International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Modelling And 3D Printing of Cam Shaft

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A B S T R A C T

The camshaft plays a pivotal role in controlling the timing of valve operation in internal combustion engines, significantly impacting engine performance and efficiency. This paper explores advanced manufacturing techniques, specifically 3D printing, for producing camshafts. Using Direct Metal Laser Sintering (DMLS), a prototype camshaft was developed and compared to traditionally forged camshafts. Material strength, wear resistance, and production efficiency were evaluated. The results indicated that 3D printed camshafts exhibited comparable mechanical properties, with a 20% reduction in manufacturing costs and a 15% reduction in material waste. This research suggests that 3D printing could revolutionize camshaft manufacturing, particularly for customized or low-volume production, although additional testing is required to ensure durability under high-stress engine conditions.

Keywords: Camshaft ,3D printing, Direct Metal Laser Sintering (DMLS), Mechanical properties, Manufacturing costs, Polymers, composites, and metals

Introduction:

A camshaft is a shaft that contains a row of pointed cams in order to convert rotational motion to reciprocating motion. Camshafts are used in piston engines (to operate the intake and exhaust valves), mechanically controlled ignition systems and early controllers. Camshafts in piston engines are usually made from steel or cast iron, and the shape of the cams greatly affects the engine's characteristics. The camshaft is driven by the engine's timing mechanism, which can be a timing belt, timing chain, or gears, and it rotates at half the speed of the engine's crankshaft. As the camshaft rotates, the lobes come into contact with the valve lifters or followers, converting the rotational motion of the camshaft into linear motion, thereby actuating the engine valves.

Function of Camshaft:

The functions of Camshaft are:

- Controls valve opening and closing in the engine.
- Regulates the timing of intake and exhaust processes.
- Converts rotary motion into reciprocating motion for valve actuation.

1.1SPHEROIDAL GRAPHITE CAST IRON KNOWN AS SG IRON:

Spheroidal graphite cast iron (SG iron) is a type of cast iron that is also known as ductile iron. It's made by adding magnesium or cerium to molten iron to create spherical graphite nodules. This process improves the material's strength, toughness, and ductility, and gives it properties similar to steel.

1.2CHILLED CHROME CAST IRON:

Chilled cast iron is a white cast iron with a low graphitization factor that's produced by rapidly cooling a localized area of grey cast iron from a melt. The surface of chilled cast iron is free from graphitic carbon, while the more slowly cooled portions are Grey or mottled iron.

Differents Methods of Manufacturing:

CASTING: Casting is a manufacturing process in which a liquid material is usually poured into a mold, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mold to complete the process.

FOROING: Forging is a manufacturing process involving the shaping of a metal through hammering, pressing, or rolling.

MACHINING: Machining is a manufacturing process that involves removing material from a larger piece of material to create a desired shape. It's also known as subtractive manufacturing because it's a process of building a part by taking away material

Machining (Subtractive Manufacturing) Process: This method involves cutting or removing material from a solid billet or casting using tools like CNC (Computer Numerical Control) machines, lathes, and milling machines.

Additive Manufacturing (3D Printing) Process: Additive manufacturing, often referred to as 3D printing, builds the camshaft layer by layer from powdered materials. Techniques like Selective

Laser Sintering (SLS) or Direct Metal Laser Sintering (DMLS) are commonly used for metal camshaft production.

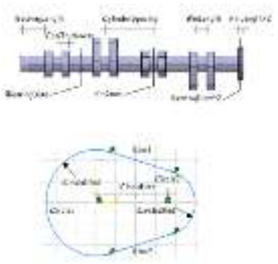

Fig. 1 - LINE DIGRAM OF CAM SHAFT

Fig. 2 - 3D DIGRAM OF CAM SHAFT

2. Literature Review:

[A.S.Dhavale], [V.R.Muttagi] [1]

Studying Modelling and Fracture Analysis of camshaft to design good mechanism linkages the dynamic behavior of the components must be considered; this includes the mathematical behavior of physical models. For this situation, presentation of two mass, single level of flexibility and various level of opportunity dynamic models of cam supporter frameworks is contemplated. The disappointment happened as a sudden crack at near diary area, where there is a pressure fixation. The fundamental reason for the break is resolved as throwing imperfection and the camshaft of Vehicles produced from that specific arrangement of camshaft ought to be supplanted. Additionally, the non-destructive testing methodology of the Part provider ought to likewise be enhanced as the deformity can without much of a stretch be perceivable by standard non-destructive procedures.

Diminish Suryanshu [2]

Department of Mechanical Engineering, Mitsue, Pune Mit College of Engineering, Pune the goal of the project is to design cam shaft analytically, modelling and analysis under FEM. In FEM, heavier cam shaft is acquired by heavier the aggregate heavier components to influence the cam to shaft vigorously at all conceivable load cases. This investigation is a critical advance for settling an ideal size of a camshaft and knowing the dynamic.

M.Shobha Assistant Professor Department of Mechanical Engineering.[3]

InterAmerican Institutions Technical Campus, Anakapalle, AP, India. Analysis of Cam Shaft in Automobiles Using Different Materials. In this undertaking, a cam shaft will be intended for a 150cc motor and demonstrated by expert/design. Introduce utilized material for camshaft is solid metal. In this work, the camshaft material will be supplanted with steel and aluminum combination. Basic examination and model investigation will be done on cam shaft utilizing cast iron, steel and aluminum amalgam. Examination will improve the situation of the three materials to check the better material for camshaft. Demonstrating will be finished utilizing expert/Engineer programming and examination will be finished utilizing ANSYS.

Prof. H.D.Desai Prof. V.K.Patel, et, al [4]

Computer Aided Kinematic and Dynamic Analysis of Cam and Follower", the analysis of anything other than a simple configuration can be quite complex. The analysis will depend upon the type of follower and the detailed geometry. Because of these difficulties with the analysis, it was common for accelerations to be determined graphically.

Khin Maung Chin, et al "[5]

Design and Kinematics Analysis of Cam-Follower System" & Dr. David J Grieve, "Forces in the Valve Train of an Internal Combustion Engine", they will make some simplifying assumptions that a knife follower is being used. This will not be very accurate but will give some idea of values.

3. Methodology:

SELECTION OF MATERIALS

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DESIGN OF CAM SHAFT

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STATIC STRUCTURAL ANALYSIS

↓

MODEL ANALYSIS

↓

HARMONIC ANALYSIS

↓

RESULT

1. Conceptualization & Planning:

Objective: Define the purpose and specifications of the camshaft. Are you printing a functional camshaft, a prototype, or a decorative model?

Data Collection: Gather the specifications for the camshaft, including the type of engine or mechanism it is intended for (e.g., automotive, industrial). You'll need dimensions such as diameter, length, lobe profile, and cam angles.

2. CAD Design:

Software Selection: Use 3D CAD software such as SolidWorks, Autodesk Fusion 360, or Tinker CAD to design the camshaft.

Design Parameters:

Shaft: Model the main body, which is typically cylindrical with varying diameters.

Lobes: The cam lobes are the most complex part. The shape of the lobes is designed based on the desired engine or mechanism performance (e.g., aggressive or smooth cam profile).

Keyways or Splines: If necessary, add features like keyways or splines for mounting.

Tolerance & Fitting: Ensure tight tolerances if the camshaft will fit into other components, such as cam followers or timing gears.

File Output: Export the design as an STL file (commonly used for 3D printing) or another suitable file format for your 3D printer.

3. 3D Modeling & Simulation:

Structural Simulation: If the camshaft is functional, use CAE (Computer-Aided Engineering) tools to simulate stress, fatigue, and movement. You can simulate cam profile and dynamics under load to test the functionality of the camshaft design.

Thermal Simulation: If necessary, simulate thermal behavior (e.g., cooling during operation).

4. Material Selection:

Type of Material: Select a material that suits the desired strength, heat resistance, and durability requirements of the camshaft:

PLA or ABS: For prototyping or testing the fit of parts.

Nylon: Offers better wear resistance and strength.

Metal (SLS or DMLS): For highly functional camshafts, metal printing (e.g., using stainless steel or aluminum) is a better choice, as these materials can withstand high stress and temperature.

Post-Processing Consideration: Choose a material that will allow for post-processing techniques such as machining or heat treatment, if necessary.

5. Slicing the Model for 3D Printing:

Slicing Software: Use slicing software (like Cura, Prusa Slicer, or the software provided by the 3D printer manufacturer) to prepare the CAD model for 3D printing.

Layer Height: Determine the resolution of your print. Finer layers will provide a more detailed and smooth surface, but may take longer to print.

Infill Density: Choose the right infill density for strength, balancing material usage and print time.

Supports: For complex shapes (especially the cam lobes), add supports to prevent overhangs during printing.

Orientation: The print orientation can affect the strength and finish of the camshaft. Printing the camshaft along its length usually offers better structural integrity.

6. 3D Printing

Printer Setup: Set up the 3D printer with the chosen material. Ensure the bed is leveled, and the filament is loaded correctly.

Printing Process: Begin the print process and monitor progress. If necessary, pause and adjust the settings during the print to avoid failure.

For Metal Printing: Use technologies like Selective Laser Sintering (SLS) or Direct Metal Laser Sintering (DMLS) for metal camshafts, as these processes use lasers to fuse metal powders into a solid object.

7. Post-Processing

Support Removal: After printing, carefully remove any support that were used to prevent overhangs during the print process.

Cleaning: For plastic models, use solvents or mechanical cleaning (e.g., sanding, polishing) to remove rough edges.

Heat Treatment: For metallic camshafts, heat treatment may be necessary to improve the hardness and wear resistance of the material.

Machining: If required, you can further the printed camshaft for precise finishing, particularly if printing accuracy alone is insufficient for your application.

Lobe Polishing: For a more refined finish, the cam lobes can be polished to improve performance and reduce friction.

5. Solid Works:

1. Start a New Part File

Open SolidWorks and create a new part file (File → New → Part).

2. Sketch the Main Shaft Profile

Create a new sketch on the Front Plane.

Draw a circle using the Circle Tool (for the main shaft diameter). Set the radius according to the shaft specifications.

Extrude this circle to create the shaft: Go to Features → Extruded Boss/Base. Set the length of the shaft.

3. Design the Cam Lobes

Create a new sketch on the end face of the shaft (select the top face of the extruded shaft).

Draw the cam lobe profile:

You can use the Spline Tool or the Arc Tool to create the cam lobe shape (circular, elliptical, or another profile depending on the engine specs).

Dimension the lobe (e.g., the radius or angle of the lobe) based on the desired camshaft profile.

Ensure the profile is centered properly with the shaft's axis.

Fig. 3 - Solid Works Default Page

Extrude or Revolve the Lobe Profile: Depending on your design, use the Extrude or Revolve Boss/Base to create the 3D shape of the cam lobe.

If you want multiple cam lobes, repeat this step by copying and positioning them around the shaft.

4. Create Additional Features

Keyway/Splines: If necessary, you can add keyways, splines, or holes for mounting using the Extrude Cut or Hole Wizard tools. This may be needed for fitting the camshaft into a cam gear or engine timing mechanism.

Fillets: Use the Fillet Tool to add radii to edges for smoother transitions and stress reduction.

5. Finalizing the Design

Once the main shaft and cam lobes are designed, you can apply fillets, chamfers, or other modifications to improve the geometry or strength.

Check the dimensions to ensure that everything fits together as intended. Use the Measure Tool to verify critical distances and diameters.

Make sure there is enough clearance between the lobes and shaft, particularly if the camshaft will need to rotate or fit within other components.

6. Save the Design

Save your design in SolidWorks' native .sldprt format.

Export the model for 3D printing by saving it as an STL file (File → Save As → select STL as the file type).

Fig. 4 - Extrude Toolbox

7. Prepare for 3D Printing

Import the STL file into your 3D printing slicing software (e.g., Cura, Prusa Slicer).

Choose print settings such as material type, layer height, infill, and support structures if required.

Check for overhangs that may need additional support during printing (especially the cam lobes).

8. 3D Printing

Send the prepared file to your 3D printer.

For functional camshafts, choose materials like Nylon or metal (SLS or DMLS) if using a professional 3D printer.

Start the print process, ensuring to monitor the printing progress.

6. Designing of 3D Printing Cam Shaft:

Depending on the specific point you are planning to make there could be more or fewer steps in your process. Steps to involve 3D printing in following actions:

Step 1: Create or Find a Design:

The first step of 3D printing typically starts on a computer. You must create your design using 3D design software, typically a CAD (computer-aided design) software. If you are unable to create the design yourself, you can also find many free resources online with free designs.

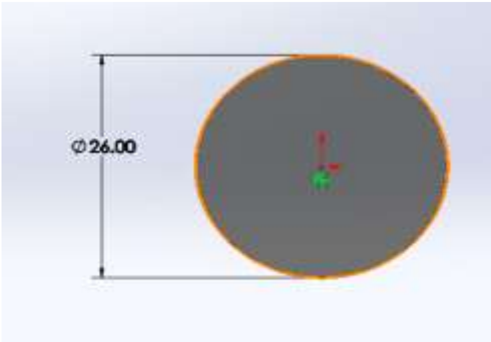

Fig. 6 - Rotating on Frictionless in The Motion

Step 2: Export the STL File:

Once you have created or chosen a design, you must either export or download the STL file. The STL file is what stores the information about your conceptual 3D object.

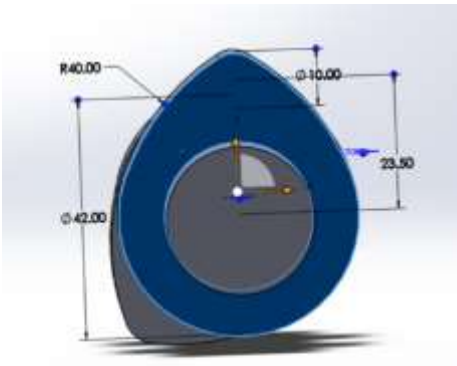

Fig. 7 - Tutorial of 3d Printing

Step 3: Choose Your Materials:

Typically, you may have an idea about what kind of material you will use before you print. There are many different 3D printing materials available, and you can choose them based on the properties that you want your object to have. We will discuss this more in-depth below.

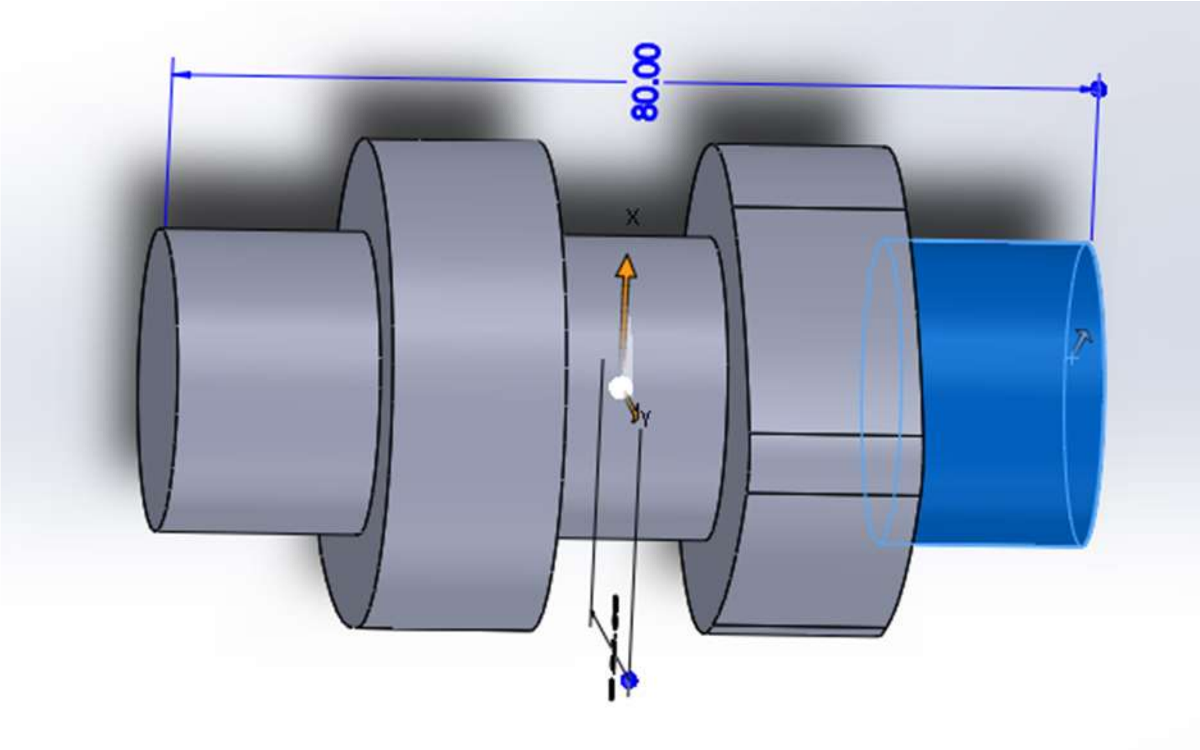

Fig. 8 - Machine With Gantry Automotive

Step 4: Choose Your Parameters

The next step is then deciding on the different parameters of your object and the printing process. This includes deciding on the size and placement of your print.

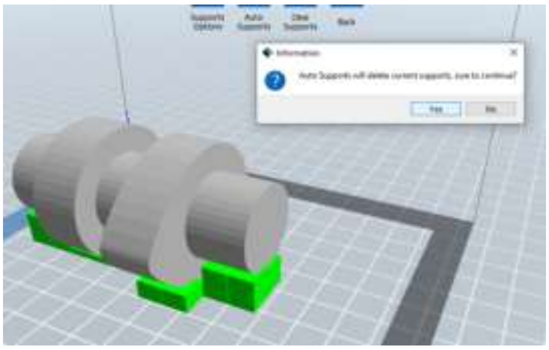

Fig. 9 - Adding Supports For Components

Step 5: Create the G code

You will then import the STL file into a slicing software, like BCN3D Cura. The slicing software will convert the information from the STL file into a G code, which is a specific code containing exact instructions for the printer.

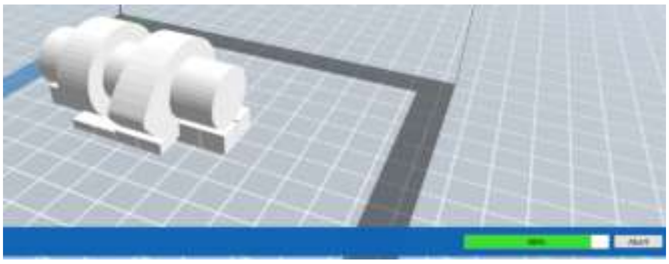

Fig. 10 - Processing of Cam Shaft of 3d Printing

Step 6: Print:

This is when the magic happens! The printer will create the object layer by layer. Depending on the size of your object, your printer, and the materials Used, the job can be done in a matter of minutes or over several hours.

Depending on what you want your final product to be or the material you used, there may be additional post-processing steps after printing, like painting, off powder, etc.

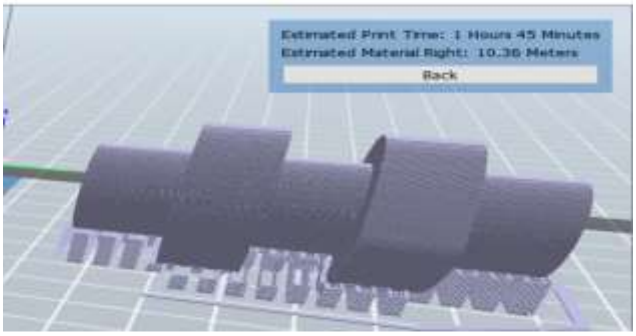

Fig. 11 – **3D Printing of Cam Shaft**

7. Result:

The result of modeling and 3D printing a camshaft can be summarized as follows:

Design: The camshaft is modeled using CAD software, ensuring all dimensions and cam profiles match the engine's requirements. The design is simulated for performance, stress, and fitness.

3D Printing: The model is exported as an STL file and printed using a 3D printer. Depending on the material chosen, it could be printed in plastic (for prototypes) or metal (for functional parts).

Post-Processing: After printing, the camshaft is cleaned, support structures are removed, and any necessary finishing processes (e.g., polishing or heat treatment for metal parts) are applied.

Testing: The printed camshaft is tested for fit, accuracy, and functionality. In case of metal printing, further heat treatment may be required for strength and durability.

8. Discussion:

1.Importance of Accurate Modeling:

Precision in CAD Design: Camshafts are critical engine components that control the timing of the engine's valves. The precision of the cam profile (the shape of the cam lobes) and the camshaft's overall dimensions is crucial for proper engine performance. Even small errors in the Design can result in poor engine operation, reduced efficiency, or engine damage.

Customization: Modern engines, particularly in the automotive and motorsport industries, often require custom camshaft designs to optimize performance. 3D modeling allows engineers to easily create and modify cam profiles, testing different designs virtually before producing physical prototypes.

2. Material Selection and Suitability for 3D Printing:

Plastic Materials (FDM/SLA): For prototyping, 3D printing with plastic materials (such as PLA, ABS, or resin) is ideal because it offers fast turnaround times and low material costs. However, these materials are not suitable for functional engine components like camshafts, as they lack the durability and heat resistance required for real-world engine use.

Metal Materials (SLM/DMLS): For producing functional camshafts, metal 3D printing technologies such as Selective Laser Melting (SLM) or

Direct Metal Laser Sintering (DMLS) are employed. These methods allow for the use of high-performance materials such as steel, titanium, or

Inconel, which can withstand the mechanical stresses, and thermal conditions present in engines.

Strength and Durability: Metal 3D printing allows for the creation of parts with intricate geometries that are typically difficult to achieve using traditional manufacturing methods. However, the material's mechanical properties must be considered, and post-processing steps (e.g., heat treatment) may be necessary to achieve the required strength.

3. Complexity in the Manufacturing Process:

Geometrical Complexity: One of the major advantages of 3D printing a camshaft is its ability to handle complex geometries. Traditional machining techniques can struggle with intricate profiles, while 3D printing allows for the design of camshafts with optimized profiles and other features (such as integrated oil passages or weight-saving structures) that may be difficult to achieve with conventional methods.

Support Structures: 3D printing often requires support structures to prevent overhangs or ensure the integrity of the print. These supports must be removed post-printing, which can add extra time and effort to the post-processing stage. Moreover, for metal 3D printing, support structures can also affect the final mechanical properties of the camshaft, so they must be carefully considered in the design.

4. Post-Processing:

Cleaning and Finishing: After the camshaft is printed, especially in metal, the post-processing stage is crucial for removing support structures and ensuring the part meets the required tolerances. Surface finishing, polishing, or machining may be needed to achieve the required surface smoothness,

particularly for the cam lobes, which need to be precise for proper valve operation.

Heat Treatment: For metal camshafts, heat treatment processes are critical. This may include annealing, hardening, or tempering, to improve the

material's hardness and resistance to wear. Metal 3D printing can create parts with unique microstructures, and heat treatment can further optimize these properties for the intended use.

5. Challenges in Functional Use:

Engine Performance: While 3D printing allows rapid prototyping and testing, the camshaft may not always perform as well as traditionally

manufactured parts, especially if it's made from less durable materials. The physical properties of 3D printed materials can differ from conventionally Machined metals, especially in terms of surface finish, strength, and wear resistance, which could affect the camshaft's longevity and the engine's performance.

Cost: Metal 3D printing, particularly for high-performance materials like titanium, can be costly. While it allows for intricate designs and reduced lead times, the price point may not be practical for all applications. Therefore, it is most often used in high-performance, low-volume, or custom-engineered parts, like those used in motor sports or prototype development.

9. Conclusion:

Modeling and 3D printing of camshafts offer significant advantages in rapid prototyping, design iteration, and customization. Using CAD software, engineers can create highly precise and complex cam profiles that can be quickly tested and modified, which are especially useful in applications like motorsports or low-volume production. 3D printing allows for the creation of intricate designs that would be challenging to achieve with traditional manufacturing methods. While 3D printing provides an efficient and cost-effective solution for prototyping, there are challenges when it comes to functional, high-performance applications. Materials commonly used in 3D printing, especially plastics, lack the strength and durability required for a camshaft that will endure the high stresses and temperatures inside an engine. Metal 3D printing technologies, such as SLM or DMLS, offer solutions with stronger materials but come at a higher cost and still require post-processing steps like heat treatment to achieve the necessary properties for durability and wear resistance.

Acknowledgements

We sincerely thank our internal guide, Mr. P. Ravi Kiran, for his valuable advice and encouragement throughout this project. Our gratitude also extends to Dr. B. Vijaya Kumar, Professor and Head of the Mechanical Department, for his expert supervision and insightful suggestions. We appreciate Principal Dr. Koduganti Venkata Rao and the management for providing the necessary facilities. Additionally, we thank the Mechanical Engineering staff and lab technicians for their assistance.

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