

# Design and Manufacturing of Sprocket using Additive Manufacturing Technology

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## ABSTRACT

Additive manufacturing, often referred to as 3D printing, has the potential to vastly accelerate innovation, compress supply chains, minimize materials and energy usage, and reduce waste. Originally developed at the Massachusetts Institute of Technology in 1993, 3D printing technology forms the basis of Z Corporation's prototyping process. 3DP technology creates 3D physical prototypes by solidifying layers of deposited powder using a liquid binder. By definition 3DP is an extremely versatile and rapid process accommodating geometry of varying complexity in hundreds of different applications, and supporting many types of materials. Z Corp. pioneered the commercial use of 3DP technology, developing 3D printers that leading manufacturers use to produce early concept models and product prototypes. Utilizing 3DP technology, Z Corp. has developed 3D printers that operate at unprecedented speeds, extremely low costs, and within a broad range of applications. This paper describes the core technology and its related applications.

Additive manufacturing, often referred to as 3D printing, is a new way of making products and components from a digital model. Like an office printer that puts 2D digital files on a piece of paper, a 3D printer creates components by depositing thin layers of material one after another, only where required, using a digital blueprint until the exact component has been created. Interest in additive techniques is growing swiftly as applications have progressed from rapid prototyping to the production of end-use products. Additive equipment can now use metals, polymers, composites, or other powders to "print" a range of functional components, layer by layer, including complex structures that cannot be manufactured by other means.

By eliminating production steps and using substantially less material, 'additive' processes could be able to reduce waste and save more than 50% of energy compared to today's 'subtractive' manufacturing processes, and reduce material costs by up to 90%. The use of additive manufacturing can potentially benefit a wide range of industries including defence, aerospace, automotive, biomedical, consumer products, and metals manufacturing.

In this project, parametric model is done in Catia V5R20 and 3D- printing is done in Cura software.

**KEYWORDS:** Additive Manufacturing, Prototypes, 3D-Printing, Deposition, Binder, Rapid Prototyping, Subtractive manufacturing

## I. INTRODUCTION

3D printing is the type of Additive Manufacturing is any of various processes for making a three-dimensional object of almost any shape from a 3D model or other electronic data source primarily through additive processes in which successive layers of material are laid down under computer control. A 3D printer is a type of industrial robot. Early AM equipment and materials were developed in the 1980s. In 1984, Chuck Hull of 3D Systems Corp, invented a process known as stereo lithography employing UV lasers to cure photopolymers. Hull also developed the STL file format widely accepted by 3D printing software, as well as the digital slicing and infill strategies common to many processes today. Also, during the 1980s, the metal sintering forms of AM were being developed (such as selective laser sintering and direct metal laser sintering), although they

were not yet called 3D printing or AM at the time. In 1990, the plastic extrusion technology most widely associated with the term "3D printing" was commercialized by Stratasys under the name fused deposition modelling (FDM). In 1995, Z Corporation commercialized an MIT-developed additive process under the trademark 3D printing (3DP), referring at that time to a proprietary process inkjet deposition of liquid binder on powder. AM technologies found applications starting in the 1980s in product development, data visualization, rapid prototyping, and specialized manufacturing. Their expansion into production (job production, mass production, and distributed manufacturing) has been under development in the decades since. Industrial production roles within the metalworking industries achieved significant scale for the first time in the

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early 2010s. Since the start of the 21st century there has been a large growth in the sales of AM machines, and their price has dropped substantially. According to Wohlers Associates, a consultancy, the market for 3D printers and services was worth \$2.2 billion worldwide in 2012, up 29% from 2011. Applications are many, including architecture, construction (AEC), industrial design, automotive, aerospace, military, engineering, dental and medical industries, biotech (human tissue replacement), fashion, footwear, jewellery, eyewear, education, geographic information systems, food, and many other fields.<sup>[1]</sup>

Additive manufacturing is the official industry standard term for all applications of the technology. It is defined as the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies. Synonyms are additive fabrication, additive processes, additive techniques, additive layer manufacturing, layer manufacturing, and freeform fabrication. The primary applications of additive fabrication are design/modeling, fit and function prototyping, and direct part production. Around the world, AM is changing the way organizations design and manufacture products. When used correctly, it can save impressive amounts of time and money. Companies maintain that AM has helped trim weeks, even months, of design, prototyping, and manufacturing time, while avoiding costly errors and enhancing product quality.<sup>[2]</sup>

## II. LITERATURE SURVEY

**Brogan Rylands and et.al** in his paper “3D Printing - To print or not to print? Aspects to consider before adoption - A supply chain perspective” has concluded that There is much complexity around 3D printing, which brings about the need to essentially reengineer value streams. It is a collaborative attempt across the whole organisation and there are many aspects to be considered, stemming not only from a business and technical perspective but also social and environmental aspects that require consideration.

This paper provided an overview of what 3D printing is, examples of industries that it is currently deployed in, how it can influence supply chains and aspects for consideration before adoption. It highlighted the need for increased awareness and collaboration in the area and future challenges and opportunities.

However, how does a company prepare for such a change? How does it educate itself? How can the fire for 3D printing be sparked in industry? When is the right time to adopt 3D printing? What additional aspects are managers currently considering when facing the 3D adoption challenge? Are all aspects of equally important or can even some aspects be disregarded? How has 3D printing impacted on manufacturing and the wider supply chain today? How will 3D printing impact manufacturing and the wider supply chain in future? How well is Australia positioned when compared to their international counterparts in regards to 3D printing? How does 3D supply chain costing compare with traditional manufacturing supply chain costing? How mature does your supply chain need to be in order to deploy 3D technology meaningfully and harvest its benefits?

It is expected that this research will contribute to academia/ theory and practice. A conceptual model or framework

incorporating major aspects to be considered for businesses before pursuing 3D printing has been developed that will need to be verified through case study/ field research in industry. It is further expected that businesses will benefit from the model through informed and improved decision making prior to deploying such cutting-edge technology on their production line.<sup>[3]</sup>

**Alexandru Pirjan Dana-Mihaela Petroşanu** in his journal “The impact of 3D Printing technology on the society and economy” concluded in this paper, we have presented and analysed the impact of 3D printing technology on the society and economy. After presenting, in the introduction, a brief history of 3D printing, in the second section we have depicted the additive technology and the materials used in rapid prototyping. In the third section, we have highlighted the main advantages and limitations of the 3D printing technology, while in the fourth section we have made a survey of the most significant existing 3D printing solutions. We have compared these 3D printing solutions, taking into account their technical specifications and prices. One can conclude that the 3-D printing technology’s importance and social impact increase gradually day after day and significantly influence the human’s life, the economy and modern society.<sup>[4]</sup>

**Vinod G. Gokhare and et.al** in his paper titled “A Review paper on 3D-Printing Aspects and Various Processes Used in the 3D-Printing” conclude that Introduction part is about the brief history of 3D printing, in the next section we have depicted the 3D-printing and the processes used in 3D-printing and the properties of the 3Dprinter materials. In the third section, we have highlighted the main advantages and limitations of the 3D printing technology. One can conclude that the 3-D printing technology's importance and social impact increase gradually day by day and influence the human's life, the economy, and modern society. 3D Printing technology could revolutionize the world. Advances in 3D printing technology can significantly change and improve the way we manufacture products and produce goods worldwide. An object is scanned or designed with Computer Aided Design software, then sliced up into thin layers, which can then be printed out to form a solid three-dimensional product. As shown, 3D printing can have an application in almost all of the categories of human needs as described by Maslow. While it may not fill an empty unloved heart, it will provide companies and individuals fast and easy manufacturing in any size or scale limited only by their imagination. 3D printing, on the other hand, can enable fast, reliable, and repeatable means of producing tailor-made products which can still be made inexpensively due to automation of processes and distribution of manufacturing needs.<sup>[5]</sup>

**Thabiso Peter Mpfu and et.al** from his journal paper titled “The Impact and Application of 3D Printing Technology” concluded that the 3D printing industry is set on a growth trajectory as evidenced by the growth forecasts. The applications of 3D printing are increasing as more and more research is carried out. 3D printing will change the way people acquire products as evidenced by the Amazon proposed model. The field is definitely a game changer with lots of prospects to look out for.<sup>[6]</sup>

**Baljinder Singh Shahi** in his paper titled “Advanced Manufacturing Techniques (3D Printing)” concluded that Additive manufacturing, starting with today's infancy period, requires manufacturing firms to be flexible, ever-improving users of all available technologies to remain competitive. Advocates of additive manufacturing also predict that this arc of technological development will counter globalization, as end users will do much of their own manufacturing rather than engage in trade to buy products from other people and corporations. The real integration of the new additive technologies into commercial production, however, is more a matter of complementing traditional subtractive methods rather than displacing them entirely.<sup>[7]</sup>

**Avishek Mishra and et.al** in his journal paper titled “Literature Survey of Convertible Wheel Drives Using Chain Sprocket” concluded that chain sprocket engagement used to drives the wheel, this discussion suggests the selection of various chain arrangement used for different types of vehicle. It shows the various advantages like transmits more power than belts. No slip takes place during chain drive. Production cost is relatively high and the chain drive has velocity fluctuations especially when unduly stretched. It has the ability to transmit motion to several shafts by one chain only. The chain drive needs accurate mounting and careful maintenance, particularly lubrication and slack adjustment. It gives high transmission efficiency (upto98percent). It can be operated under adverse temperature and atmospheric conditions. It permits high speed ratio of 8 to 10 in one step.<sup>[8]</sup>

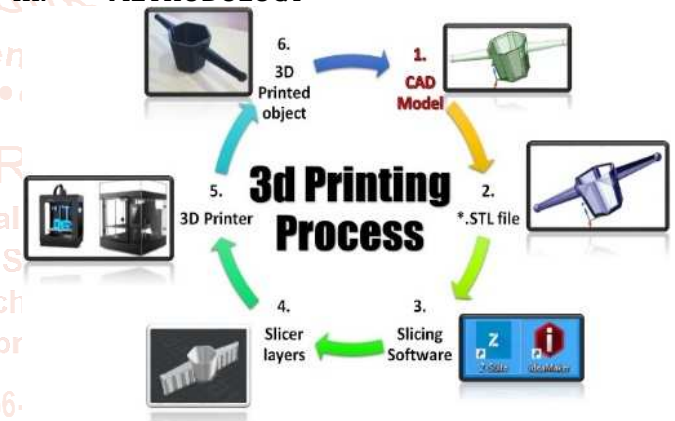
**Abhishek Barua and Sasmita Kar** in their journal titled “Review on Design Optimization of Sprocket Wheel Using Different Techniques” concluded that it is interesting to observe that mostly researchers have chosen Finite Element Analysis to optimize the sprocket. Mostly they have chosen different grades of steel as their base material. Few have tried to substitute the steel with composite material also. As compared to steel, composites are not so easy to be machined using traditional machining processes. Few of the researchers have optimized the sprocket using FEA software without performing the experiment validation. Hence, it can be concluded that more weight reduction can be achieved by re-designing the sprocket geometry like teeth profile, hub, bolt holes, pockets etc. and more torque can be achieved. Since metals will be going to deplete someday, researchers are searching for more alternative materials. Polymer composites are slowly finding its place as a replacement to steel. Re-designing of sprocket can be done by using the different compositions of polymer matrix composites and more weight can be optimized without reducing the power transmission. Metal-Matrix composite can be also used as a substitute to steel for manufacturing of sprocket. Cost of material is an another factor which restricts the use of alternate materials in place of existing materials for sprocket manufacturing for automobiles and machineries. New manufacturing techniques can also be introduced or the existing methods can also be optimized for fast and precision manufacturing of the sprockets. So the above techniques can be used for further development of chain sprocket and more efficiency can be achieved during power transmission.<sup>[9]</sup>

**Nikhil P. Ambole, Prof. P. R. Kale** in their journal paper “A Review on Carbon Fiber Sprocket Design Analysis and Experimental Validation” concluded that This literature

review work includes study of design and analysis of sprocket chain. Also study the various optimization techniques. For the finite element-based optimization purpose the study of suitable software for optimization of weight and selection of alternate material will carry out by referring different books and earlier research works published in reputed journals.<sup>[10]</sup>

**Suthar Nirav and et.al** in his journal entitled “Proposed Work on Sprocket Side Stand Retrieve Mechanism in Two-wheeler Vehicle” concluded that “Sprocket- side stand retrieve mechanism for two-wheeler vehicle” will definitely good retrieve system. This mechanism is not requiring to any extra fuel or alternative and direct current. It works with directly by the chain drive. The chain drive gets power from the engine. So manufacturing and maintenance cost is economical. Since the setup is compact it does not affect the performance of the vehicle. This system can be implemented in all types of bikes by changing small variation in size and cost of this system also very low and so it will not affect the economic level also. While compare to other system this will be the life saver.<sup>[11]</sup>

### III. METHODOLOGY



There are some procedures for printing. First you must create a computer model for printing the object. For creating that, you can use Computer Aided Design Software like AutoCAD, 3DS Max etc. After the object file is created, the file needs to be modified. The object file contains numerous amounts of curves. Curves cannot be printed by the printer directly. The curves have to be converted to STL (Stereo lithography) file format. The STL file format conversion removes all the curves and it is replaced with linear shapes. Then the file needs to be sliced into layer by layer. The layer thickness is so chosen to meet the resolution of the 3D printer we are using. If you are unable to draw objects in CAD software, there are many websites available which are hosted by the 3D printing companies to ease the creation of 3D object. The sliced file is processed and generates the special coordinates. These coordinates can be processed by a controller to generate required signal to the motor for driving extruder. This layer by layer process generate a complete object.

### IV. DESIGN

Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is

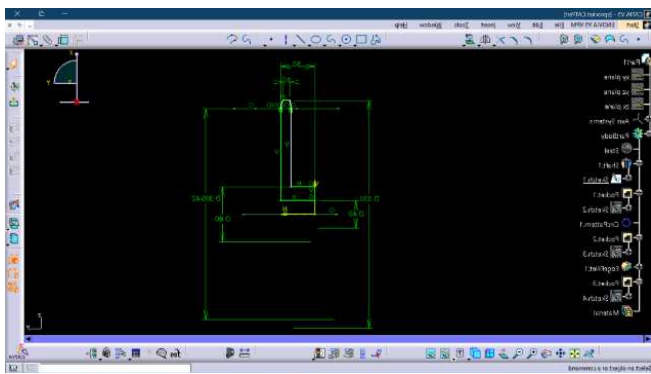
often in the form of electronic files for print, machining, or other manufacturing operations.

CAD software for mechanical design uses either vector-based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects. However, it involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application- specific conventions.

The **sprocket** that is to be printed in this project is designed in one of the popular CAD software, CATIA.

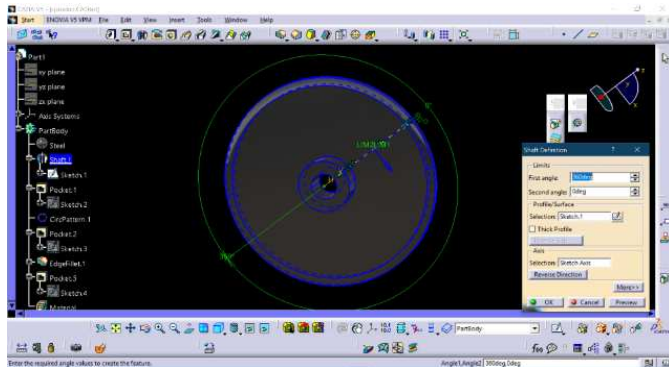
The sprocket is designed in Catia in the following way:

- In Catia, part modelling is to be selected first. Then, by selecting one of the three planes, the following 2-d sketch is drawn using appropriate measurements.



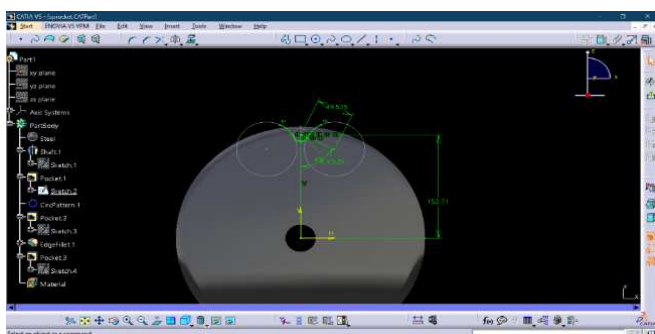
**Fig.1. Catia (sketch 1)**

- Using the revolve or shaft command, revolve the selected sketch through 360° about the central axis.



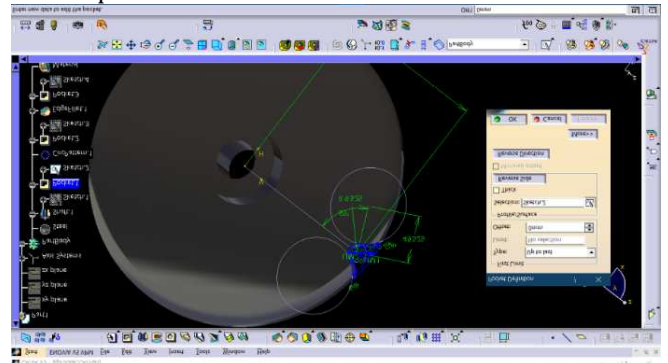
**Fig.2. Catia (revolve/shaft command)**

- Now select one of the faces and select sketch option. Draw the 2-dimensional tooth profile of the gear teeth.



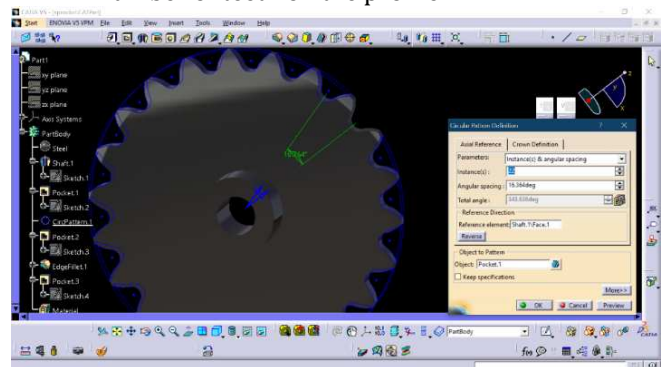
**Fig.3. Catia (sketch 2)**

- Using pocket command, cut through the previously revolved surface to form one part of the tooth profile.



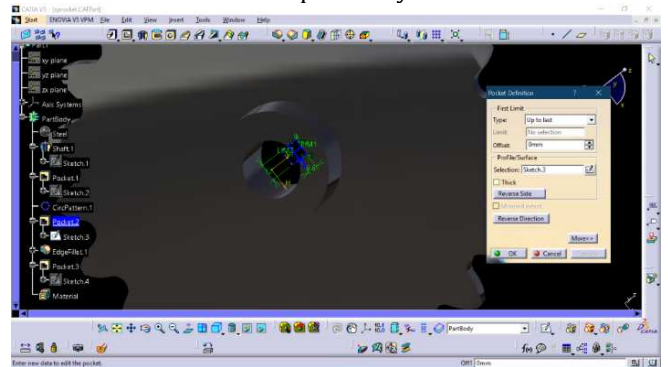
**Fig.4. Catia (pocket command)**

- Select circular pattern and specify the angular spacing of each tooth of the gear and the total number of teeth on the profile.



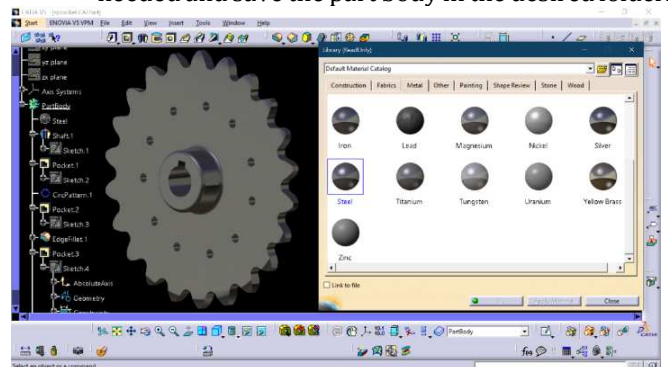
**Fig.5. Catia (circular pattern command)**

- A groove in the hub of the sprocket can be made similarly by using pocket command and removing the material with reference to the sketch drawn on the surface of the part body.



**Fig.6. Catia (pocket command)**

- Choose and apply the material to the part body if needed and save the part body in the desired folder.



**Fig.7. Catia (material selection)**

The sprocket that is to be 3-d printed is designed and saved in the computer and it has to be modified further to print it in a 3-d printer

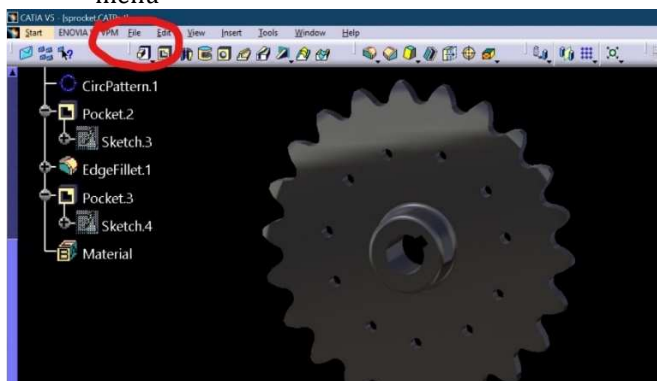


**Fig.8. Sprocket 3-D model**

**Conversion to STL File Format**

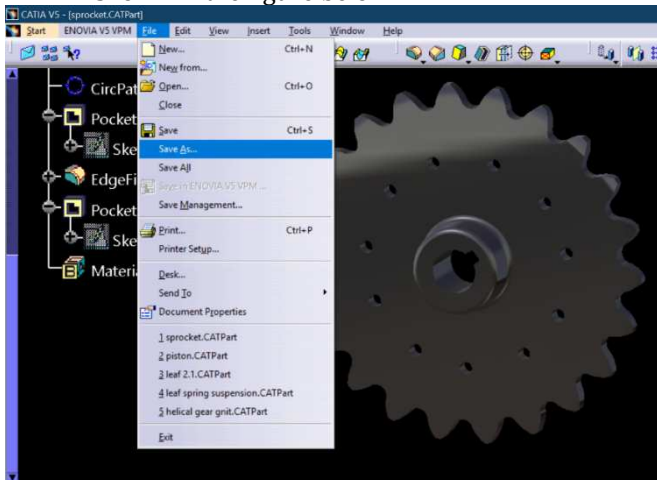
The object (sprocket, in this case) can be converted to STL format file by the following procedure:

- Open the previously saved design file in the CAD software (CATIA, in this case) and find 'File' on the menu



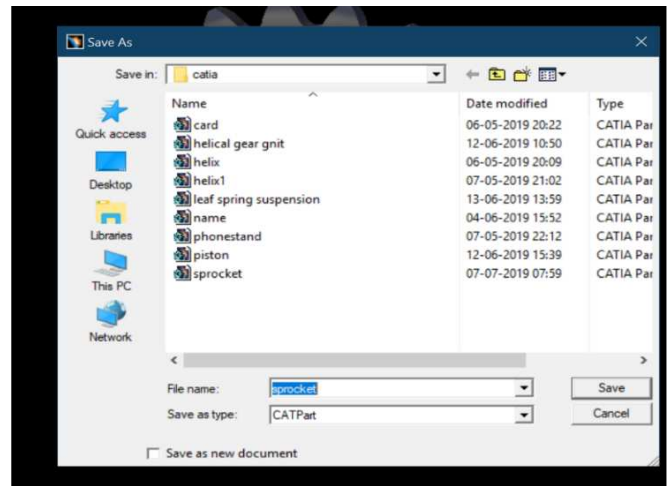
**Fig.9. Catia (file menu)**

- Click on the 'File' menu and select 'Save as' as shown in the figure below.



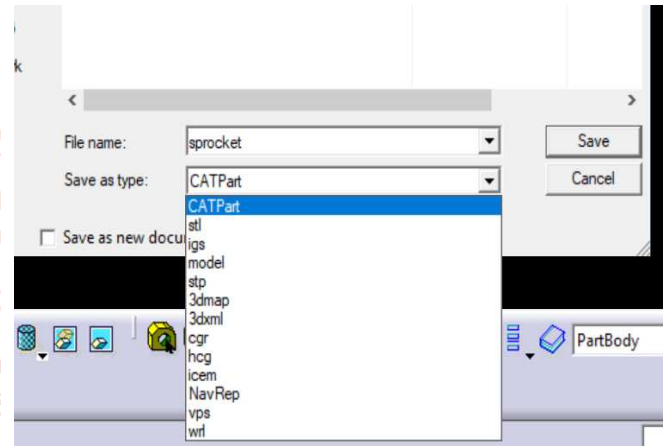
**Fig.10. Catia (save as)**

- After selecting 'Save as', the following window appears.



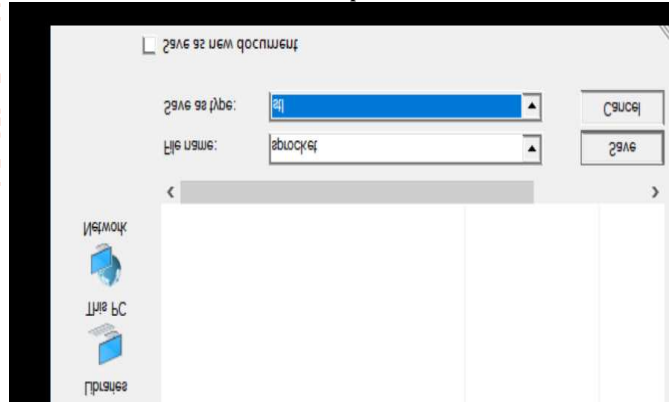
**Fig.11. Saving part file**

- Now select '.stl' from the list of options to save the file.



**Fig.12. Selecting STL format**

- Save the file in the respective folder.



**Fig.13. saving .stl file**

The 3d printer should be connected to the pc or the laptop, on which you have been working and the software like CURA from Ultimaker or Ideamaker has to be pre-installed on the computer.

**V. RESULTS**

The sprocket is manufactured with the PLA material by Fused Deposition Modelling using 3D-printing machine.

**VI. CONCLUSION**

In this project modelling of SPROCKET is carried out with CATIA V5R20 software by using various commands. After creating model we save the component in '.stl' file. Import the component into the 3D Printing machine by using cura

software, by using FDM (Fused Deposition Modelling) method with PLA material (Poly Lactic Acid). And then we get the component. Design and 3D Printing of sprocket is done.

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