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DESIGN AND FABRICATION OF TRIPLY PERIODIC MINIMAL SURFACE POROUS GYROID STRUCUTRES FOR BIO MEDICAL APPLICATIONS USING FUSED DEPOSIT MODELING PROCESS

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Abstract: This paper presents the efforts made in the design and fabrication of porous triply periodic minimal surface gyroid structure made of polylactic acid material in order to determine the difficulties faced while designing of porous structures produced with the fused deposit modeling for biomedical applications. The problem concerning with the fabrication of gyroid structure with conventional method. The work is focused on designing the gyroid triply periodic minimal surface polylactic acid structure and studying the design considerations of structures. The three-dimensional triply periodic minimal surface-based lattice structures with porosity ranging from 20% to 70% porosity were designed and fabricated. This work establishes the appropriate porosity to minimize the mismatch of elastic modulus between the implant and the bone by adding the porosity to the implant structure.

Keywords: Triply Periodic Minimal Surface, 3D printing, Fused Deposition Modeling Process, Gyroid, Porosity.

I. INTRODUCTION

Triply periodic minimal surface gyroid porous structure eliminates the weight concern and bone osseointegration [1]. Additive manufacturing (AM) is a process that produces the parts by adding the material together, typically layer-by-layer method, based on the three-dimensional (3D) computer-aided design (CAD) data. The AM technology allows complex designs and also impacts on the manufacturing procedures in various fields including automobile, aerospace and biomedical engineering. Due to the improvement in additive manufacturing technology and the availability of various materials, the AM technology is used to produce orthopedic implant structures and scaffolds [2]. In particular for fabricating these porous structures fused deposition modelling process has been used [3]. By designing them in design software (PTC CREO 7.0) and using polylactic acid as a material [4]. Because of latest AM technologies such kind of complex structures are fabricated and used in biomedical applications [5]. The main objective of this project is to minimize the elastic modulus between implant structure and bone so that there will be no stress shielding. Generally, cortical bone has elastic moduli ranging from 3 to 30 Gpa and polylactic acid material elastic moduli ranging from 0.05 to 14 Gpa [6].

II. METHODOLOGY

Designing and fabricating

1. Initially, design a 3D CAD model using CREO software.
2. Then using lattice features present in software create a porous structure.
3. By varying unit cell gaps in the structure porosities are varied.
4. Then the structure with porosity can be seen for visual confirmation.
5. This process gets repeated with porosity ranging from 10% to 50%.
6. As the porosity increases the structure strength decreases and implants fails.
7. The structures which are designed saved in STL file format for 3D printing machine to fabricate it.
8. Fused Deposition Modeling process has been opted for fabrication technique.
9. Polylactic acid material has been chosen because of its stress strain behaviour and low elastic modulus value .
10. Finally, the gyroid structures are printed with the help of designed models.

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Software used for design
1. PTC CREO 7.0 is used to design every structure of the project.
2. This structures porosity also added in PTC CREO 7.0
3. Some of the commands used to design the structures are Sketch, Line, Rectangle, Extrude, Engineering, Lattice, Cell type, etc.

III.DESIGN OF GYROID STRUCTURE

PTC CREO software is a flexible and powerful integrated solution that helps you design parts faster and more efficiently. CREO delivers the next generation of modelling software that enables companies to realize the value of the digital twin. This feature is very useful in companies that work in R&D. Since most automobile, aerospace and biomedical industries need to be competitive. CREO is formerly known as "CREO Elements/Pro", is an advanced high-end CAD/CAM/CAE. It is used, among other tasks, for Design (parametric and direct solid/surface modelling), Engineering analysis (static; dynamic; electro-magnetic; thermal, using the finite element method; and fluid, using the finite volume method), Manufacturing finished design by using included machining modules. The design of the parts of triply periodic minimal surface gyroid structures is done in CREO.

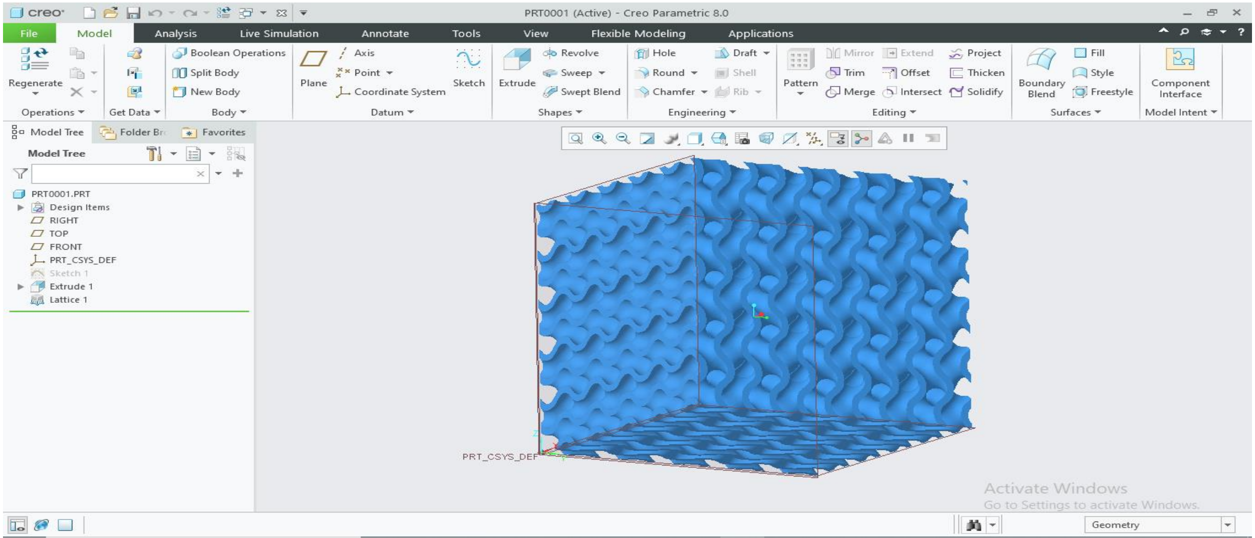

Fig. 1 Gyroid structure with 20% porosity designed in PTC CREO

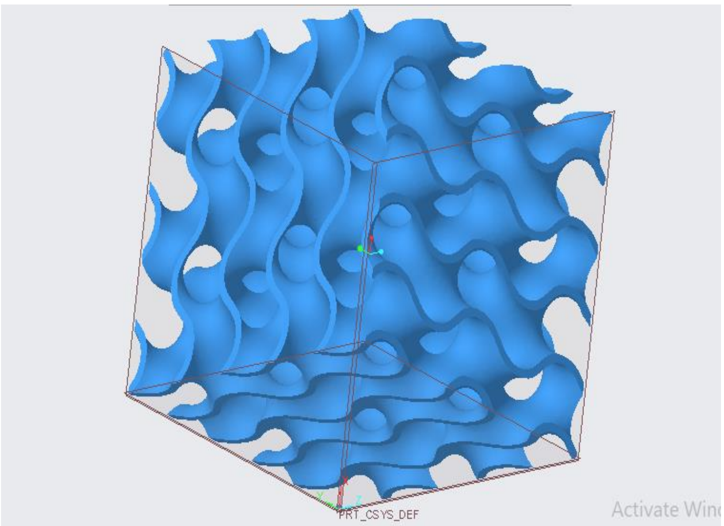

Fig. 2 Gyroid structure with 40% porosity designed in PTC CREO

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IV.MATERIAL

The material for the fabrication of the gyroid structure is:

- Polylactic acid

V.FABRICATION

The below gyroid structure is designed in PTC CREO with porosity about 20%. A simple cube is developed with varied porosities and polylactic acid as material and FDM technique is used for manufacturing this lattice structures. This structure which acts as an implant reduce stress shielding and bone osseointegration. FDM process constructs three dimensional objects directly from CAD data which are in STL file format. A temperature controlled layer by layer addition of thermoplastics process.

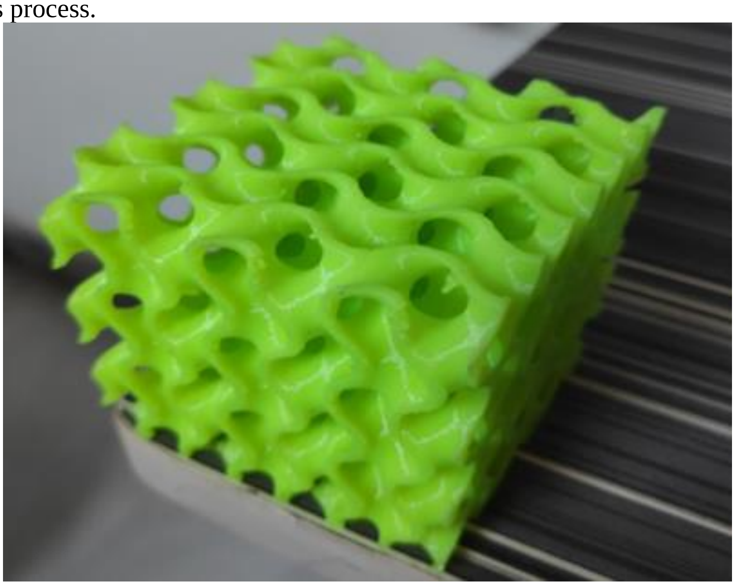

Fig. 3 Gyroid structure with 20% porosity

The below gyroid structure with increase of porosity leads to ease of bone ingrowth.

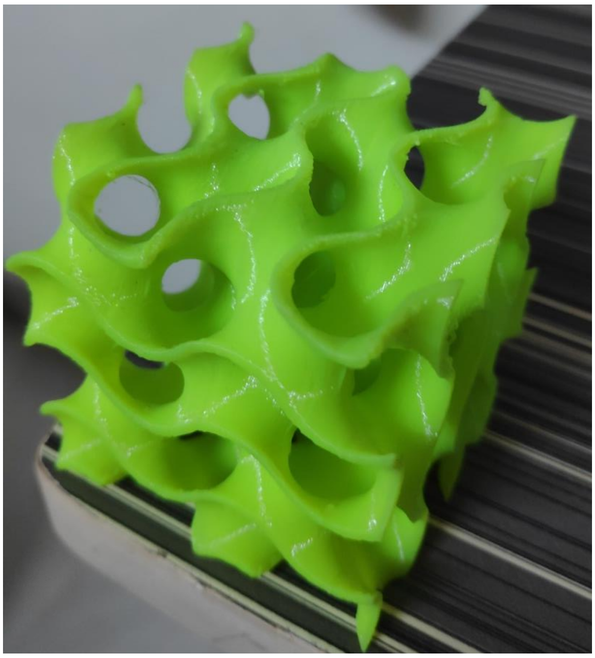

Fig. 4 Gyroid structure with 30% porosity

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From below figure with gyroid structure 50% porosity meets optimum level of matching elastic modulus of bone and implant.

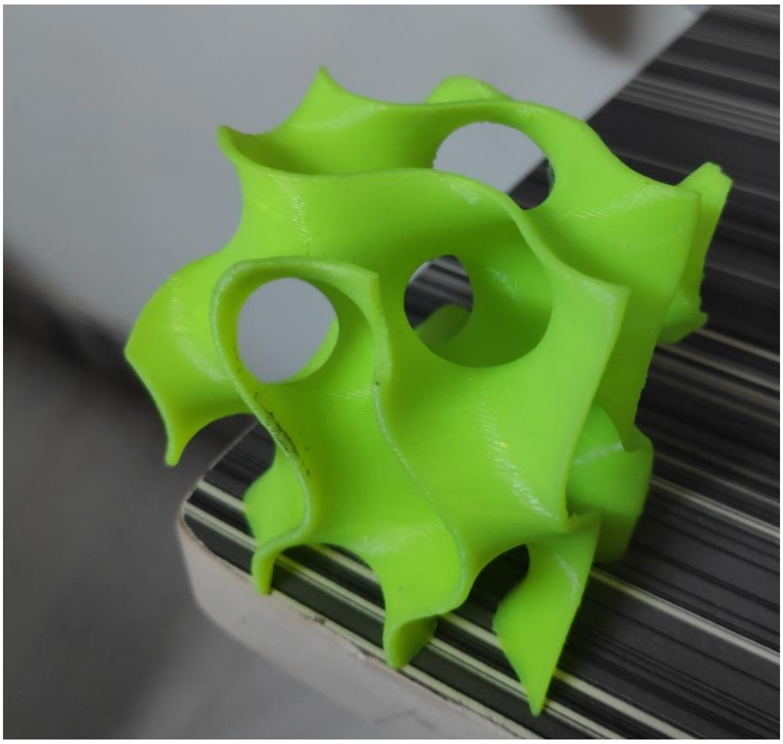

Fig. 5 Gyroid structure with 50% porosity

Finally the below figure gyroid structure with 70% porosity may fail due to its strength to weight ratio and may cause further bone related problems.

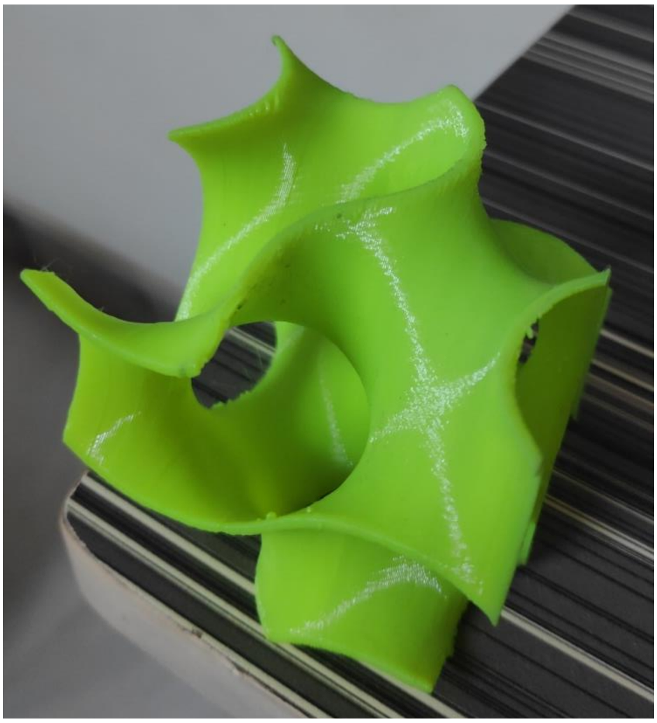

Fig. 6 Gyroid structure with 70% porosity

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VI.CONCLUSIONS

In this paper, the study of the triply periodic minimal surface gyroid structure led to the following conclusions

- In this paper gyroid structure with porosity embedded has been fabricated.
- The polylactic acid material has low elastic modulus compared to metallic implants.
- The porosity to volume of the structure has been observed.
- Decreasing the porosity leads to increase of bone osseointegratoion.
- FDM technique helped in prototyping and produce functional products.

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