Prototyping Of a Two-Wheeler Clutch Hub Using Reverse Engineering of a Mechanical Component

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ABSTRACT
Reverse engineering in mechanical engineering refers to the process of deconstructing a product or system to understand its design, components, and functionalities, often for the purpose of replicating, modifying, or improving it. This process involves various techniques such as scanning, 3D modelling, and analysis of materials and structures to extract valuable information from a physical object. The applications of reverse engineering are vast, ranging from the production of spare parts for obsolete machinery to the development of new products based on existing designs. It also plays a critical role in innovation, enabling engineers to identify design flaws, enhance performance, and reduce manufacturing costs by reinterpreting and improving existing systems. Reverse engineering typically begins with capturing the geometry of the object, often through methods like laser scanning or computed tomography (CT) imaging, which generate highly accurate digital representations. These models can then be analyzed and modified using CAD (Computer-Aided Design) software.

Keywords: Reverse Engineering, Mechanical Components, 3D Scanning, CAD, Material Analysis, Product Replication, Design Optimization, Aerospace, Automotive, Manufacturing,

1.INTRODUCTION

Clutch is a machine part which is used to transfer the motion or torque from driving shaft to the driven shaft smoothly. In automobiles we can see the various examples of the clutches and its various types such as single plate clutch, multi plate clutch, centrifugal clutch and cone clutch likewise. As to increase the speed of the vehicle we need to change the gear according to the need and also idle gearing is required, at that time clutch plays an important role in the engine transmission. In the two-wheeler SI engine vehicles, we generally observe multi plate type wet clutch. The multi plate type wet clutch consists of various parts like clutch housing, pressure plate, friction plate, clutch plate, Clutch Hub, compression spring, etc. As the clutch is used to engage and disengage the flywheel, and undergoes lot of torque and pressure it needs to be designed precisely. The smooth transfer of power is the main aim of the clutch. Various types of materials are used for the clutches like steel and its alloys. The material plays important role in the performance of the clutch.

2. LITERATURE REVIEW

H. James De [1] H. James De, presented at The University of Utah, focuses on enhancing the reverse engineering process through the application of specialized knowledge from the engineering domain. Reverse engineering traditionally involves capturing the physical geometry of existing objects typically using 3D scanning technologies and then reconstructing accurate digital models. However, this process often faces challenges such as incomplete or noisy data, especially when dealing with complex mechanical parts.

Nikola, [2] Nikola Gjeldum and colleagues from the University of Split, presented at the 10th International Conference on Mechanical Technologies and Structural Materials in 2021, explores the application of reverse engineering techniques to enhance the design and functionality of motorcycle brake caliper brackets. They began by 3D scanning a wooden model of the existing brake caliper bracket to capture its precise geometry. The scanned data was then imported into CATIA design software, where the bracket was digitally reconstructed and optimized. This process allowed for accurate definition of all dimensions and facilitated modifications to accommodate larger brake discs, thereby improving the motorcycle's braking performance

Aljinovic, [3] Aljinović, presented at the 8th International Conference on Mechanical Technologies and Structural Materials in 2018 at the University of Split, explores the integration of modern manufacturing technologies in preserving and promoting cultural heritage. This research demonstrates how 3D scanning, computer-aided design (CAD), and additive manufacturing can be applied to replicate and preserve historical artifacts. The team focused on the "Girl from

Salona," a statue dating back to the 2nd century, as a case study. They employed 3D scanning to capture the precise geometry of the statue, followed by CAD optimization to refine the digital model. The optimized model was then used to produce physical replicas using Fused Deposition Modeling (FDM), a common 3D printing technique.

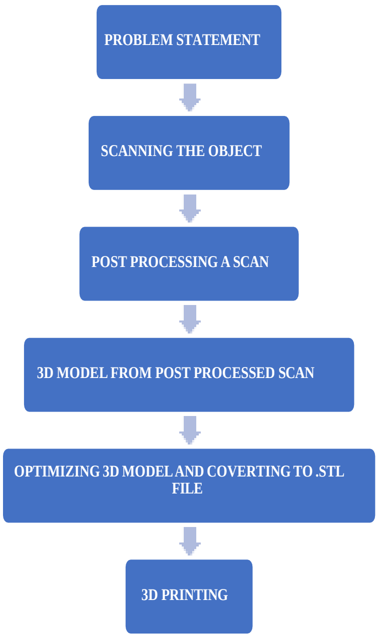
E. J. Chikofsky [4] Elliot J. Chikofsky is a seminal work that lays the foundation for understanding the processes involved in analyzing and improving existing software systems. In this work, Chikofsky explains reverse engineering as the practice of examining a software system to identify its components and their relationships, with the goal of creating higher-level abstractions or representations that were not explicitly available. This process is crucial for understanding legacy systems, especially when original documentation is missing or outdated. Design recovery, a key part of reverse engineering, focuses specifically on extracting design information that clarifies what the system does, how it achieves its functionality, and why it was designed in a certain way.

S. Motavalli [5] Motavalli and Bidanda's work presents a significant advancement in reverse engineering, offering a practical solution for generating accurate CAD models from physical parts. The PAIRS system exemplifies how integrating imaging technologies with CAD software can optimize the design and modification processes in manufacturing

W.L Kwonk [6] W.L. Kwonk, titled Reverse Engineering: Extracting CAD Data from Existing Parts focuses on techniques and methodologies for capturing precise geometric data from physical components and converting it into accurate CAD models. This process is essential when original design data is missing or unavailable, enabling engineers to recreate digital representations for analysis, modification, or manufacturing. The study discusses the use of various scanning technologies—such as coordinate measuring machines (CMM), laser scanners, and structured light systems—to collect detailed surface data. It also covers data processing steps like noise filtering, feature extraction, and surface fitting to transform raw measurements into usable CAD geometry.

F Gottwald, [7] a continuous ink jet metal material device to form a removable metal fabrication on a reusable surface for immediate use or salvaged for printing again by remelting.

3. METHODOLOGY



3.1 Problem Statement

In automotive engineering, the clutch hub is an essential component in the clutch mechanism of vehicles. It serves as the intermediary between the engine and the drivetrain, transmitting rotational power from the engine to the transmission. In two-wheel drive (2WD) vehicles, the clutch hub plays a vital role in ensuring smooth engagement and disengagement of power during shifting, acceleration, and deceleration. The clutch hub needs to be designed to accommodate a range of forces and temperatures, while ensuring longevity and consistent performance.

3.3 Scanning

The part is scanned by using Calibry nest scanner preparing the part to be scanned, and performing the actual scanning to capture information that describes all geometric features of the part such as steps, slots, pockets, and holes. Three-dimensional scanners are employed to scan the part geometry. Scanners capture hundreds and even thousands of separate frames during each scan. These frames then should be stacked together in a consistent way to create a point cloud. Tracking refers to the way it is done and to the information used to achieve that. It is literally how a scanner keeps track of what it looks at and how it moves in respect to the object.

Fig 3.1 Scanned I mage 01

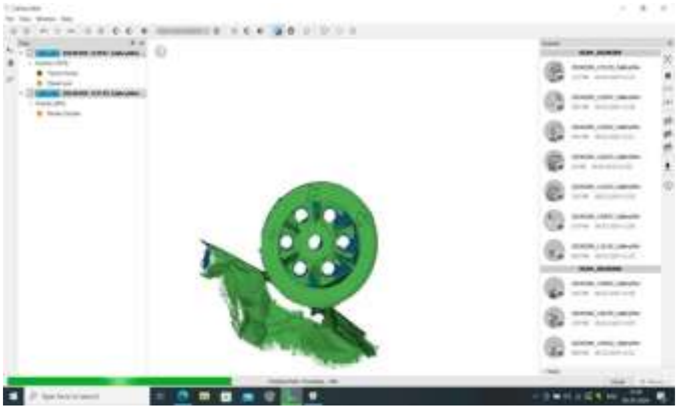


Fig 3.2 Scanned I mage 02

3.4 Post Processing

- After scanning is finished, all captured frames are saved in a file with an a scan extension. These files are saved on a PC/laptop a scanner is connected to. These files can then be processed either on the same computer, or can be transferred to any other computer to be processed in Calibry Nest.
- Unprocessed scans may contain certain amount of noise picked up during scanning. This noise may appear due to glares, reflections or poor calibration. In most cases it is recommended to clean scans during registration. It is done by default, but cleaning may be deactivated in Settings.
- When unprocessed scans are opened in Nest, the data may look noisy and layered. It is totally normal, especially if the scan was made without activating the Live3D mode.
- In many cases it can be difficult to scan the entire object from all possible angles and capture all folds, mounting holes, and indentations. So, the final result may contain holes. In Nest holes can be filled either during finalization, or after finalization.
- Resolution defines how detailed the resulting polygonal model will be. Its value is defined in millimetres or in fractions of a millimetre. The smaller this value is, the more detailed the final result will be

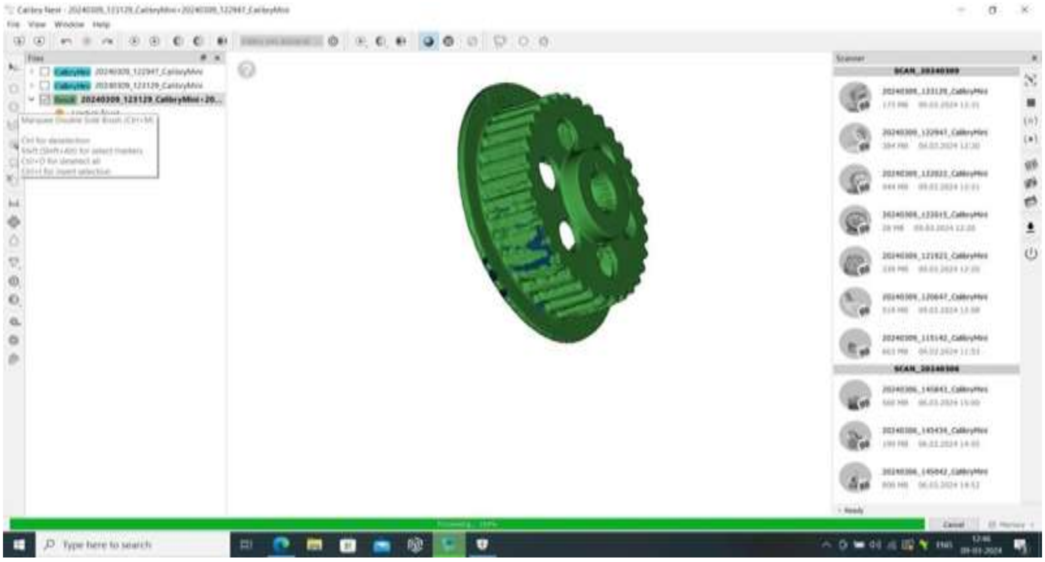


Fig: 3.3 Post Proceed Image 01

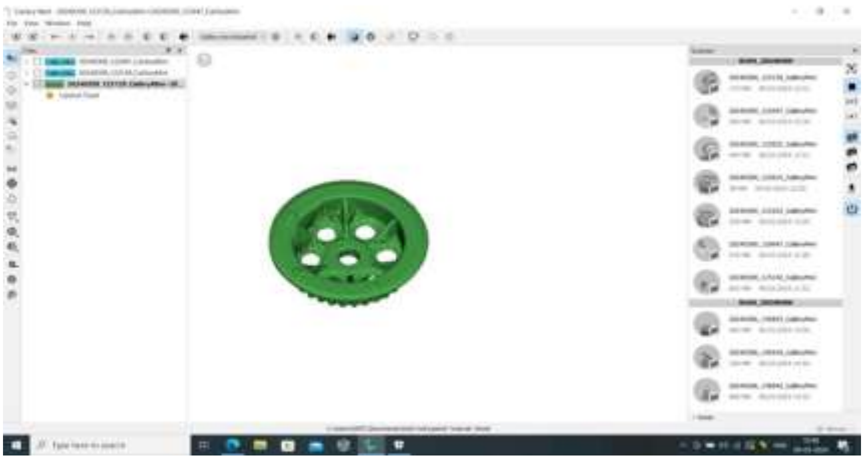


Fig: 3.4 Post Proceed Image 02

4. DESIGNING OF PROTOTYPING OF A TWO-WHEELER CLUCTCH HUB USING REVERSE ENGINEERING IN MECHANICAL COMPONENENTS

Here we selected the 3D printing technology, for making the objects as the designed components was converted in a STL format, here the design data will convert as a STL data this conversation is for to print the objects in a Rapid prototype, FUSED DEPOSITION MODELING. Here for printing the designed components was layer by layer formed as STL data.

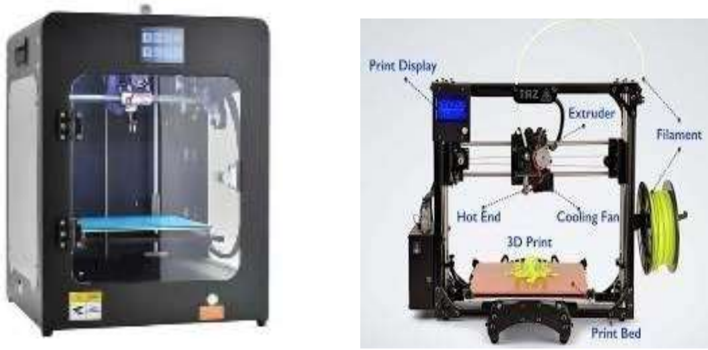


Fig: 4.1 Fused Deposition Modeling Machine

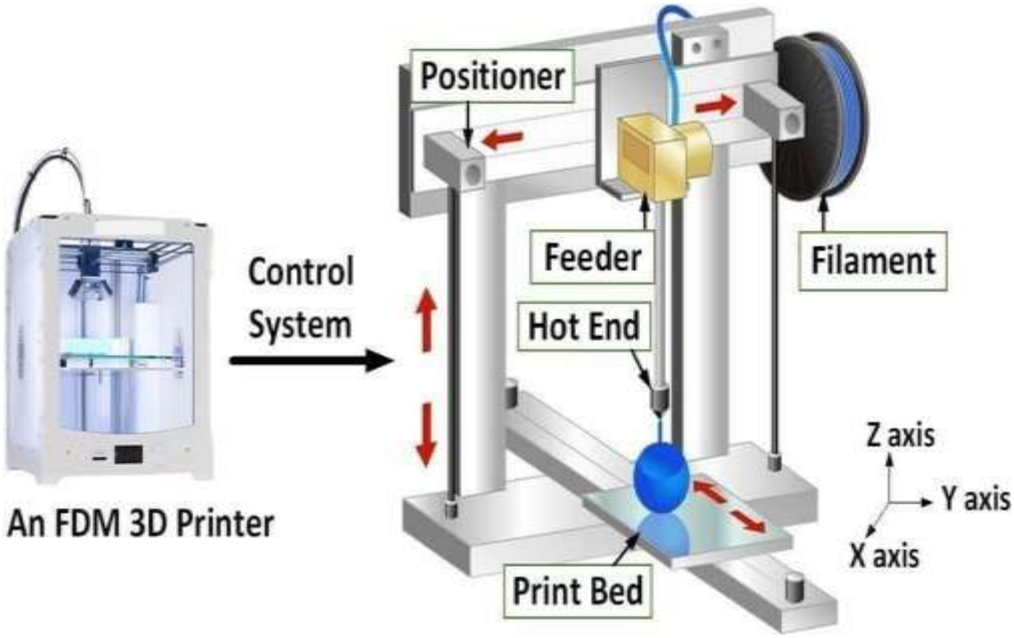


Fig 4.2 Machine Build Parts

4.1 Material

Material selection is a process which is performed to select the best materials which may have the potential to perform well both in industrially and commercially. Material used for the gripper making here in the 3D printing machine PLA filament reel. These are the thermoplastic materials.

Fig: 4.3 Poly lactic acid Wire Filate

Fig 4.4 Different Colour Material

4.2 DESIGN AND FABRICATION OF 3D PRINTING

The design of the printer was determined as per the required printing area. The frame, base and supporting structure was done by using low weight material.

Fig 4.5. Fused Deposition Modeling Machine

4.3 CONVERTING THE DESIGN IN STL FORMAT

Once the design is completed in the cad software, we then convert this drawing file in STL format. This file format is supported by various packages and 3d printers. An STL file describes a raw unstructured triangulated surface by the unit normal and vertices (ordered by the right-hand rule) of the triangles using a three-dimensional Cartesian coordinate system.

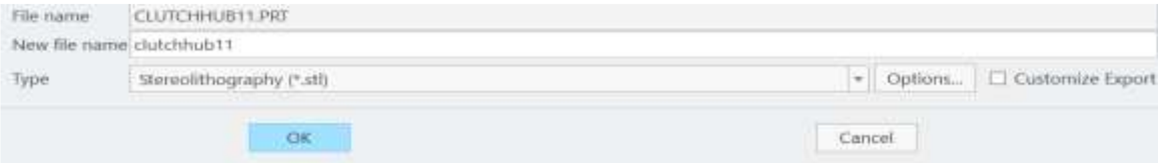


Fig 4.6: Converting of Design Data into Stl

4.4 SLICING

Once a model is created, it's time to "slice" it. Since 3D printers cannot conceptualize the concept of three dimensions, like humans, engineers need to slice the model into layers in order for the printer to create the final product. Slicing software takes scans of each layer of a model and will tell the printer how to move in order to recreate that layer. Slicers also tell 3D printers where to "fill" a model. This fill gives a 3D printed object internal lattices and columns that help shape and strengthen the object. Once the model is sliced, it's sent off to the 3D printer for the actual printing process We use Slicing software (Ulti maker Cura) to slice the file and determine the position of the object in which it is going to be printed. Once this is done then we generate G-codes from „Export G-code" option.

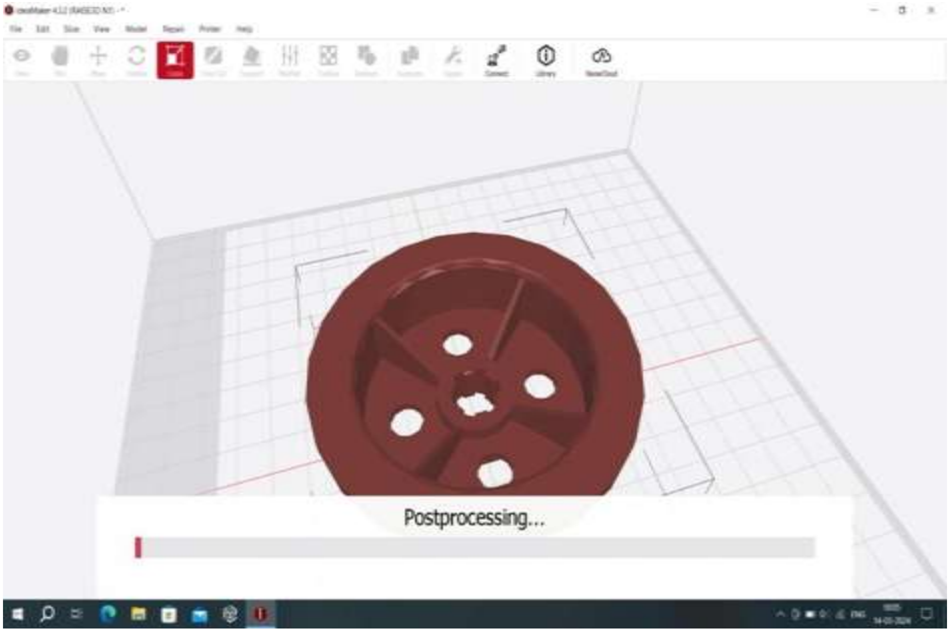


Fig 4.7: Slicing The Part -01

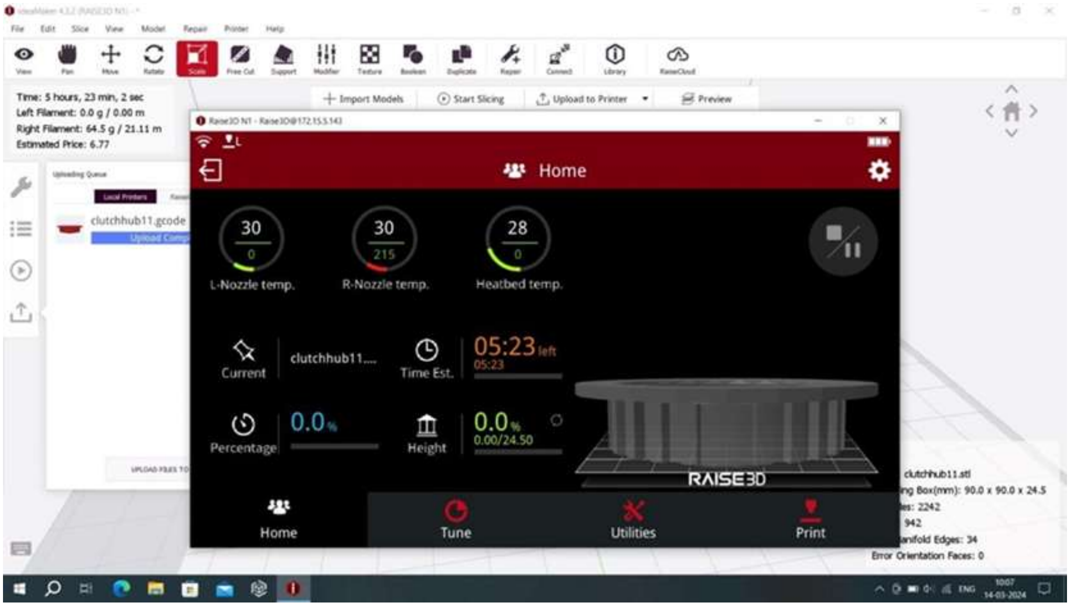


Fig 4.8 Setting the Slicing Process

5. 3D PRINTING PROCESS

3D printing is an additive process whereby layers of material are built up to create a 3D part. This is the opposite of subtractive manufacturing processes, where a final design is cut from a larger block of material. As a result, 3D printing creates less material wastage. That is why "3D Printing" is also called additive manufacturing in contrast to traditional methods of production that are primarily subtractive in nature, also called as "subtractive manufacturing" or molding/casting processes. Applications of 3D printing are emerging almost by the day, and, as this technology continues to penetrate more widely and deeply across industrial, maker and consumer sectors, this is only set to increase. Most reputable commentators on this technology sector agree that, as of today, we are only just beginning to see the true potential of 3D printing. When the modelling and slicing of a 3D object is completed, it’s time for the 3D printer to finally take over. The printer acts generally the same as a traditional inkjet printer in the direct 3D printing process, where a nozzle moves back-and-forth while dispensing a wax or plastic-like polymer layer-by-layer, waiting for that layer to dry. Then adding the next level. It essentially adds hundreds or thousands of 2D prints on top of one another to make a three-dimensional object. There are a variety of different materials that a printer uses in order to recreate an object to the best of its abilities.

3D printing, also known as additive manufacturing, is a transformative technology that allows for the creation of three-dimensional objects from digital models.

5.2 Working of 3D Printer

The FDM 3d printer deposits the material on a heating bed by heating and extruding the filament resin and setting it layer upon layer.

This process is simple and includes 3 phases:

4.31 Pre-processing:

In this phase we imported cad design using cad software such as geo-magics .stl file. After this, format which slices the model geometry and determines the path of layer deposition.

4.32 Production:

The 3d printer heats the thermoplastic resin and converts it into a semi liquid form. Then it deposits the resin in an ultra-thin bead to form the model. Where support is needed the 3d printer deposits removable material that acts as scaffolding.

4.33 Post processing:

The actual finished model is ready and does not need any further machining. The support material is removed by hands or by dissolving it into a detergent or water.

5.3 Types of 3D Printing Technology

The term 3D printing encompasses several manufacturing technologies that build parts layer-by-layer. Each vary in the way they form plastic and metal parts and can differ in material selection, surface finish, durability, and manufacturing speed and cost.

There are several types of 3D printing, which include:

- Stereolithography (SLA)
- Selective Laser Sintering (SLS)
- Fused Deposition Modelling (FDM)
- Digital Light Process (DLP)
- Multi Jet Fusion (MJF)
- Poly Jet
- Direct Metal Laser Sintering (DMLS)
- Electron Beam Melting (EBM)

5.4 Machine Set Up

Machine have to give the STL data input through the pen drive the data will be shared to machine after the commands received as per the command directions the printing nozzle will be move.

Fig 5.1: Machine Set Up

5.5 Nozzle Set Up

The nozzle will be melts the PLA+ material and after it will be deposited layer by layer on the bed by the command instructions. The nozzle will move with the help of guide bars. These printers have extreme flexibility in what can be printed. They can use plastics to print rigid materials, like sunglasses. They can also create flexible objects, like phone cases or bike handles, using a hybrid rubber plastic powder. Some 3D printers even have the ability to print with carbon fiber and metallic powders for extremely strong industrial products.

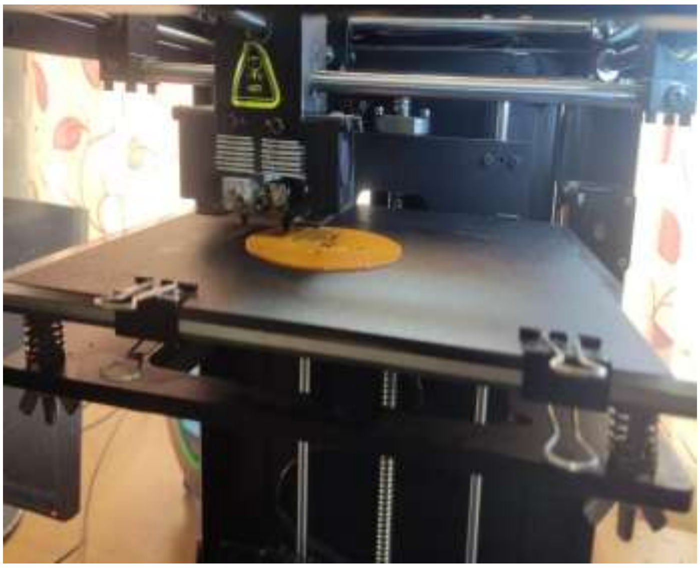


Fig 5.3: Printing Image 01

Fig 5.4: Printing Image 02

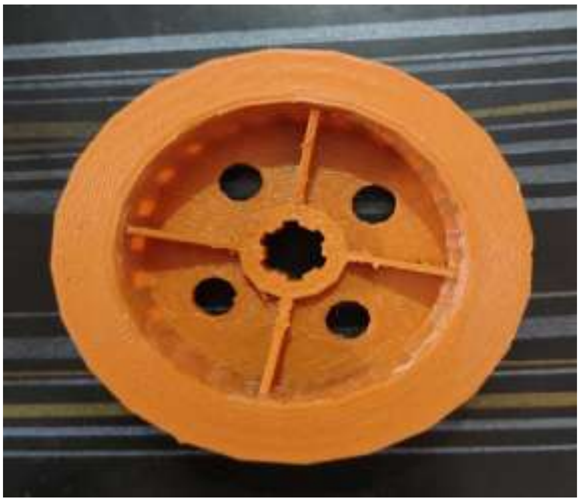


Fig 5.5: Product Part 01

Fig 5.6: Product Part 02

5.6 POST-PROCESSING

After completion of the print, the model was allowed to cool before removal from the build plate to avoid warping. The following post- processing steps were applied:

1. **Support Removal:** Using needle-nose pliers and precision cutters, support structures were carefully detached without damaging detailed features.
2. **Sanding:** The surface was smoothed using 120 to 400+ grit sandpaper, especially around visible layer lines and support-affected zones.
3. **Dimensional Verification:** Callipers were used to verify key dimensions such as bore diameters, mounting hole spacing, and overall width.
4. **Finishing (Optional):** Primer or epoxy resin could be applied to improve surface finish and minor durability for display or light handling

6. RESULTS

The 3D printing of the using Prototyping of a Two-Wheeler Clutch Hub Using Polylactic Acid (PLA) material successfully demonstrated the capabilities of additive manufacturing for mechanical prototyping. While PLA's mechanical and thermal limitations restrict its use in functional engine components, it served well for visual representation and design validation.

7. DISCUSSION

The process from design to finished prototype was executed in several structured steps:

Step 1: CAD Modelling

A detailed SolidWorks model was developed, considering bore alignment, wall thickness, and space for cooling jackets. The model was scaled down appropriately for the printer's build volume.

Step 2: STL Export and Validation

The model was exported as an STL file and checked for mesh integrity. Cura was used for slicing, applying optimal orientation and support strategies.

Step 3: Material Selection

PLA was selected due to its cost-effectiveness and printability, with the trade-off of low strength and heat resistance acknowledged.

Step 4: Slicing Configuration

Slicing parameters included a 0.2 mm layer height and 20–40% infill. Support was enabled for overhangs, with an estimated print time of 12–15 hours.

Step 5: Printing Execution

The model was printed in two halves on an FDM 3D printer. Standard PLA settings were used, and regular monitoring ensured print success.

Step 6: Post-processing

- Support Removal: Carefully extracted with tools like flush cutters and tweezers.
- Cleaning: Stringing and blobs were removed; defects were touched up.
- Sanding: Multi-stage sanding gave a polished finish.
- Dimensional Tuning: Callipers and files were used to correct tolerances.
- Optional Painting: Enhanced appearance with metallic colours.

Step 7: Assembly and Validation

Segments were aligned and glued using cyanoacrylate. Dowel pins ensured alignment. Final measurements matched CAD dimensions, validating the prototype's integrity.

Step 8: Observed Limitations

- One edge cracked due to PLA brittleness.
- Visible layer lines remained unless extensively sanded.
- Internal cavity accuracy was constrained by nozzle limitations.

8. CONCLUSIONS

We successfully achieved its objectives of dissecting the underlying structure and functionality of the target system. Through the application of advanced analysis methods and software tools, key insights were uncovered regarding its architecture and behaviours. Despite encountering certain challenges, the accuracy and validity of the obtained information were confirmed, laying a solid foundation for practical application Reverse engineering is the process of analysing a product or system to understand how it works and how it was designed. It involves taking apart the product or system and examining its components, functions, and interactions. it is a valuable tool for product development and innovation. It can help to identify areas for improvement, optimize existing designs, and ensure compatibility between different systems or products. However, it is important to note that reverse engineering can also raise ethical concerns, particularly if it involves copying or replicating an existing product without permission from the original designer.it can help to gain insight into how a product or system was designed, which can be useful for a range of purposes. For example, it can help to identify areas for improvement or optimization, or it can be used to create a new product that is based on an existing design and also it can be used to ensure compatibility between different systems or products. By understanding how a particular system works, it may be possible to create a new system that is compatible with it, or to modify an existing system to work with it.

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