Optimization of Sheet Metal Brackets Using 3D Printing Technology

Mandar Omprakash Shete[1]

[1]*Mechanical Engineer, Sinhgad College of Engineering, Vadgaon, Pune- 411041, Maharashtra, India.*

---***---

Abstract: The proliferation of 3D printing technology has created a extraordinary demand for engineering services which create and deliver its benefits. At the head of these services is design optimization for 3D printing. The 3D printing industry has long recognized that engineering design for 3D printing is a critical capability to loose the benefits of the technology. In automobile industry lot of automobile part (bracket, supports, clips etc.) will be optimize using 3D printing technology. In this project we are considering Sheet Metal Bracket for optimization purpose. In optimization exiting automobile Sheet Metal Bracket material will be replace by thermoplastics materials. The main focus of this project is achieved by converting the sheet metal brackets to plastic brackets which will ultimately reduce weight and production cost associated with automobile. Automobile sheet metal brackets which we selected for optimization will be design using CATIA V5. Nonlinear analysis of automobile part will be done using ANSYS 19 software. Comparative results between sheet metal and polypropylene will be studied.

Keywords: Optimization, 3D printing, Analysis, Topology, Modal, Battery Bracket.

1. INTRODUCTION

Recently in automobile industry reduction of weight is one of many concerns. Such reduction of weight is achieved with the help of replacing different metal components with thermoplastic materials. The fuel efficiency of the vehicle can be increase by reducing the overall weight of vehicle by replacing metal components with thermoplastic component. Additive manufacturing has emerged as an effective method of manufacturing. Different components can be easily manufactured only with the help of a CAD model and a manufacturing machine setup. Fused Deposition Modelling (FDM).FDM has become the most popular and widely used AM technique with half of the machines on the market being of this kind. The layer wise printing process allows for the manufacture of functional and intricate parts at a relatively low cost.

In this paper, battery supporting bracket is selected for the replacement. Sheet metal battery supporting bracket is replaced with polypropylene thermoplastic material which is proved to be effective than other thermoplastic material. Static analysis and modal analysis is done on sheet metal and polypropylene battery supporting bracket and comparison is done. The compatibility of replaced polypropylene battery supporting bracket is checked. Topology optimization is also done to check the required thickness of the battery supporting battery bracket.

1.1 Literature Survey:

1) **Merulla et.al:** In this paper the increasing importance of additive manufacturing is explained. It is also explained that 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 misuse of the development and can potentially lead to compromise solutions. In 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.

2) **Melissa et.al:** The topology optimization exercise removes material from all locations wherever it's not necessary to support the particular hundreds or satisfy specific boundary conditions, ensuing elements usually contain structures that are not constant in cross section and resemble tree branches or bones, and therefore, termed as 'bionic' or 'organic'. Topology optimization could be a "mathematical approach that, among a given style house, and a group of hundreds and boundary conditions, provides an answer that respects sure 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. Because of this Stratified approach, the engineering components may be designed with nice quality. A very important facet of the topologically optimized style 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.

3) **F.Brites et.al:** Among natural fillers, cork has been acknowledged as a suitable varied of various cellular materials that ar wide utilized in engineering applications because of their low conductivity to heat, noise and vibration, high abrasion resistance and flexibility, high compressibility quantitative relation, among completely different characteristics. The eco-friendly choices of natural fillers-based composites produce them a extremely promising and property answer to huge markets within the main if additive manufacturing technologies, like 3D printing, are used. Through 3D printers, engineers, styleers and styleers can manufacture design and ornament merchandise with a free quality of mathematics. Throughout this analysis work, plastic matrices of HDPE – obtained from normal suppliers – were bolstered with altogether completely different ratios of cork waste and natural cork powders – obtained from cork transformation industries – to go looking out the optimum mixture for 3D printing. The results of cork powders content at intervals the plastic on the morphological, physical and mechanical properties of the composites were investigated through the density, optical analysis, wettability, thermal analysis and tensile testing. Cork-based composites were processed by associate extrusion system, and thus the mixture of compound, adhesive and fillers is mentioned. The results show that the addition of pure cork and cork waste are processed with polymers like HDPE, having adequate physical and mechanical properties.

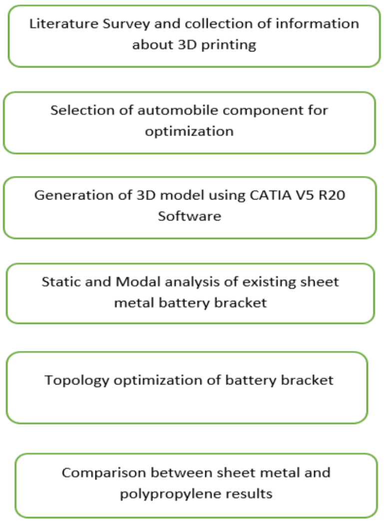
4) **Karjol et.al:** In this paper the replacement of the existing sheet metal electronic unit bracket is replaced with the help of polypropylene material. Modal analysis is done to achieve the required natural frequency targets so as to avoid resonance and the part is also checked for the load cases 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.

5) **Yongsheng Ma et.al:** 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-manufacturable. With the help of additive manufacturing those metal components which previously were non manufacturable can be easily manufactured.

6) **Aubrey L. Woern et.al:** In order to help researchers explore the total potential of distributed use of post-consumer compound waste, this text describes a recyclebot, that may be a waste plastic extruder capable of creating industrial quality 3D printing filament. The device style takes advantage of each the open supply hardware methodology and also the paradigm developed by the open supply self-replicating fast model (RepRap) 3D printer community. Specifically, this paper describes the look, fabrication and operation of a RepRapableRecyclebot, that refers to the Recyclebot's ability to produce the filament required to for the most part replicate the elements for the Recyclebot on any variety of RepRap 3D printer. The device prices but $700 in mate rials and might be invented in concerning twenty four h. Filament is created at zero.4 kg/h victimization zero.24 kWh/kg with a diameter ±4.6%. Thus, filament is factory-made from industrial pellets for printing.

7) **Tianyun Yao et.al:** 3D Printing is wide utilized in scientific researches and engineering applications, starting from part to biomedicine. However, very little is understood concerning the mechanical properties of 3D printing materials. So as to push the mechanical analysis and style of 3D printing structures, the last word durability of FDM PLA materials with totally different printing angles were studied on paper and by experimentation. A theoretical model was first of all established to predict the last word durability of FDM PLA materials supported crosswise isotropous hypothesis, classical lamination theory and Hill-Tsai eolotropic yield criterion, so verified by tensile experiments. Compared with previous models, this model provided 2 forms of in-plane shear modulus calculation ways, therefore the calculation results were additional reliable. The specimens, designed per this plastic-multipurpose take a look at specimens commonplace ISO 527-2-2012, were written in seven totally different angles (0o, 15o , 30o , 45o , 60o , 75o , 90o) with 3 layer thicknesses (0.1 mm, 0.2 mm, 0.3 mm) for every angle. The relative residual total of squares between theoretical knowledge and experimental knowledge were all about to zero, therefore the results that the theoretical model will accurately predict the last word durability of FDM materials for all angles and thicknesses were confirmed. It had been conjointly found that the last word durability shriveled because the printing angle becomes smaller or the layer becomes thicker. This theoretical model and scientific method can even be applied to alternative 3D printing materials fancied by FDM or SLA techniques.

Methodology:



3D MODEL:

The design of sheet metal battery supporting bracket is taken and its CAD model is generated in CATIA V5 R20. Similar CAD model is generated for polypropylene battery supporting bracket. Thickness of sheet metal bracket is 2 mm. An increased thickness of 3 mm is considered taking into account the stiffness of replaced material based on previous experiences.

Specifications:

Bracket base dimensions: 240 mm × 175 mm

Height of bracket: 5 mm

Thickness of sheet: 2 mm

Battery dimension: 220 mm × 158 mm × 173 mm

Weight of battery: 10 kg

Weight of bracket: 0.714 kg

Material: Steel (sheet metal)

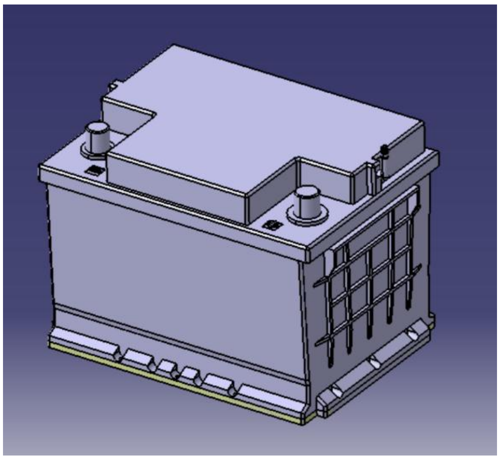


Fig. 1: CATIA model of Battery

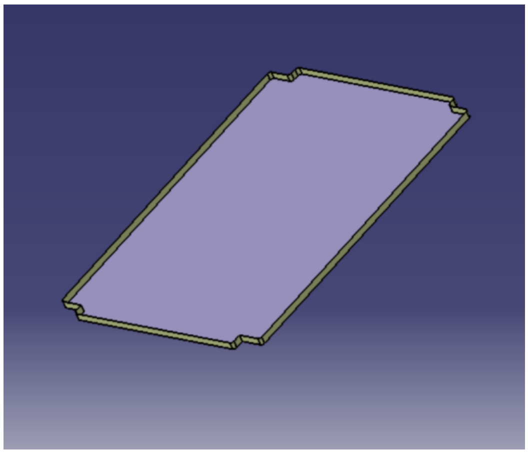


Fig. 2: CATIA model of sheet metal bracket

STATIC ANALYSIS:

In this FEA of battery mounting sheet metal bracket we are taking 100 N remote forces (C.G of Battery + Battery weight). The weight of the battery is taken 10 kg.

Static analysis is done on both sheet metal and polypropylene battery supporting bracket and stresses are shown in Fig. 3 and Fig. 4. Analysis is done by using ANSYS 18.1.

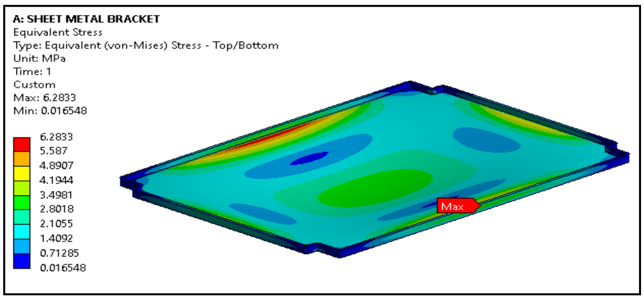


Fig. 3 Equivalent stress of battery mounting sheet metal bracket

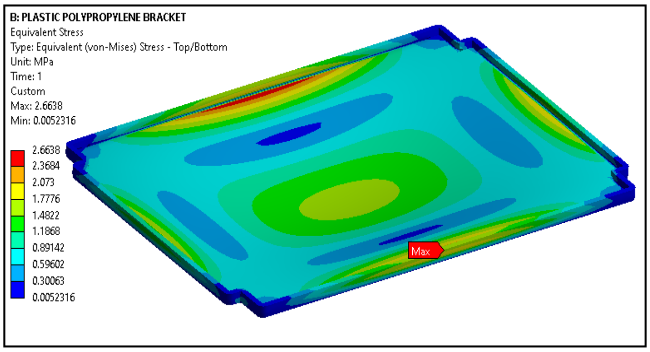


Fig. 4 Equivalent stress of battery mounting polypropylene bracket.

Maximum stress obtained in the sheet metal battery supporting bracket is 6.2833 MPa and maximum stress obtained in polypropylene battery supporting bracket is 2.6638 MPa.

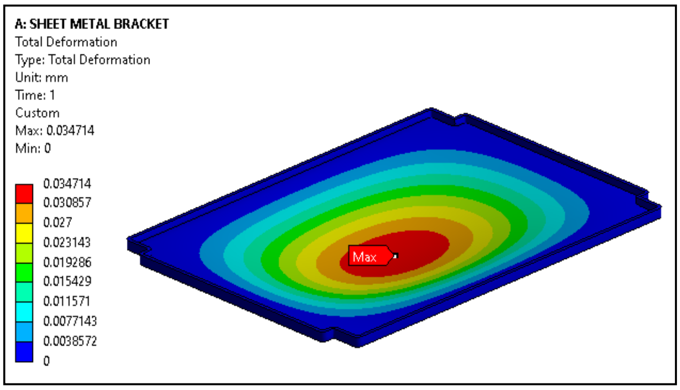


Fig. 5: Total deformation in sheet metal battery supporting bracket

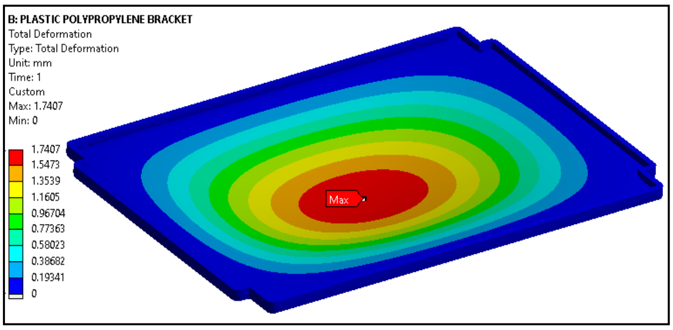


Fig. 6: Total deformation in polypropylene battery supporting bracket.

Maximum deformation obtained in sheet metal battery supporting bracket is 0.034714 mm and maximum deformation obtained in polypropylene battery supporting bracket is 1.7407 mm,

MODAL ANALYSIS:

Static analysis tells us whether the material will fail or not in static scenarios. Modal analysis is necessary to know the natural frequencies and vibration characteristics of the sheet metal as well as polypropylene material. Modal analysis is done to achieve the required natural frequency targets so as to avoid resonance.

Maximum amplitude is also found out with the help of graph shown in Fig 7 and Fig. 8 respectively.

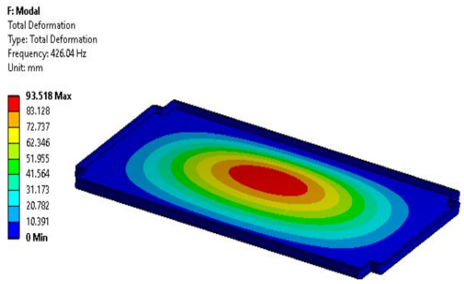


Fig. 7: First mode shape of the sheet metal battery supporting bracket.

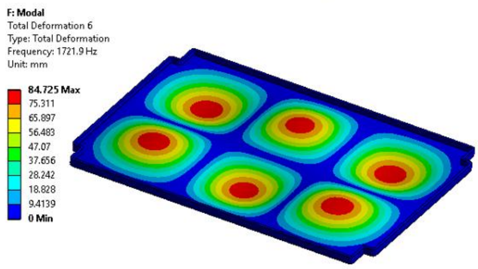


Fig. 8: Sixth mode shape of sheet metal battery supporting bracket.

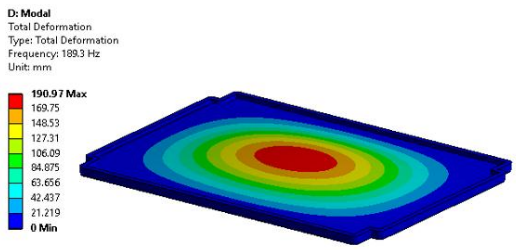


Fig. 9: First mode shape of polypropylene battery supporting bracket.

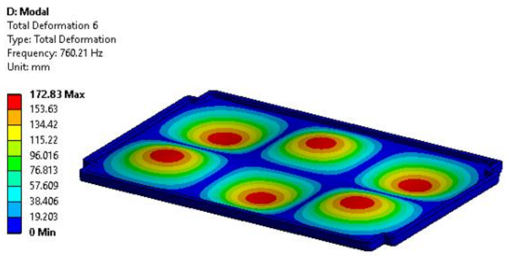


Fig. 10: Sixth mode shape of polypropylene battery supporting bracket.

Tabular Data

	Mode	Frequency [Hz]
1	1.	426.04
2	2.	703.95
3	3.	997.25
4	4.	1167.6
5	5.	1273.6
6	6.	1721.9

Fig. 11: Tabular data of sheet metal battery

Tabular Data

	Mode	Frequency [Hz]
1	1.	189.3
2	2.	313.23
3	3.	444.73
4	4.	519.13
5	5.	563.49
6	6.	760.21

Fig. 12: Tabular result for polypropylene bracket

As shown in the Fig. 13 the maximum amplitude if acceleration for sheet metal battery supporting bracket is 57.742 m/s^2 and from Fig. 14 the maximum acceleration for polypropylene battery supporting bracket is 33.385 m/s^2

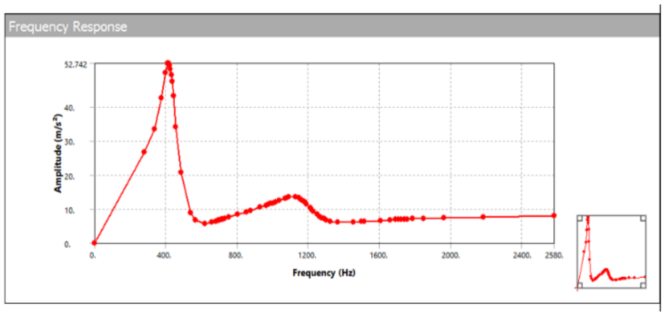


Fig. 13 Frequency response curve for sheet metal battery bracket

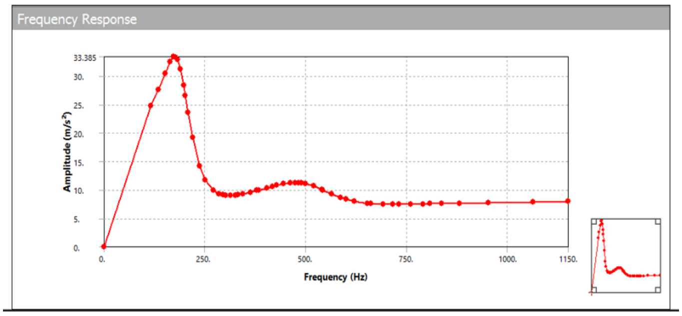


Fig. 14 Frequency response curve for polypropylene battery bracket

TOPOLOGY OPTIMIZATION:

Topology optimisation may be a "mathematical approach that, inside a given style house, and a collection of masses and boundary conditions, provides an answer that respects sure constraints and either minimizes or maximizes the target variable.

The topology optimisation exercise removes material from all locations wherever it's not necessary to support the particular masses or satisfy specific boundary conditions, ensuing elements typically contain structures that aren't constant in cross section

Topology optimisation is completed to see the thickness of fabric at totally different locations underneath the given load conditions. It offers the optimum style of explicit element underneath given loadcases therefore on save material and price.

The conventional technique utilized by business whereas convergency the flat solid bracket to plastic bracket is predicated on expertise of style engineer. Recently in business topology optimisation is employed. Topology optimisation may be a mathematical technique that optimizes material layout inside a style house, for a given set of masses, boundary conditions and constraints with the goal increasing the performance of the system.

TO is totally different from house optimisation within the sense that the look will attain any form inside the look house, rather than coping with predefined configurations. Today in some cases results from topology optimisation will be directly factory-made victimisation additive producing; TO is therefore a key a part of style for additive manufacturing.

Fig. 9 shows the required thickness at particular locations. If density values vary between 0.0 to 0.4 the material at that particular location can be neglected. Topology optimization is done in ANSYS 18.1

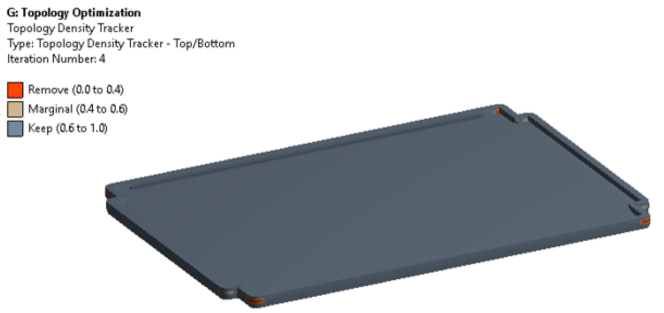


Fig. 15: Topology optimization

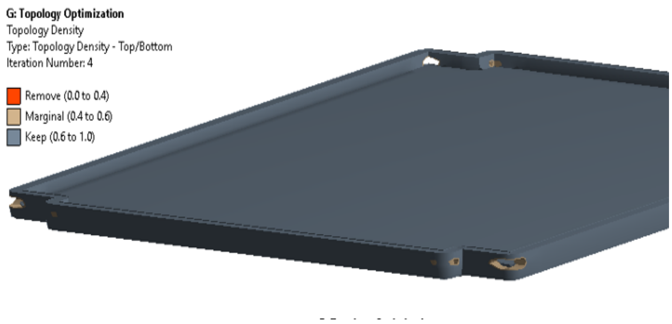


Fig. 16: Material removal suggestion in topology optimization

Topology optimization is done in Ansys software. After applying boundary condition and loading condition it gives the required density at different locations of the component. As given above if the density at particular location varies from 0-0.4 it is shown with help of red colour i.e. material at that particular location is not adding to the strength and it can be removed. If density varies from 0.4-0.6, it is marginal density and thickness at that particular location can be reduced without altering its strength. Topology optimization gives the unused material location and amount which is helpful to further reduce the weight of component.

RESULTS:

a. Mass

Table 1: Mass

Mass of sheet metal bracket in KG	Mass of 3D printed polypropylene bracket in KG	Percentage reduction in Mass
0.714	0.1256	82.4 %

b. Stress

Table 2: Stress

	Stress induced in sheet metal battery bracket (MPa)	Stress induced in polypropylene bracket (MPa)
Maximum	6.2833	2.6638
Minimum	0.016548	0.0052316

c. Modal Frequencies

Table 3. Modal frequencies

Mode	Frequency for sheet metal battery bracket (Hz)	Frequency for polypropylene battery bracket (Hz)
1	426.04	189.3
2	703.95	313.23
3	997.25	444.73
4	1167.6	519.13
5	1273.6	563.49
6	1721.9	760.21

2. Conclusion:

The optimization of selected component i.e. battery bracket is done by replacing existing sheet metal battery bracket by 3D printed polypropylene battery bracket. The weight of the existing sheet metal battery bracket is reduced which will in turn increase the fuel economy of the vehicle. The static loading characteristics of 3D printed battery bracket is better than existing sheet metal battery bracket which will subsequently increase the life of battery bracket. Topology optimization is also done to find out the excessive material so as to further reduce the weight of the optimized battery bracket. It can be concluded that the 3D printed battery bracket have less weight, better load bearing capacity and longer life than the existing sheet metal battery bracket. The selected component is one of the components which is replaced by thermoplastic material with the help of 3D printing. Similarly different components of automobile like engine bracket, seats.

3. Acknowledgement:

I 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. I am very grateful to Prof. C. A. Joel, Project Guide for being incredibly supportive throughout the work and his exhaustive guidance and patience he has while listening my approaches and supporting my endeavor.

4. References:

1. Andrea Merullaa, Andrea Gattob, Elena Bassolib, SorinIon 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.