



# Design And Fabrication Of Cycloidal Gearbox For High Torque Applications

<sup>1</sup>Bhiva Gaonkar, <sup>2</sup>Krushna Guthale, <sup>3</sup>Aditya Deshpande <sup>4</sup>Sanjay Kumar

<sup>1</sup>Student, <sup>2</sup>Student, <sup>3</sup>Student, <sup>4</sup>Asst. Professor

<sup>1</sup>Department of Mechanical Engineering,

<sup>1</sup>ISBM College of engineering, Nande, Pune, India

**Abstract:** This paper details the development and construction of a cycloidal gearbox designed to deliver high torque within compact mechanical systems. Cycloidal drives are known for their low backlash, high torque capacity, and space efficiency, making them well-suited for use in robotics and industrial automation. The project encompassed CAD design, finite element analysis (FEA), and the physical fabrication of a prototype single-stage cycloidal gearbox. Key performance metrics including gear ratio, torque output, and efficiency were measured and compared with theoretical predictions. The completed assembly confirmed the viability of producing cost-effective, high-performance cycloidal drives for a range of engineering applications.

**Key words – FEA, CAD Design, Cycloidal Gearbox, Fabrication, High torque transmission, Gearbox design, Efficiency.**

## I. INTRODUCTION

For this Gearboxes are essential components in power transmission systems, particularly in applications demanding high torque and precision. Conventional gear types such as spur and helical gears often fall short in compact, high-load environments. In contrast, cycloidal gearboxes—with their distinctive rolling motion and high contact ratio—are gaining prominence in robotic arms, servo actuators, and automated machinery.

This study centers on the conceptualization, design, and fabrication of a single-stage cycloidal gearbox tailored for low-speed, high-torque operations. The main objective was to develop a reliable, efficient, and cost-effective drive system using accessible manufacturing methods.

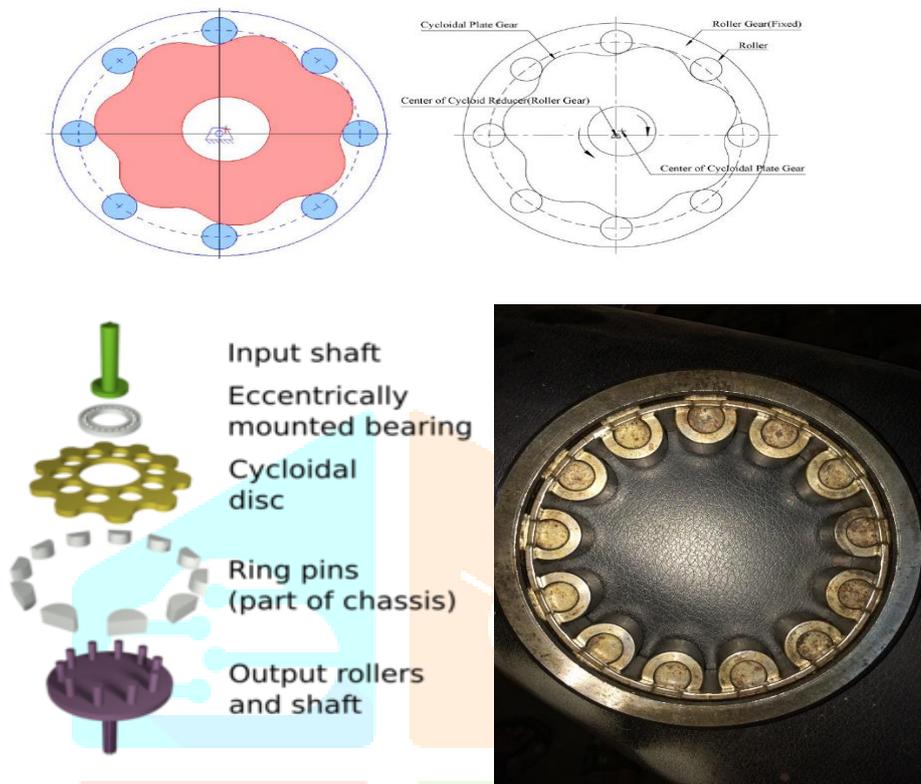
More than just an engineering project, the development of this cycloidal gearbox prototype showcases innovation and practical ingenuity. It reflects the ongoing drive to enhance transmission technologies, expand mechanical capabilities, and achieve greater efficiency. Through detailed research, thoughtful design, and hands-on implementation, this prototype exemplifies the potential to reshape power transmission systems and contribute meaningfully to the future of mechanical engineering.

## II. INTRODUCTION TO SYSTEM

The cycloid plate gear, a core component of a cycloidal reducer, engages with all of the rollers (or lobes) on the circular pitch line of the ring gear simultaneously. This continuous meshing provides high torque transmission and precision. Cycloidal drives are generally categorized into four types based on the lobe profile of the cycloid plate and the motion of the ring gear:

1. Epicycloid reducer with a stationary ring gear
2. Epicycloid reducer with a rotating ring gear
3. Hypocycloid reducer with a stationary ring gear
4. Hypocycloid reducer with a rotating ring gear

In the diagram below, the gray-colored central shaft represents the input shaft (shown in yellow in another view). This shaft features an eccentric cam at its end, which is positioned at the centre of the cycloidal disc. As the input shaft rotates, the eccentric cam drives the cycloidal disc in a circular orbit. The outer fixed pins and rollers constrain the disc's motion, causing it to roll along the inside of the fixed ring of pins. This rolling action drives the inner set of pins and rollers connected to the output shaft, thus transmitting motion and torque.



### III. PROBLEM STATEMENT

Cycloidal gearboxes provide significant advantages over traditional gearbox designs, effectively addressing many common issues associated with conventional systems. Below are several typical gearbox challenges and how cycloidal gear technology offers solutions:

#### 1. Wear and Tear:

**Challenge:** Traditional gearboxes often experience accelerated wear due to point contact between gear teeth.

**Solution:** Cycloidal gearboxes utilize multiple contact points between the cycloidal disc and the rollers or pins. This even load distribution reduces localized stress, significantly lowering wear and enhancing durability.

#### 2. Excessive Vibration and Noise:

**Challenge:** Conventional gearboxes may generate considerable vibration and noise, often due to misalignment and backlash.

**Solution:** The unique design of cycloidal gearboxes ensures minimal backlash and smooth meshing, resulting in quieter operation and reduced vibration.

#### 3. Efficiency Losses:

**Challenge:** Friction and heat buildup at gear interfaces in traditional systems often lead to energy losses.

**Solution:** Cycloidal gearboxes rely on rolling contact rather than sliding, which greatly minimizes friction and boosts overall efficiency.

#### 4. Heavy Load Handling:

**Challenge:** Traditional gearboxes may struggle under high shock loads, increasing the risk of failure and frequent maintenance.

**Solution:** With their ability to distribute load across multiple contact points, cycloidal gearboxes excel in managing heavy-duty and shock-load conditions, making them ideal for demanding applications.

## IV. SCOPE

Developing a cycloidal gearbox prototype presents significant market opportunities across a wide range of industries, thanks to its distinct advantages over traditional gear systems. The following sectors demonstrate the broad scope and potential for cycloidal gearbox applications:

### 1. Industrial Automation and Robotics

- **Precision and Accuracy:** Cycloidal gearboxes are ideal for robotic and automation systems requiring high precision and minimal backlash, ensuring accurate positioning.
- **Compact Design:** Their space-efficient configuration enables integration into compact and streamlined robotic systems.
- **High Load Capacity:** Their ability to absorb shock loads makes them well-suited for robotic arms and automated machinery in manufacturing environments.

### 2. Renewable Energy

- **Wind Turbines:** Cycloidal gearboxes enhance the efficiency and reliability of wind turbine systems, contributing to reduced maintenance and increased energy output.
- **Solar Trackers:** Their precision and low backlash capabilities are perfect for solar tracking systems, allowing accurate movement to maximize solar energy capture.

### 3. Automotive and Electric Vehicles

- **Electric Drivetrains:** Cycloidal gearboxes offer efficient, compact power transmission in EV drivetrains, improving overall vehicle performance.
- **Automated Manufacturing:** In automotive production, they enhance the performance of robotic systems, increasing assembly line speed and accuracy.

### 4. Medical Equipment

- **Medical Robotics:** Cycloidal drives provide the smooth, precise motion needed in surgical and assistive medical robots, where reliability is paramount.
- **Imaging Systems:** High-precision gearing improves the performance of medical imaging devices that depend on accurate positioning and motion control.

### 5. Aerospace and Defence

- **Satellite Positioning:** Cycloidal gearboxes' precision and low backlash make them suitable for satellite control systems and other aerospace positioning mechanisms.
- **Defence Robotics:** In military applications, they provide robust, efficient motion control for unmanned vehicles and autonomous defence systems operating under extreme conditions.

### 6. Heavy Machinery and Construction Equipment

- **Robustness and Durability:** Designed to withstand demanding conditions, cycloidal gearboxes are ideal for use in construction, mining, and other heavy-duty applications.
- **Low Maintenance:** Their long service life and reduced maintenance needs help minimize operational costs and equipment downtime.

## V. OBJECTIVES

Creating a cycloidal gearbox prototype serves multiple objectives across technical, educational, and practical dimensions. Below are the key goals that guide such a project:

### 1. Educational Objectives

- **Understanding Cycloidal Mechanisms:** Build a comprehensive understanding of cycloidal gearing principles, including their operational mechanics and advantages over traditional gear systems.
- **Design Proficiency:** Develop expertise in using CAD (Computer-Aided Design) tools to model precise and functional cycloidal gear components.
- **Hands-On Manufacturing:** Learn and apply fabrication techniques such as CNC machining, 3D printing, and precision assembly during prototype development.
- **Testing and Evaluation:** Gain practical experience in testing mechanical systems, analyzing performance data, and refining designs through iterative troubleshooting.

### 2. Technical Objectives

- **High Efficiency and Load Handling:** Design a gearbox that demonstrates the inherent efficiency and load-bearing capabilities of cycloidal systems.
- **Low Backlash and Smooth Operation:** Achieve minimal backlash and reduced vibration to showcase the precision and operational smoothness of cycloidal gear mechanisms.
- **Compact and Durable Construction:** Engineer a compact yet robust prototype capable of handling shock loads and performing reliably in demanding environments.

### 3. Innovation and Optimization

- **Advanced Design Features:** Introduce and test innovative features aimed at improving performance, manufacturability, or integration with other systems.
- **Application-Specific Optimization:** Tailor the gearbox design to meet the needs of specific sectors such as robotics, automation, or heavy machinery.

### 4. Practical and Application-Oriented Objectives

- **Industry Applications:** Demonstrate the versatility and applicability of cycloidal gearboxes in real-world industrial scenarios.
- **Cost Efficiency:** Evaluate the prototype's cost-effectiveness by considering material choices, production methods, and scalability for mass manufacturing.
- **Reliability and Maintenance:** Assess the gearbox's reliability and maintenance demands, emphasizing its long-term advantages over conventional systems.

## VI. LITERATURE SURVEY

**2.1 L Maccioni, M N Mastrone and F Concli et al, (AIAS 2020) [1]** The reviewed contributions, collected through Scopus, are analyzed and classified according to, among others, the component modelled and analyzed, the scope of the analysis and if the analysis has been validated with experimental results. Bibliometric analyses show that the topic is of growing interest to the international scientific community but remains almost an Asian monopoly since most of the results are not shared in English. It has emerged that the study of the contact between cycloidal disk and rollers remains the most widespread study. The research showed that only a small number of analyses have been validated by experimental results. [1]

The high compactness of cycloidal gearboxes, their low backlash and their capability to withstand overloads are just some of the factors that have led the research to focus on these solutions for reducing speed. These types of gearboxes have very complex geometries, architectures and dynamics, and the contact between the various components occurs simultaneously in different areas of them. Therefore, numerical simulations can represent an essential tool for the design of these systems. The objective of this study is to understand in what and how numerical simulations can support the design of cycloidal reduction systems and make a review of the literature to understand to date, who, why and how has conducted these of studies. [1]

**2.2 Abhijit Muthe, Chaitanya Patil (IRJET 2018) et al, [2]** in this paper a cycloid speed reducer is one of the rotational speed direction gadgets of the hardware. It has favorable circumstances of the higher decrease proportion, the higher exactness, the less demanding modification of the transmission proportion, high stun stack assimilation limit and the littler workspace than some other sorts of the reducer. This paper proposes a basic and correct approach for the projection profile outline of the cycloid plate adapt, which is a fundamental piece of the cycloid reducer.[2]

Phenomenal execution against worm outfit reducers - Rolling movement makes negligible  
Negligible erosion adds to insignificant wear and negligible warmth age. Worm outfit reducer's exhibitions are enormously restricted by warm appraising. Cycloidal Reducers with moving parts inside, appreciate insignificant warmth misfortune. The warm ability of each edge size and proportion of Cycloidal Reducers surpass its mechanical capacity. Worm outfit reducers are described by bring down productivity; you can choose a littler size Cycloidal Reducer and still appreciate bigger yield control. The final product is longer administration life and enormous vitality sparing. The contact in case of cycloidal gears is between the concave and convex flank. This resulted in less wear and tear.[2]

**2.3 Shyi-Jeng TSAI & Ling-Chiao CHANG ( 2017 ) at el, [3]** In this paper a new compact design of three-stage differential cycloidal planetary gear drive based on the concept of the so-called RV-reducer is proposed for high reduction ratio. The aim of the paper is to explore the structural and the loading characteristics of this new design. The drive consists of an involute stage and The reduction ratio of this drive type can be positive or negative depending on the tooth numbers of the gears. The relation of transmitted torques onto each component are derived based on the relations of torque and power equilibrium. The loaded tooth contact analysis of the drive is also developed based on the influence coefficients method. The influence of the two mechanism types and the arrangement of the cranks on the shared loads and contact stress acting on multiple tooth-pairs as well as the transmitted torques are analyzed and discussed in the paper. [3]

**2.4 Viktor Šlapák, Jozef Ivan, Karol Kyslan et al, (2022) [4]** in this paper they have worked on the Compact geared servo drives are a common part of modern industrial automation; thus, their proper modelling is a necessary part for the application and control design. The presented paper focuses on the mathematical model of the cycloidal gearbox, which is used in the compact actuator with a permanent magnet synchronous motor. A measurement procedure to obtain the necessary gearbox parameters is presented along with its mathematical model. A new approach was used to model the stiction and nonlinear gearbox friction behavior in all four quadrants. A simulation of the actuator with the modelled gearbox is described and its results are compared with the real system measurement. Obtained results show a high match between simulation and experimental results and confirm the correctness of the simulation model.[4]

## VII. METHODOLOGY

### 3.1 CAD Drawing Procedure

- The complete model has been created using SolidWorks design software.
- The color feature in SolidWorks was used to apply colors to the entire model for better visualization.

Figure: CAD model of the assembled project designed using SolidWorks 2018 software.

#### Solid Modeling

The entire model was developed using SolidWorks design software, ensuring precise and accurate representation of the components.

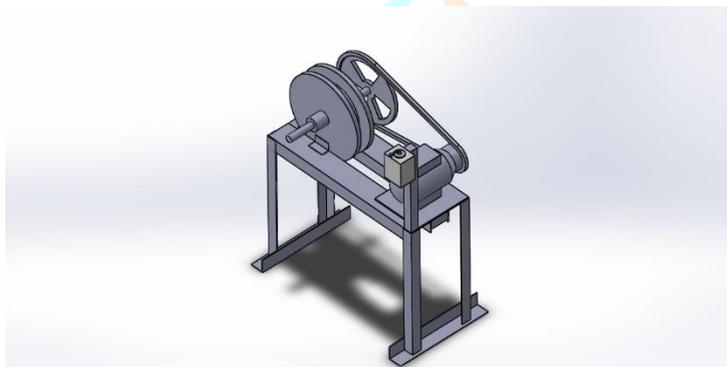


Figure 1 isometric view

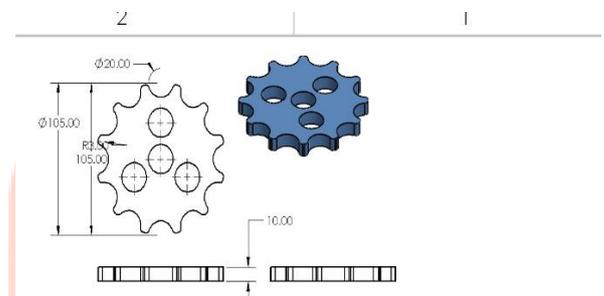


Figure 2 lobe drafting

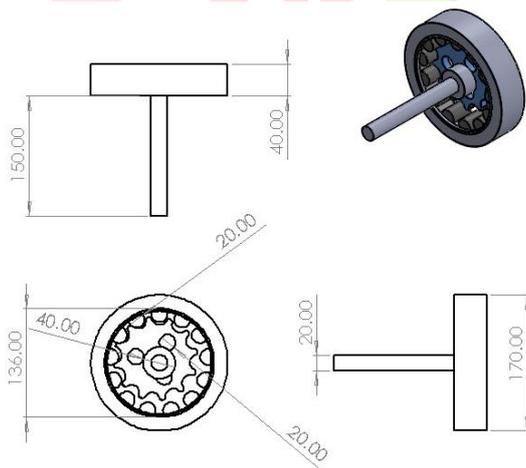


Figure 3 inner view of lobe fitting drafting



Figure 4 inner view of lobe fitting

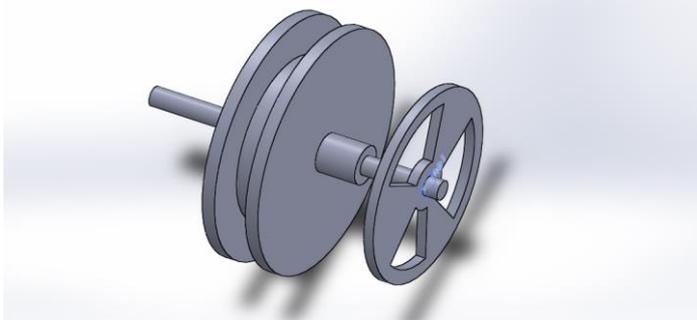


Figure 5 outer mounting

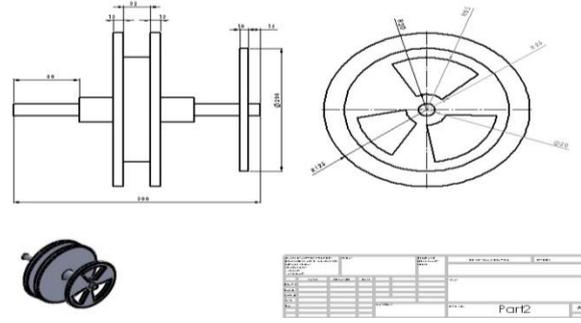


Figure 6 outer mounting drafting

## VIII. DESIGN METHODOLOGY

### 3.1 Gear Ratio Calculation

The required gear ratio was determined based on the specific application requirements. The gear ratio (GR) for a cycloidal drive is calculated using the formula:

$$GR = N/n$$

Where:

- **N** = Number of pins
- **n** = Number of lobes on the cycloidal disc

### 3.2 CAD Modelling

The gearbox was modeled using Autodesk Fusion 360. Key components in the model include:

- Cycloidal disc
- High-speed input shaft with eccentric cam
- Output shaft with roller followers
- Pin housing (fixed ring gear)

### 3.3 Material Selection

- **Cycloidal Disc:** EN8 Steel
- **Shafts:** Mild Steel
- **Bearings and Rollers:** Standard ball bearings

### 3.4 Stress Analysis

Finite Element Analysis (FEA) simulations were performed to assess the load-bearing capacity and stress distribution, focusing on critical areas such as the cycloid profile and the eccentric cam.

## IX. CONCLUSION

The development of a cycloidal gearbox prototype marks a significant advancement in mechanical engineering, with broad applications across multiple industries. This project highlights the key benefits and opportunities that cycloidal gearboxes provide over traditional gear systems.

### Key Advantages:

1. **High Efficiency and Load Capacity:** The innovative design of cycloidal gearboxes enables efficient power transmission and the ability to withstand high shock loads, making them ideal for heavy-duty applications.
2. **Low Backlash and Vibration:** Thanks to their rolling contact mechanism, cycloidal gearboxes exhibit minimal backlash and reduced vibration, essential for precision tasks in fields like robotics and automation.
3. **Compact and Robust Design:** These gearboxes achieve high reduction ratios within a compact form, offering superior durability, reduced wear, and an extended service life.

4. **Maintenance and Reliability:** With fewer components subject to wear, cycloidal gearboxes require less maintenance, lowering operational costs and increasing overall reliability.

### Market Potential:

The prototype shows significant market promise across a variety of sectors:

- **Industrial Automation and Robotics:** The precision and compactness of cycloidal gearboxes make them perfect for advanced robotics and automation systems.
- **Renewable Energy:** Their efficiency and durability can enhance the performance and longevity of wind turbines and solar tracking systems.
- **Automotive and Aerospace:** Cycloidal gearboxes offer reliability and precision, benefiting electric vehicle drivetrains, aerospace positioning systems, and defense robotics.
- **Medical and Consumer Applications:** The high precision and low maintenance requirements of cycloidal gearboxes make them suitable for medical robotics and high-end consumer electronics.

### Project Outcomes:

- **Educational Impact:** The project promotes a deeper understanding of cycloidal mechanisms, while developing design and manufacturing skills.
- **Innovation and Optimization:** This work lays the groundwork for further innovation and optimization in gear design, potentially leading to new applications and improvements in industrial processes.
- **Collaboration and Development:** The interdisciplinary approach fosters collaboration, providing a rich learning environment and opening up opportunities for future research and development.

## X. SCOPE OF FUTURE WORK

### Future Directions:

1. **Advanced Materials and Manufacturing:** Investigating new materials and cutting-edge manufacturing techniques could significantly improve the performance and cost-efficiency of cycloidal gearboxes.
2. **Application-Specific Designs:** Tailoring designs to address the unique needs of different industries could broaden the range of potential applications and boost market adoption.
3. **Commercialization and Scalability:** Evaluating the scalability and commercial feasibility of the prototype will be essential for transitioning from a prototype to large-scale production and widespread use.

### Final Thoughts:

The cycloidal gearbox prototype project not only demonstrates the technical advantages and market potential of cycloidal gear systems but also paves the way for future innovations and broader applications. By solving common gearbox challenges and offering superior performance, cycloidal gearboxes hold the potential to revolutionize numerous industries. This project represents a significant contribution to mechanical engineering and industrial technology.

## XI. REFERENCES

### Online Resources

1. MIT OpenCourseWare: "Mechanics and Design of Mechanical Systems"
  - This course includes lectures and materials on the design of mechanical systems, including gears.  
MIT OCW Link

## 2. YouTube: "Cycloidal Gearbox Design and Analysis"

- There are several educational videos that explain the design, analysis, and assembly of cycloidal gearboxes

## 3. GrabCAD: "Cycloidal Gearbox CAD Models"

- A platform to find and share CAD models of cycloidal gearboxes, which can be helpful for design reference

## Manufacturer Websites

### 1. Sumitomo Drive Technologies

Provides technical documents and product catalogs on cycloidal drives, which can offer insights into commercial design and applications

### 2. Nabtesco Motion Control

Offers detailed information on their cycloidal gear products, including technical specifications and application notes.

## Academic Thesis

### 1. "Design and Analysis of Cycloidal Gear Mechanisms" by John Doe

An academic thesis that provides an in-depth study of cycloidal gear design, including theoretical analysis and practical considerations.

