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MANUFACTURING OF RAPID PROTOTYPES OF MECHANICAL PARTS USING REVERSE ENGINEERING AND 3D PRINTING

Salah Amroune[1,2,*], Ahmed Belaadi[3], Moussa Zaoui[1,2], Noureddine Menaseri[1,2], Barhm Mohamad[4], Khalissa Saada[1,2], Riyad Benyettou[1,2]

[1] University Mohamed Boudiaf of M'sila Algeria
e-mail: salah.amroune@univ-msila.dz
[2] Laboratoire de Matériaux et Mécanique des Structures (LMMS). Université de M'sila
[3] Université 20 août 1955-Skikda, B.P.26 route El-Hadaiek Skikda-Algérie
e-mail: ahmedbeladi1@yahoo.fr
[4] Department of Petroleum, Koya Technical Institute, Erbil Polytechnic University, 44001 Erbil, Iraq
e-mail: barhm.mohamad@epu.edu.iq
**corresponding author*

Abstract

This article focuses on the design and manufacture of mechanical parts that have complicated shapes using the technique of reverse design using a scanner or an MMT for data acquisition in the form of a point cloud, using CAD software (CATIA). The digital model created is used for a virtual representation of the final product. Then we get the physical model on a 3D printer (also called additive manufacturing process) for later use in sand moulds. To have the imprint in the sand mould, we go through the fusion of the physical model (part). The use of this technique in the industry, allows us to save a lot of time in terms of model preparation and simple to implement, especially if it is mechanical parts that do not have a definition drawing, or they are worn out, then structural analysis was applied on the model using FE based software and tools to prove the quality of the product. Von Mises equivalent strains and stresses were predicted and decreased with increasing areas and honeycomb thickness. The objective of this article is to give an overview of this relatively modern technology and its various applications.

Keywords: Point cloud, honeycomb, retro design, 3D printing, left surfaces, Von Mises

1. Introduction

Many methods of shape reproduction are based on a Reverse Engineering (RE) approach. Indeed, the objective is to convert a set of discrete data into a continuous model which can be used as the basis for many applications, in particular machining or even rapid prototyping. The procedure can be characterized by 4 main stages: data acquisition; processing of acquired data; CAD modeling (Varady et al, 1997; Amroune et al., 2018) and finally additive manufacturing (3D) printing which uses computer-aided design (CAD) data to perform a continuous layering of different shapes to produce 3D objects (Vaezi et al., 2013; Melchels et al., 2012; Bahnini et al., 2018; Liu et al., 2018; Guvendiren et al., 2016; Guida et al., 2019; Rengier et al., 2010; O'Brien et al., 2015). Therefore, there are several materials commonly used to 3D print. From ceramics to metal, passing through gold or plastic, the materials most commonly used in 3D printing remain thermoplastics. Indeed, they are extremely handy and are designed to be very resistant (Wu, H. C., & Chen, T. C. T., 2018). The Applications of 3D printing technologies aim to reduce manufacturing costs and time (Schubert et al., 2014). Several applied research works, including a major study on 3D printing in the field of medicine led by Lee Ventola (2014), who concluded that organs made with 3D printing are already important and exciting, but that some of the most revolutionary applications, such as the printing of vital organs, will need time to evolve. A recent study by (Katseli et al., 2020) on a novel all-3D-printed cell-on-a-chip device as a useful electro analytical tool; which aim to describe a new cell-on-chip electrochemical device entirely manufactured by 3D printing. The result proves that the cell-on-chip electrochemical device exploits the significant advantages of 3D printing (mainly high manufacturing speed and reproducibility, low equipment and material costs, flexibility and transferability, design and respect for environment) and is a promising integrated sensor for routine and on-site applications.

In this study we want to show through parts made on 3D print through the scanning operation (CMM or scanner), then the processing of data using CAD software (CATIA V5) and ends by printing the model, that the use of this technique in industry, allows us to save a lot of time in terms of model preparation and simple to implement, especially if it is mechanical parts that have no definition drawing or they are worn out. The aim of this work is to give an idea of a relatively modern technology and its various applications.

2. Materials and techniques used

The 3D printing technique is also known as additive manufacturing. It is a process used for the creation of 3D objects whose layers are formed under the control of a computer to create an object. The objects that are produced can be geometric in shape and are mainly produced using digital model data. The printer used in this work is of type "Anycubic i3 mega" with a resolution which varies between (0.05-0.3 mm) and a printing speed of 60 mm/S. The diameter of the wire is 0.9 mm the material used is PLA type, the melting temperature 210 °C and the working space is (210 x 210 x 205 mm). The reverse engineering technique is generally applied to generate complex 3D surfaces in the form of data, as an example turbine blade (Figure 1a). A FARO-type laser scanner is used for data acquisition (Figure 1b), then the data acquisition is transmitted to a computer in the form of point clouds (more than 1 million points) grouped in a text file which contains three coordinates (x, y and z). The profile of the gas turbine blade model is generated using the CATIA V5R20 software. The 3D model of a gas turbine blade with root was produced in two stages (Digitized Shape Editor, Quick Surface Reconstruction). These two were then combined to create a single volume. The geometric model of the gas turbine blade is illustrated in Figure 1c.

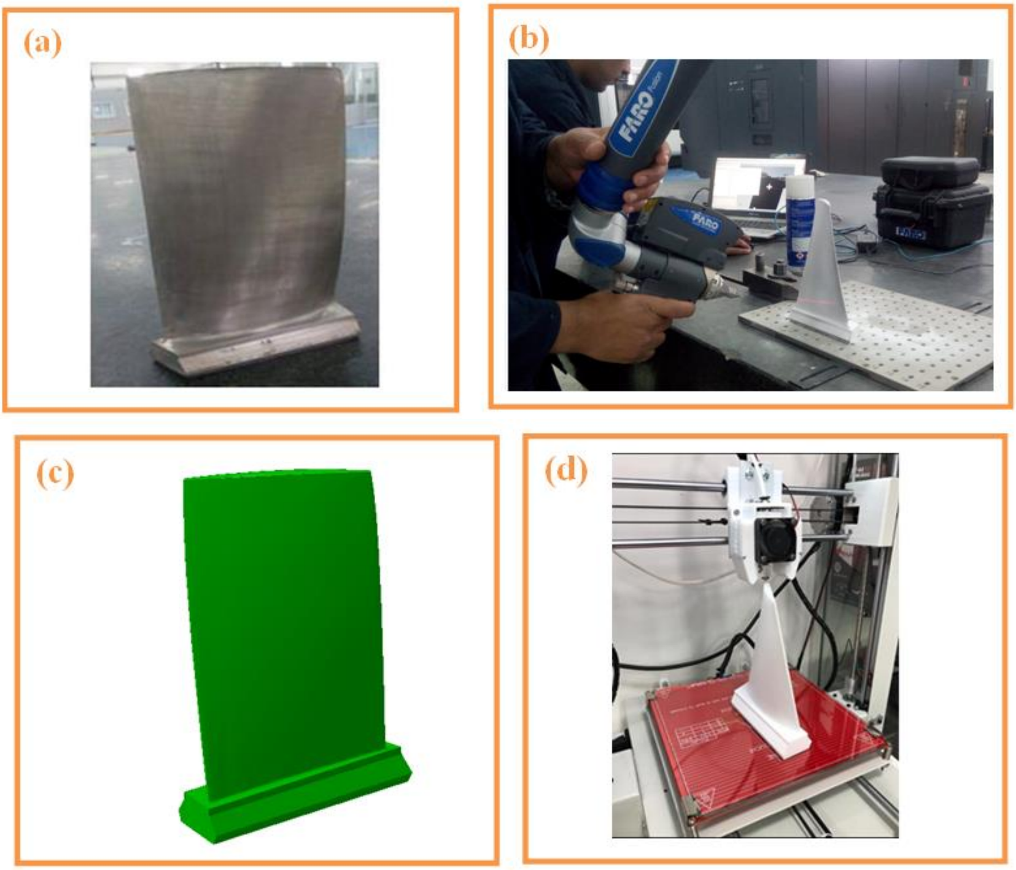


Fig. 1. The manufacturing process: (a) gas turbine blade (b) FARO scanner (c) reproduces the geometric shape on CATIA V5 (d) 3D printing.

For the second part (Figure 2) the data is acquired by the MMT of Type MITUTOYO. Three-dimensional measuring machines (CMMs) are machines used in dimensional metrology. They make it possible to obtain the coordinates of the measured points (probed) on a mechanical part; we sometimes speak of metrology by coordinates. With the measurement carried out, a digital comparison is made of a known quantity with the measured quantity. Consequently, taking coordinates makes it possible to highlight deviations from the nominal and therefore to verify that the dimensions. The measurement of geometric quantities can be carried out both with simple measuring means such as callipers or micrometres, as with more complex means such as CMMs. (Portal CMM) and Manual (300x250x300 mm).

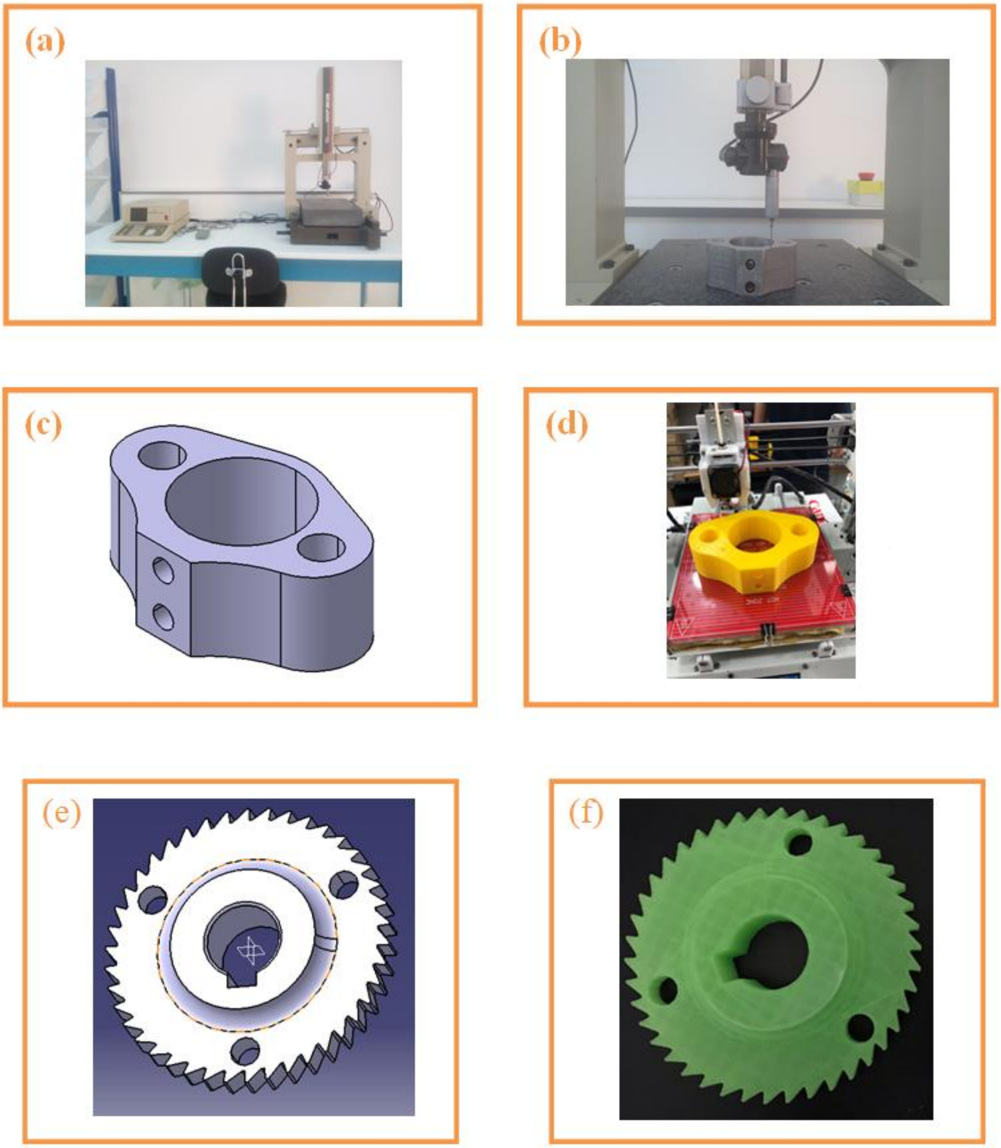


Fig. 2. The manufacturing process: (a) MMT MXF 203 three-dimensional measuring machine (University of M'sila), (b) CMM probe, (c, e) reproduce the geometric shape on CATIA V5, (d, f) 3D printing.

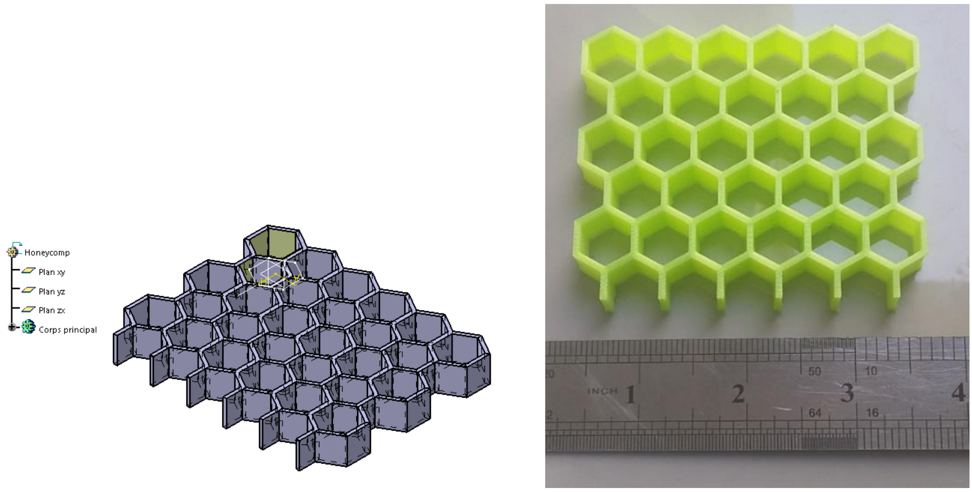


Fig. 3. (a) Actual model (b) The dimensions of specimen.

3. Results and Discussion

3.1 Scanning and 3D printing process

In this study, we used two methods of data acquisition (Faro scanner and CMM), we note that the use of the Faro scanner is faster in terms of data acquisition time, the result obtained is the same, in both cases we obtain a text file which contains the data in x, y and z form compared to a reference frame of the part. The operation is summarized by the flowchart (Figure 4) of CATIA software which gives us an STL file from a digital file. Parametric CAD models contain design intent, a structured combination of 3D prismatic functions driven by specific dimensions. An IGES or STEP output is a simplified version of this parametric 3D CAD model, generally represented by this external "skin" of the CAD surface, allowing users to share 3D data between several platforms that do not share a common internal language.

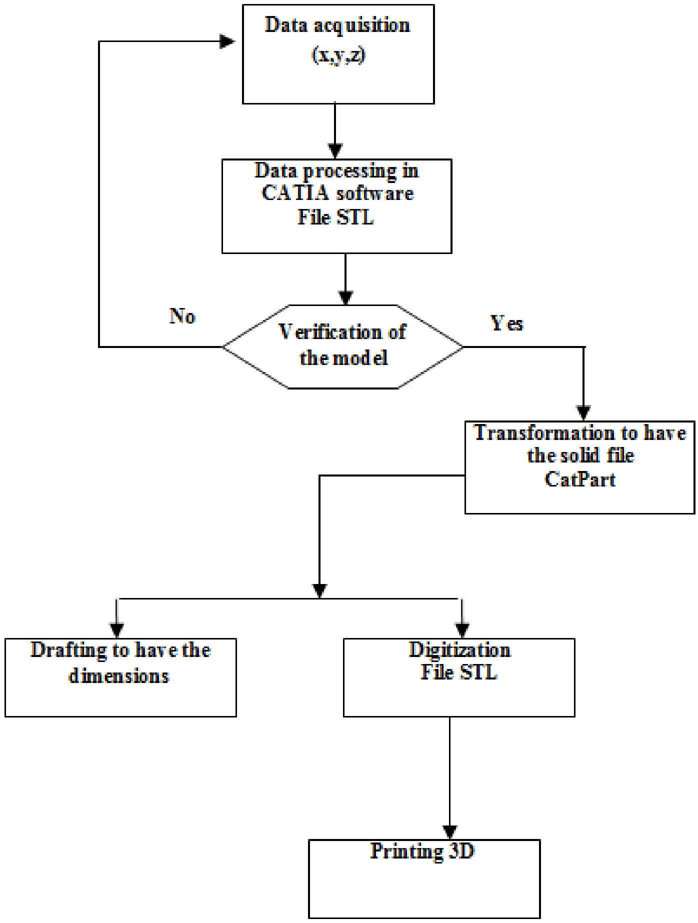
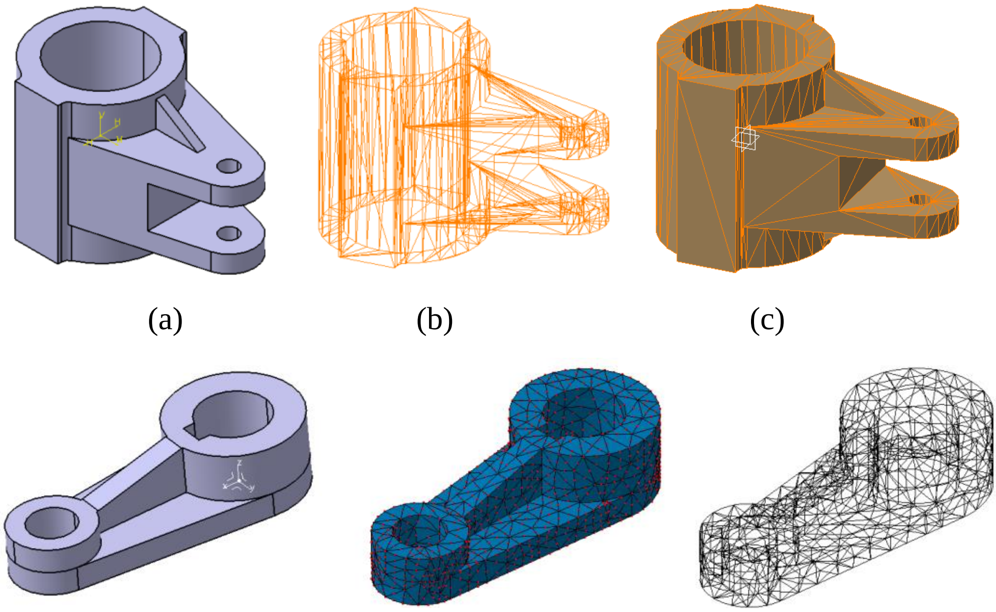


Fig. 4. Data acquisition flowchart.

Knowing what changes may be necessary, a user can design a part to make these intended areas easier to modify without fighting against bulky surfaces, leave or drafts in the CAD Model. In Figures 5a-5f, examples of the parts or format STL format are shown, applied in CATIA V5 where we show the passage of the different models from 3D model to STL format with wireframes and STL format with mesh and points. These different formats help us to arrive at the final format before printing the model on 3D print.



(a) (b) (c)

(d) (e) (f)

Fig. 5. Example of STL format applied in CATIA V5 (a, d) 3D model (b, e) STL format with mesh and points (c, f) STL format with wired.

The final step is to print the object on a 3D printer. Additive manufacturing can provide a number of different options for preparing custom scaffolding for part creation. The prototypes of the parts manufactured in this study are shown in Figures 1d and Figure 2d. The colour of the white (Figure 1d) or yellow (Figure 2d) print wire does not matter, it is just to show our prototype. There is another parameter which makes the difference between a model and another, it is the density of impression which characterizes the prototype worked out and gives an idea on the robustness and the resistance of the final part. It remains to be noted that there are other types of printing materials, notably wood and metal. This method of printing can offer very high quality – both high resolution and full colour models. In theory, the process can be almost zero waste, because the powder can be reused, and no support material is required. The few of the printing methods which have undergone full LCA, inkjet printing of green materials has shown some of the greatest potential for sustainability. However, experimental materials often do not yet meet quality standards for consumer products. Inkjet printers can print more than one part at a time. The printing time correlates more strongly to part height than to the amount of material printed.

3.2 Structure analysis of selected Honeycomb using Finite Element Analysis

The analysis of the stress distribution for entire of honeycomb structural engineering is invariably complex and for many problems it is extremely difficult and time-depend to obtain analytical solutions. The finite element method is a technique of numerical analysis to obtain approximate solutions. It has now become a very important and powerful tool for the digital solution of a wide range of engineering problems. The method used for the analysis of solid structures of complex shapes and complicated boundary conditions.

Type of mesh	Type of element	Properties of node and settings	Size of the element (mm)	Total number of nodes	Total number of elements	Geometric tolerance (mm)
Linear tetrahedron	Linear	3d octree mesh	5.356	1267	3038	0.1

Table 1. The characteristics of mesh.

In Figure 6 Equivalent Von Mises stress were found to maximum at the fixed ends whereas tends decrease towards the centre. Also, discontinuity in stress distribution has been observed over the honeycomb.

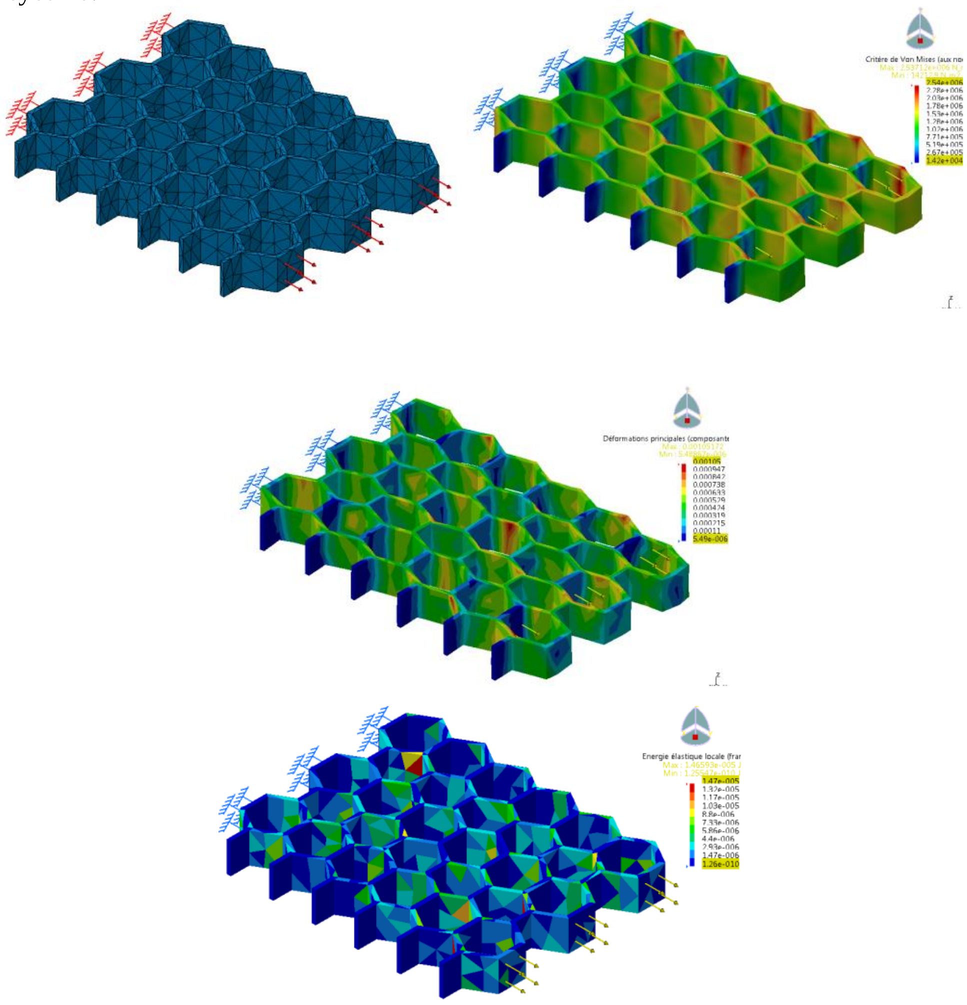


Fig. 6. Example Structure analysis Honeycomb (Stress, strain; energy).

The slope-deflection theory where deflection is given as:

$$\delta \max = \frac{qL^4}{348EI} \tag{1}$$

Where; δ max= max deflection at centre, q = load per unit length, E = Modulus of elasticity, I = Area moment of inertia.

4. Conclusions and Perspectives

This study allowed us to conclude the following main points:

- Production time and costs are reduced.
- The design and manufacturing defect can be easily identified.
- Able to produce parts and conceptual models at different scales (enlargement or reduction of printed objects).
- The production of more complex objects can be produced at lower cost.
- Saving material.

Also, we can use it in the field of machining to generate the G code. Finally, static structural tests were executed to find stress and deformation regions; minimum and maximum von-mises stress as well as total deformation. Since the model has been analysed on multiple dimensional parameters, it can be used as per the requirement and economics of the project. The FEA method is suitable from the experimental setup because it may be used for the comparison of behaviour of various other configuration honeycomb structures by changing the parameters of materials. Further the results may be improved by refining the geometric design, meshing, element type, boundary conditions etc.

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