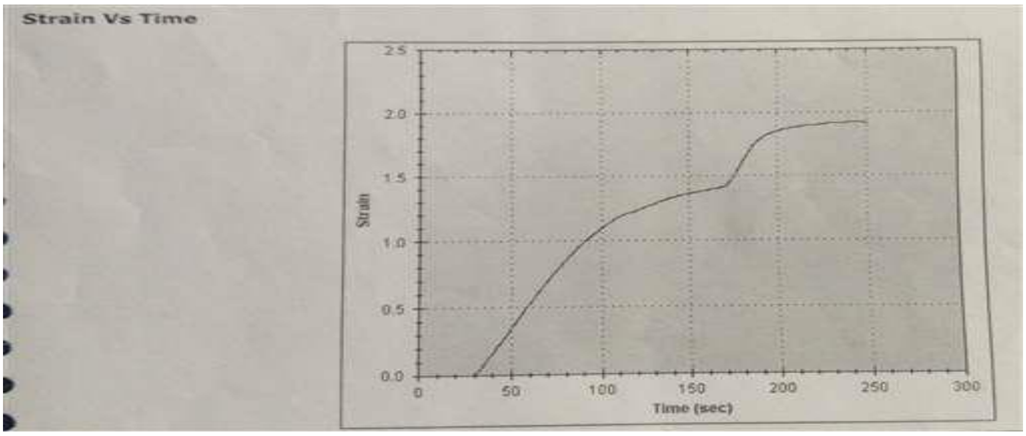


Fig. Strain Vs Time Curve of Plastic Polypropylene Bracket.

The Stress-Strain curve obtained from given testing is shown. The plot of Polypropylene bracket is similar to the Stress- Strain plot of brittle materials because Polypropylene acts as brittle material under high loading conditions. Therefore Ultimate Tensile Strength (Sut) is considered as a strength criteria for validation.

The Ultimate Tensile strength ($S_{ut}$) and Total deformation of Polypropylene battery bracket obtained from Universal testing machine is 2.2 MPa and 1.8 mm respectively.

## 6. Modal Analysis of Polypropylene Battery Bracket on ANSYS 18.0

Analytical modal analysis of polypropylene battery bracket is done on ANSYS 18 Software. Modal analysis is performed to find out the natural frequencies of battery bracket to avoid the resonance condition. For modal analysis all the corners are kept fixed. Following are the natural frequencies of six different mode shapes for polypropylene battery bracket.

As shown in the graph the amplitude acceleration obtained for polypropylene battery bracket in the ANSYS is 33.385 $m/s^2$.

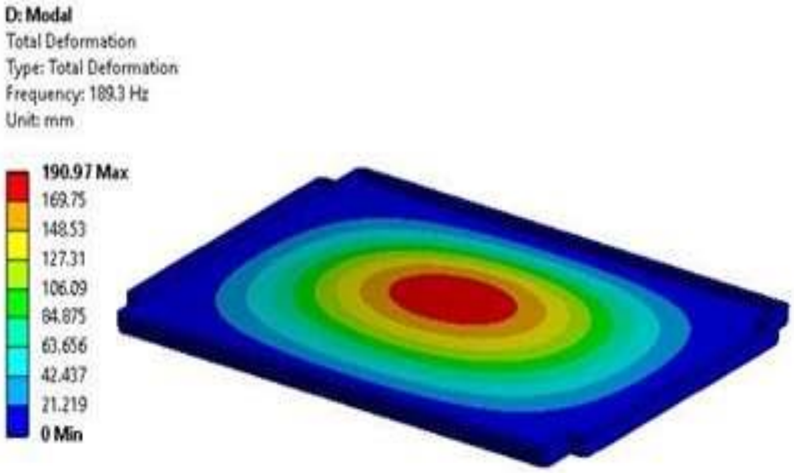


Fig. 5 Modal Analysis Results From ANSYS- First mode Shape

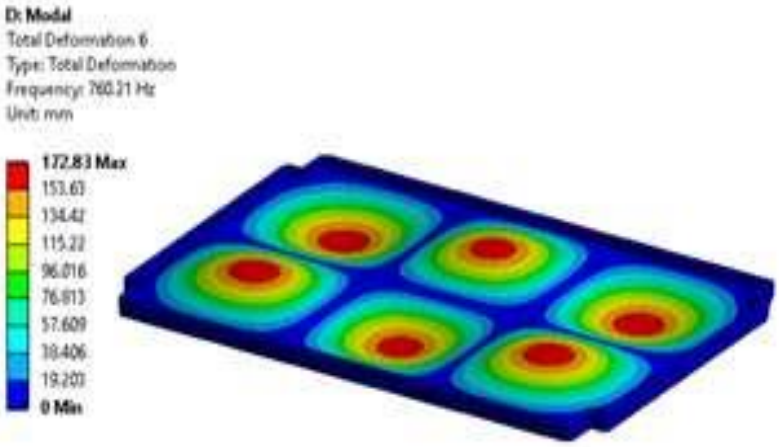


Fig. 6 Modal Analysis Results From ANSYS- Sixth mode Shape

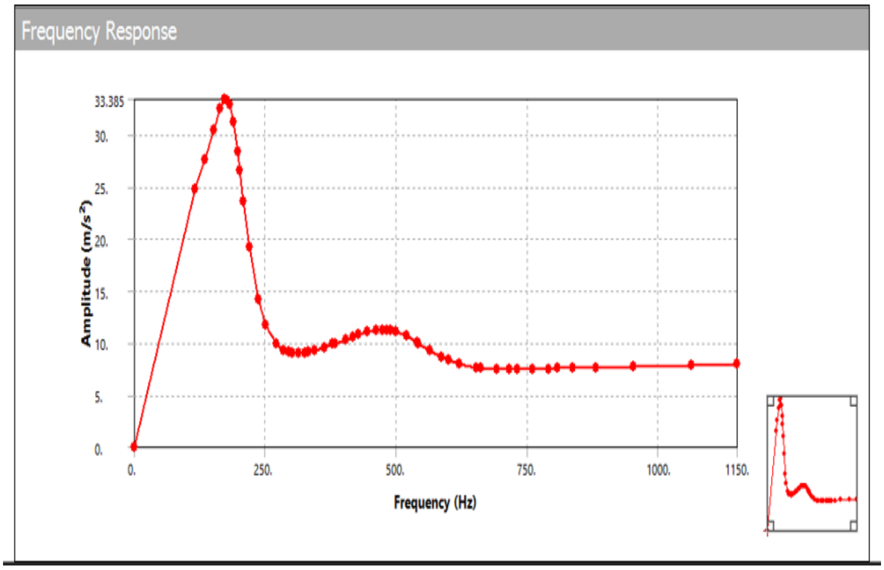


Fig. 7 Frequency response curve for polypropylene battery bracket

## 7. Experimental Modal Analysis Polypropylene Battery Bracket on FFT Analyzer

Experimental Modal analysis is done on FFT Analyzer Setup. The testing setup is shown in following picture.

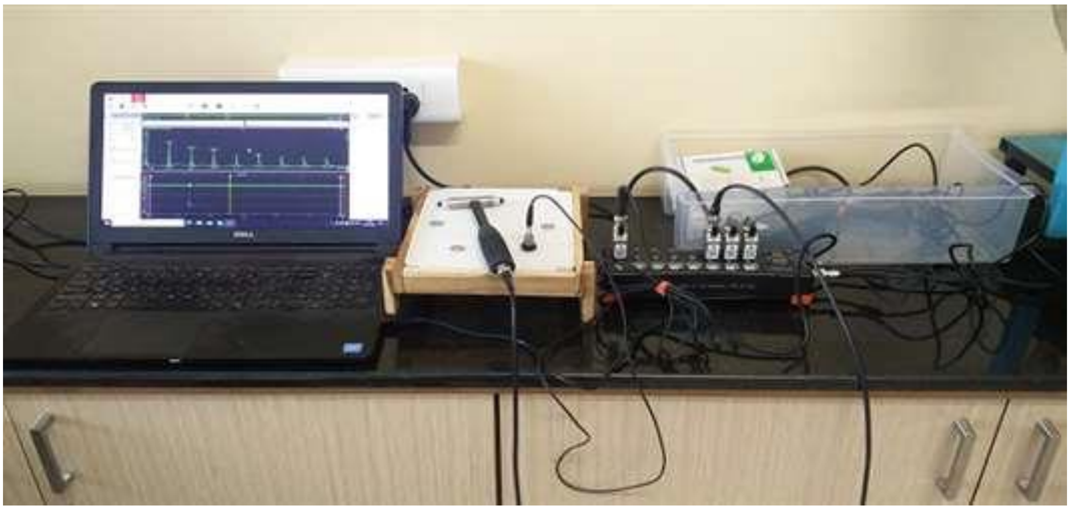
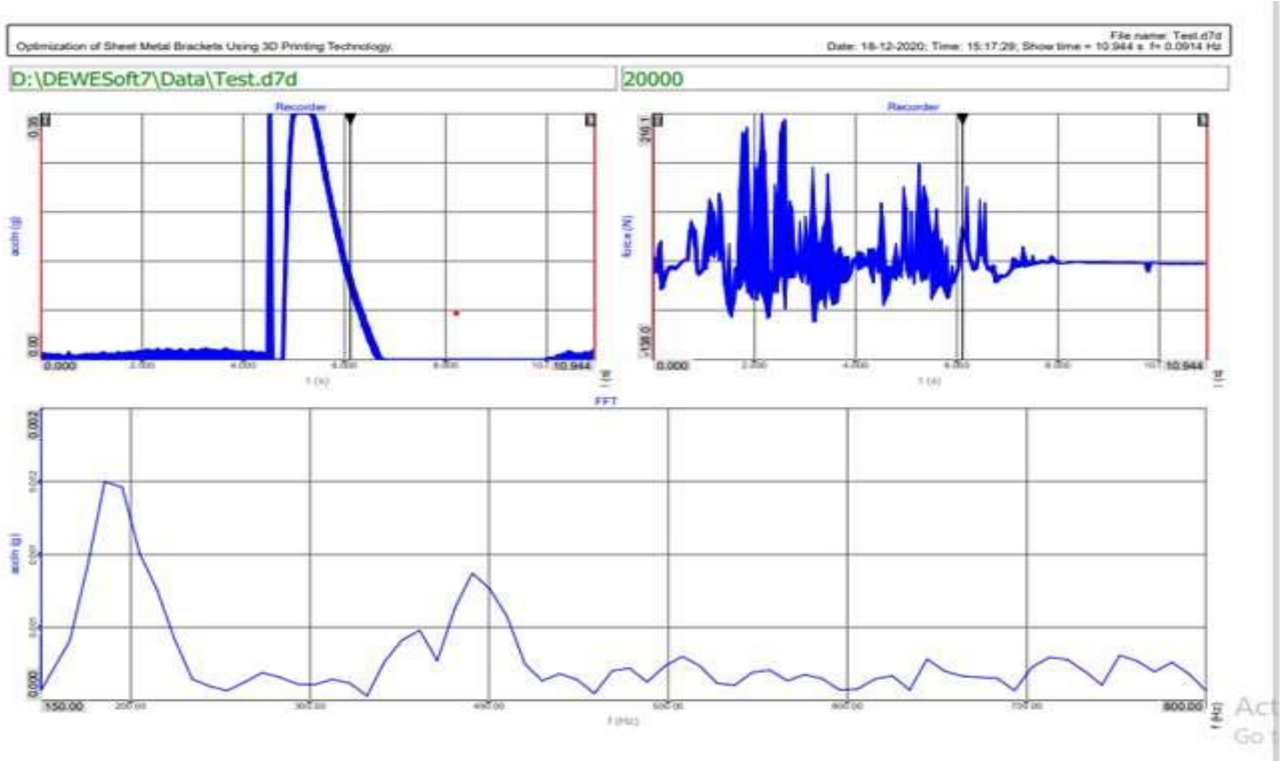


Fig. 8 Experimental Modal Analysis Setup

The Fixture is made which will fix four corners. The Polypropylene battery bracket is mounted on fixture and impact with hammer is given on six different locations and readings are noted. The accelerometer mounted on battery bracket records the vibrations in longitudinal as well as transverse direction. The accelerometer is connected to the computer and plot is generated on FFT software. The readings obtained from the accelerometer are in the form of Amplitude vs Time. But it is difficult to analyze this data so this plot is converted to Amplitude Vs frequency curve using FFT (Fast Fourier Transform) Software. This will give the value of maximum frequency and its location. In Modal Analysis the resulting graph is shown by Dewesoft X3 application.



Optimization of Sheet Metal Brackets Using 3D Printing Technology.

File name: Test.d7d
Date: 18-12-2020; Time: 15:17:29; Show time = 10.944 s f= 0.0914 Hz

D:\DEWESoft7\Data\Test.d7d

20000

Fig. 9 Acceleration Vs Frequency Curve obtained

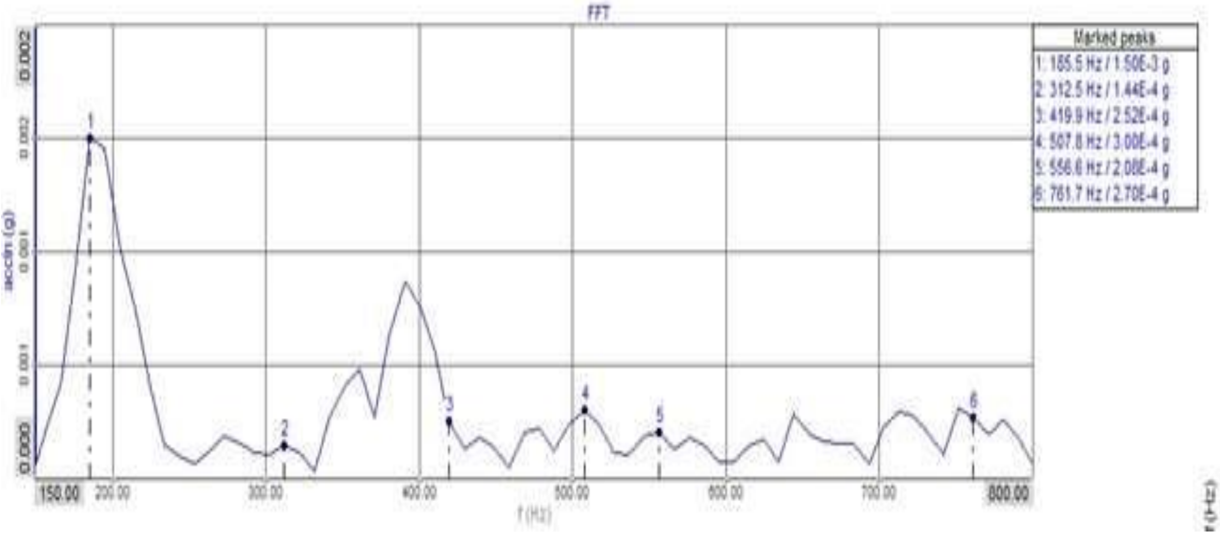


Fig. 10 Acceleration Vs Frequency Curve obtained in FFT analyzer

The amplitude acceleration obtained is 34.35 m/s². The result is validated with analytical results obtained from ANSYS Software

Table 1. Amplitude Acceleration Obtained

| Sr. No. | Amplitude acceleration obtained in ANSYS (m/s$^2$) | Amplitude acceleration in obtained Experimental Analysis(m/s$^2$) |
|---|---|---|
| 1 | 33.385 | 34.35 |

Table 2. Modal(Natural) Frequencies obtained

| Mode No | Frequency obtained in ANSYS (Hz) | Frequency obtained in Experimental testing (Hz) |
|---|---|---|
| 1 | 189.3 | 185.5 |
| 2 | 313.23 | 312.5 |
| 3 | 444.73 | 419.9 |
| 4 | 519.13 | 507.8 |
| 5 | 563.49 | 556.6 |
| 6 | 760.21 | 761.7 |

## 8. CONCLUSION

The maximum stress induced in Polypropylene battery bracket for given load conditions obtained from ANSYS Software is 2.66 Mpa and that obtained from experimental (UTM ) is 2.2 Mpa.

Percentage error between Amplitude Acceleration obtained from ANSYS and Experimental testing is 2.8 %

Percentage error between Modal Frequencies obtained from ANSYS and Experimental testing is 1.9 %

Percentage error between analytical and experimental analysis obtained in both modal and static analys is are in acceptable limits. Therefore, the analytical results obtained from ANSYS are validated and are true.

## 9. ACKNOWLEDGEMENT

We wish to thank Mr. Praveen Ingavale for his technical guidance and support. Sincere thanks to Prof. V. N. Kapatkar, Head of Mechanical Department, Sinhgad College of Engineering, Pune for providing encouragement and support. We are very grateful to Prof. C. A. Joel, Project Guide for being incredibly supportive throughout the work and her exhaustive guidance and patience she has while listening our approaches and supporting our endeavor. We are very thankful to Mr. Akshay Benkar, Lab Assistant for helping us in Experimental testings.

## 10. REFERENCES

[1] Andrea Merullaa, Andrea Gattob, Elena Bassolib, Sorin Ion Munteanuc,*, “Weight reduction by topology optimization of an engine subframe mount, designed for additive manufacturing production”, pp 1014–1018, 2019.

[2] Melissa Orme, Ivan Madera , Michael Gschweitl and Michael Ferrari "Topology Optimization for Additive Manufacturing as an Enabler for Light Weight Flight Hardware" 25 November 2018.

[3] F.Britesa*, C. Malçaa,b, F.Gaspara, J.F.Hortaa, M.C. Francoa, S. Biscaiaa, A. Mateusa, "Cork Plastic Composite Optimization for 3D Printing Applications", Procedia Manufacturing 12 ( 2017 ) 156 – 165.

[4] Karjol, A. and Virmalwar, A., "Optimization of Sheet Metal Bracket by Use of Thermoplastics," Tata Technologies Ltd., SAE Technical Paper, doi:10.4271/2016-28-0224,January 2016.

[5] Jikai Liu, Yongsheng Ma, "A survey of manufacturing oriented topology optimization methods" Department of Mechanical Engineering, University of Alberta, Edmonton, AB, Canada, pp 161-175, 24 july 2016.

[6] Aubrey L. Woern a, Joseph R. McCaslin b, Adam M. Pringle c, Joshua M. Pearce "RepRapable Recyclebot: Open source 3-D printable extruder for converting plastic to 3-D printing filament", Aug-2015.

[7] Tianyun Yao, Zichen Deng, Kai Zhang, Shiman Li, "Method to predict the ultimate tensile strength of 3D printing Polylactic acid (PLA) materials with different printing orientations", 2014.