REVERSE ENGINEERING AND PROTOTYPING OF DISC BRAKE CALIPER

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Abstract – Disc brake calipers are the components which plays a vital role in automotive braking systems, which are responsible for slowing down or stopping the vehicle. This project aims to understand the design and functionality of a disc brake caliper through Reverse engineering and create a new, improved prototype. We will disassemble an existing disc brake caliper, analyse its components, and understand its working principles. Using techniques such as 3D scanning and CAD modelling we will create a digital representation of the caliper. This digital model will serve as the basis for our prototyping phase, where we will leverage rapid prototyping technologies to create a physical model of the disc brake caliper. The goal of this project is not only to replicate the existing design but also to identify potential areas for improvement and innovation. By integrating reverse engineering and prototyping, we aim to enhance the performance and efficiency of disc brake calipers.

 Keywords: Disc Brake Caliper, Rapid Prototyping, Reverse Engineering, 3D Scanning, Calibry Nest Software.

1. INTRODUCTION

Figure 1. Disc Brake Caliper

Principle of disc brake calipers is Brake rotors of disc brakes rotate with the wheels, and brake pads, which are fitted to brake calipers, clamp on these rotors to stop or decelerate the wheels. The brake pads pushing against the rotors generate friction, which transforms kinetic energy into a thermal energy. This thermal energy generates heat, but since the main components are exposed to the atmosphere, this heat can be diffused efficiently. This heat-dissipating property reduces brake fade, which is the phenomenon where braking performance is influenced by the heat. Another advantage of disc brakes is its resistance to water fade, which occurs when the water on the brakes significantly reduces braking force. When the vehicle is in motion, the rotor spins at high speeds and this rotational motion discharges the water from the rotors themselves, resulting in stable braking force. 7 Disc brakes are generally used in passenger cars, but due to their stable performance at higher speeds and resistance to brake fade, they are gradually spreading into the commercial vehicle segment, where drum brakes were traditionally chosen for their longer service life. There is increasing demand from customers for longer service life and higher quality, and Akebono is committed to meeting them through further development of the disc brake's reliability. There are two types of disc brakes. The "opposed piston type disc brake" has pistons on both sides of the disc rotor, while the "floating type disc brake" has a piston on only one side. Floating caliper type disc brakes are also called sliding pin type disc brakes.

2. Introduction to Reverse Engineering

Figure 2. Reverse Engineering Process

Reverse engineering is a process of analyzing already existing product components for the purpose of replicating the design or knowledge that will be formed from the extracted information. A typical Reverse engineering project involves working backwards on a particular product to establish the technology and design applied by the original manufacturer. The extracted information allows users of the Reverse engineering process to reproduce or change the product. Designers and engineers are always looking for ways to improve new and existing products. The Reverse engineering process provides access to the information and knowledge needed to change and improve the product manufacturing process and its working capabilities. Simplification of the production process can lead to cheaper and ultimately improved production. Reverse engineering process usually consists of three steps: 3D scanning, 3D modelling and 3D printing of the prototype

3. Introduction to 3D Scanning
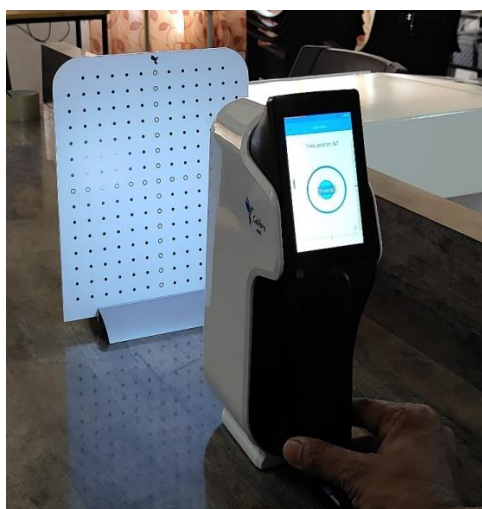
Figure 3. 3D Scanning Equipment

3D scanning is a non-contact non-destructive technology that digitally captures the shape of an object using a laser. 3D scanners create "position clouds" of data from the surface of the object. In other words, 3D scanning is a way of storing the exact size and shape of objects in a computer as a three-dimensional digital representation. 3D laser scanners measure to the smallest detail and record all types of shapes to recreate "position clouds" of data in a very short time. 3D scanning is the optimal method for measuring and 2 inspecting objects of complex shapes that require a large amount of data for their correct description..
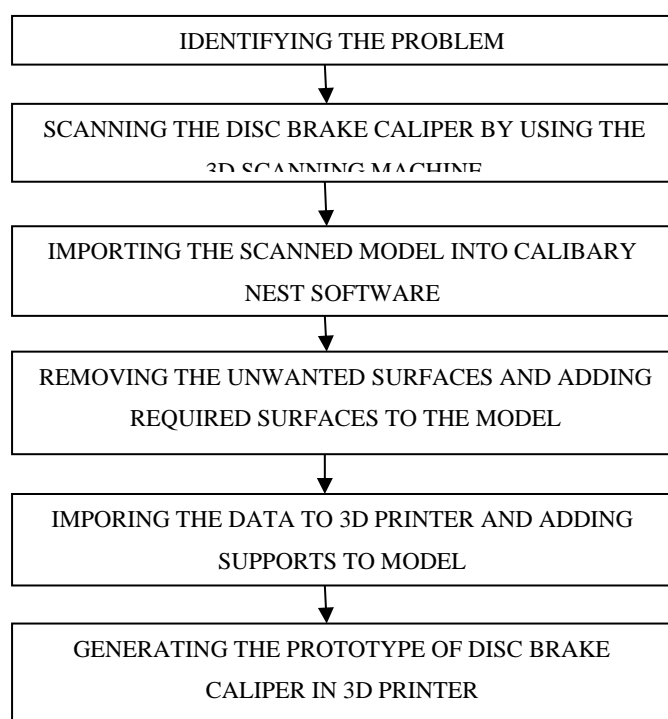
4. Introduction to 3D Printing
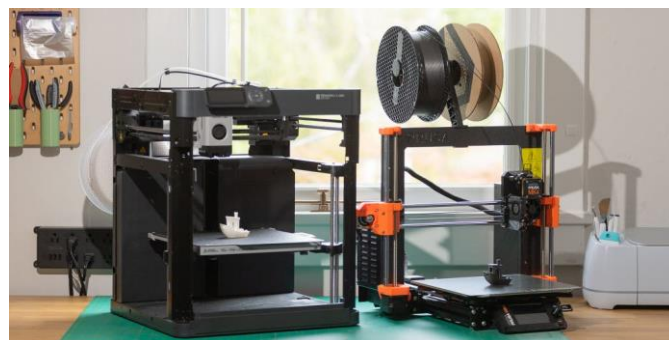
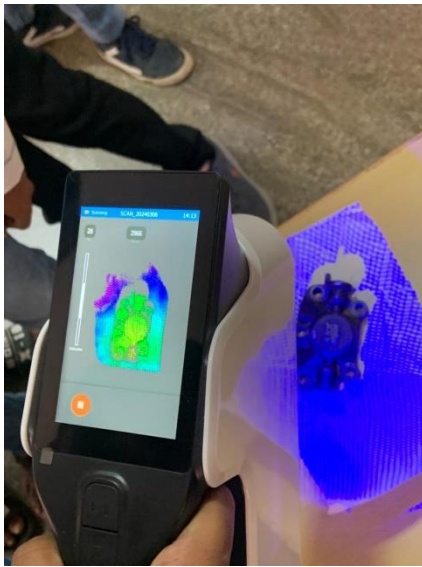**Figure 4. 3D Printing Machine**

3D prototyping, also known as rapid prototyping or additive manufacturing, is the process of creating a physical object from a digital 3D model. It involves the layer-by-layer construction of a three-dimensional object using a variety of materials and technologies. 3D prototyping allows for the quick and cost-effective production of prototypes, models, and functional parts for various industries and applications. The process of 3D prototyping typically begins with designing a digital model using computer-aided design (CAD) software or by scanning an existing object to create a digital replica. The digital model is then sliced into thin cross-sectional layers by specialized software in preparation for the 3D printing process.

5. Experimentation

5.1. Methodology

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IDENTIFYING THE PROBLEM
          ↓
SCANNING THE DISC BRAKE CALIPER BY USING THE
3D SCANNING MACHINE
          ↓
IMPORTING THE SCANNED MODEL INTO CALIBARY
NEST SOFTWARE
          ↓
REMOVING THE UNWANTED SURFACES AND ADDING
REQUIRED SURFACES TO THE MODEL
          ↓
IMPORING THE DATA TO 3D PRINTER AND ADDING
SUPPORTS TO MODEL
          ↓
GENERATING THE PROTOTYPE OF DISC BRAKE
CALIPER IN 3D PRINTER
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5.2. 3D Scanning of the Component

Figure 5. 3D Scanning of the component

Ensuring precise data capture with a 3D scanner necessitates calibration as a first step. Place the object on a platform with wrinkled paper to optimize scanning quality. Connect the scanner to a computer using a data conversion module for seamless data transfer. Position the scanner at a 45-degree angle and commence scanning while rotating the object to ensure thorough coverage. Repeat the scanning procedure from different perspectives to capture the complete component. Following this, review the scanned data on either the scanner screen or a PC and utilize Calibry Nest software for processing. This methodical approach ensures accurate and thorough 3D data capture, facilitating further analysis or application.

5.3. Rendering of 3D Scanned Data
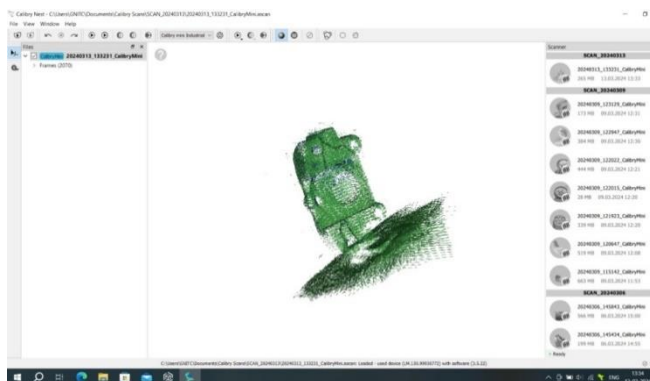

Figure 6. 3D Scanned Data

Rendering scanned data into photorealistic or non-photorealistic images involves converting raw point data captured by a scanning device into a visual representation resembling the original object or scene. This process, essential for various applications like 3D modeling and virtual reality, calculates light interactions to create realistic lighting, shadows, and textures. However, rendering can be time-consuming, influenced by computer processing power and scene complexity, necessitating high-end hardware for optimal performance. Once rendered, the output closely mirrors the original, offering a detailed and accurate representation. In some cases, the process may require multiple passes for complete coverage, ensuring the desired output quality.
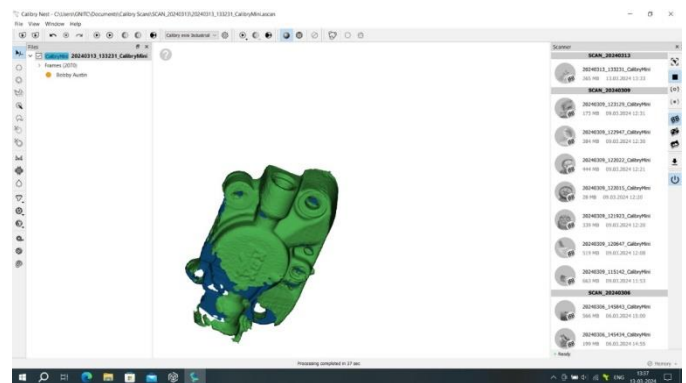
Figure 7. 3D Scanned Data after Rendering

5.4. Merging of 3D Data
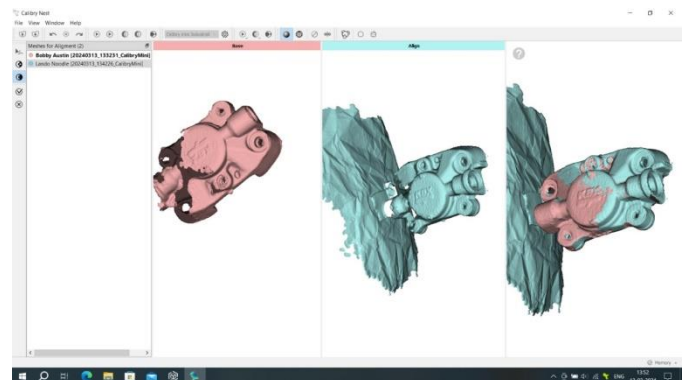

Figure 8. Component after Merging

After completing the rendering process, the next step involves merging both sides of the rendered component to form a single unified piece. This merging process requires selecting reference points on each side and joining them accordingly. Once the reference points are identified, both sides of the component are joined together.

Following the merging step, the model is exported into Geomagic software to facilitate the creation of a 2D sketch of the component. This exportation allows for further refinement and manipulation of the rendered model, enabling the

generation of precise 2D representations for further analysis or fabrication purposes.

## 5.5. Designing in Geomagic Software
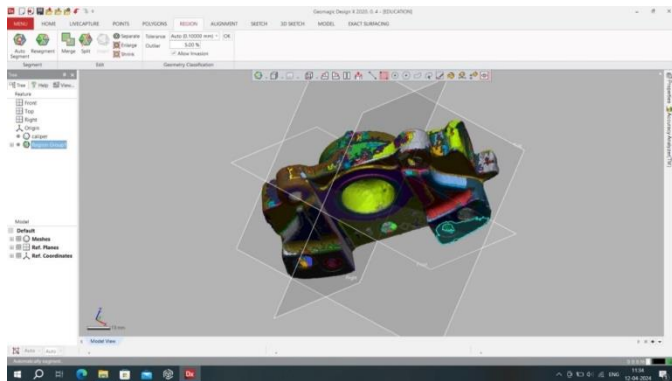
Figure 9. Importing the Data into Geomagic Software

- Export the 3D component into Geomagic software to generate a 2D sketch.

- Use design tools within Geomagic to create a 2D profile of the component.

- Choose a side of the component and begin creating the 2D profile.

- Extrude this 2D profile to convert it into a 3D component.

- After creating the 3D component, make any necessary design adjustments.

- Export the finalized 3D component to a 3D printing software for prototype creation.

- After completing the designing in geomagic software, the STL file export in 3D printing software. Hence component is ready for printing.
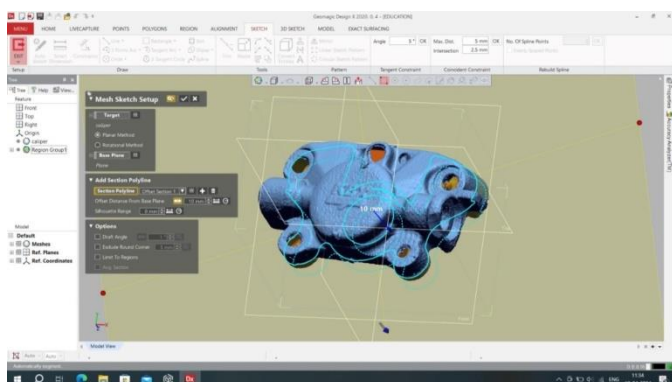

Figure 10. creating the 3D Component

5.6. Importing into a 3D Printing Software
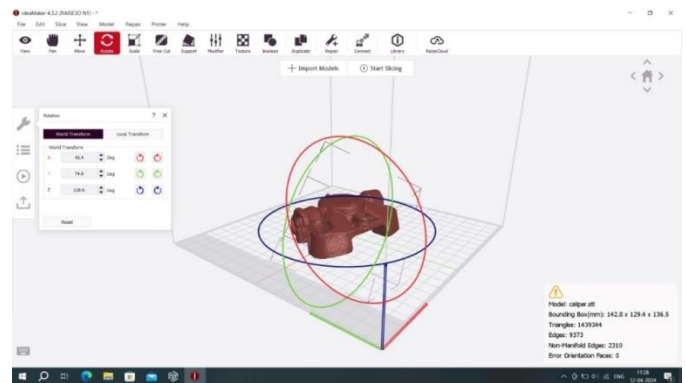
Figure 10. Creating the support structures

Now select the specifications of the component like the scale of the component, material to be used for printing etc. now after selecting the optimal position of the component for printing, we have to slice the component before importing it into the printer. Now after slicing we have to give support structures to the component for supporting the component while 3D printing. These support structures can be removed after printing the component. While selecting the position of the component we also have to take the support structures into consideration. Now after creating the support structures, we have to save the file and upload this file to the 3D printer.

5.7. 3D Printing
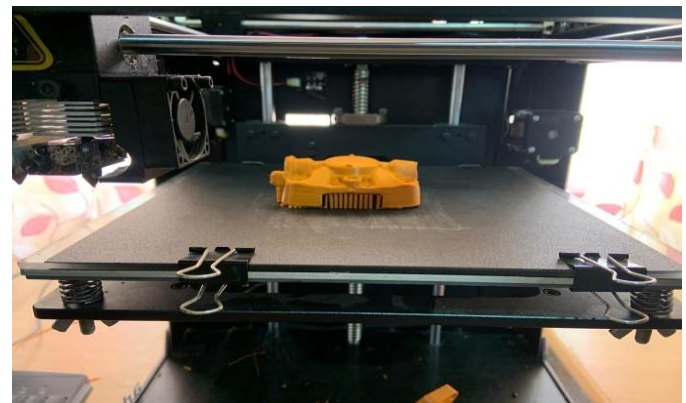
Figure 11. 3D Printing

After uploading the component to the 3D printer, the printer will display it on its screen. Now select the temperature of nozzle and heat bed before starting the printing. Now after the nozzle and bed have attained the set temperature, we've set a temperature of 220o c for the Nozzle and a temperature of 60°C o the heat bed. Now after attaining the set temperature, we have to start the printing. The printer uses FDM (Fused deposition Modeling) for printing the component. This process involves heating the material up to plastic state and

placing it in layers till the desired shape or component is obtained.

Figure 11. Prototype of Component

After printing remove the support structures and take photos of the component. For our component it took us 5 hours and 28 minutes for the 3D printing. The support structures are generated just to support the component and should be removed after completing 3D printing.

6. Results

Figure 13. 3D Printed Component

- Material used to create a prototype is Polylactic acid (PLA)

- Time taken to form a prototype in 3D printer is 2hrs 50 min

7. Conclusion

We used polylactic acid (PLA) as the 3D-printing material because it is a biodegradable plastic made from renewable sources like corn starch. PLA has many benefits, such as a low melting point ideal for lightweight and consumer use. The choice of 3D printing material would have depended on the intended use of the prototype of disc brake caliper. Factors like strength, weight, and cost would have played a crucial role in material selection. After printing, we assessed the quality of the 3D printed disc brake caliper by comparing its dimensions and tolerances with those of the original component.

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