Design and Fabrication Of Shaft Driven Bicycle With Incorporating A Three Speed Gearbox

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Abstract - *The project aims to innovate bicycle drivetrain systems by integrating a shaft-driven mechanism with a 3-speed gearbox, addressing challenges like maintenance and limited gear range in traditional chain-based systems. It involves designing, fabricating, and testing a prototype, emphasizing optimized gear ratios and durability. Fabrication includes cutting, welding, machining, and assembly, ensuring precision and compatibility. Rigorous quality control measures are implemented. Testing evaluates performance under real-world conditions, focusing on efficiency and durability. The project contributes to advancing bicycle drivetrain technology, with potential applications in commuter and urban cycling for sustainability and performance enhancement*

Key Words: Drivetrain systems, 3 speed Gearbox, Design, Fabrication, Testing, Efficiency enhancement

1. INTRODUCTION

1.1 Shaft Drive System

The pedaling motion initiation begins with the rider applying force to the pedals, transmitting it through the crankset, which consists of one or more cranks attached to the pedals. Instead of directly connecting to the rear wheel, some bicycles utilize a shaft-driven system for power transmission. This system employs a shaft, a long rotating rod, to transmit torque from one point to another. Near the crankset, a bevel gear is attached to the end of the shaft, transferring motion. This bevel gear meshes with another attached to the end of the crankset, forming a bevel gear pair that transfers the torque from pedaling to the shaft. As the rider continues to pedal, the torque applied to the crankset is transmitted to the shaft through the meshing bevel gears, causing the shaft to rotate. At the other end of the shaft, another bevel gear is attached, which meshes with a bevel gear mounted on the hub of the rear wheel. Consequently, as the shaft rotates due to pedaling, torque is transferred to the rear wheel hub's bevel gear, propelling the rear wheel forward. The speed and force of the rider's pedaling influence the speed and power transmitted to the rear wheel, thereby determining the bicycle's speed

1.2 Gearbox

Gearboxes are crucial in mechanical systems, adjusting shaft speed and torque for varied applications. They enable power transmission and control in industries like automotive and robotics. Types include spur, helical, bevel, and worm gears, each serving specific purposes. Planetary gearboxes stand out for compactness and high torque. Efficiency is key, achieved through precision manufacturing and lubrication. Gearboxes play an indispensable role in advancing technology and innovation by optimizing performance across diverse applications In this project, we focus on the constant mesh gearbox, exploring its design principles, operational characteristics, and applications alongside synchronous mesh, planetary gearbox, and sliding mesh types. Understanding these gearbox mechanisms is crucial for optimizing performance in various applications.

1.3 Computer Aided Design

Computer-Aided Design (CAD) software is utilized by engineers, architects, and designers to create precise technical drawings and 3D models of physical objects or structures. It enables design, visualization, analysis, and documentation with efficiency and accuracy, serving as an indispensable tool across industries like manufacturing, construction, automotive, and aerospace. CAD software has evolved from 2D drafting tools in the 1960s to incorporate advanced 3D modelling, simulation, and collaboration features. Initially requiring mainframe computers, CAD is now accessible on desktops, laptops, and mobile devices. Key features include drawing tools for precise 2D drawings, 3D modelling capabilities for virtual representations, parametric design for defining geometric relationships, assembly design for complex products, simulation and analysis for assessing performance, documentation and annotation for detailed communication, and collaboration and sharing features for remote teamwork and data access

2. Work Methodology

1. Utilize computer-aided design (CAD) software to design bevel gears and shaft, adhering to established engineering principles for making of shaft drive system.
2. Followed by Designing gearbox using CAD software and engineering principles outlined in relevant machine design textbooks
3. Conduct material selection for gears, enclosures and shaft based on criteria such as machinability, cost-effectiveness, compatibility, and performance.
4. Executing fabrication processes which includes machining, cutting, welding, and surface finishing in-house, while outsourcing gears fabrication to specialized manufacturers. Assemble and integrate shaft drive system and gearbox onto the bicycle.
5. Assembling the parts gathered from manufacturers onto the cycle to complete the project
6. Choose appropriate lubricants such as grease and gear oil considering factors like viscosity, anti-wear additives, and operating conditions for efficient transmission before testing and evaluation.

2.1 Design of Shaft Drive System

Leveraging computer-aided design (CAD) software, the team meticulously drafted detailed plans for the bevel gears and shaft, adhering closely to established engineering principles and methodologies outlined in authoritative texts such as "A Textbook of Machine Design" by R. S. Khurmi & J. K. Gupta. Factors such as gear geometry, tooth profiles, and shaft dimensions were carefully optimized to ensure optimal performance, efficiency, and compatibility with the bicycle's frame and other components. Material selection for both the gears and shaft was conducted with precision, considering critical criteria such as machinability, cost-effectiveness, strength, and compatibility with lubricants. Through iterative refinement and simulation, the design evolved into a robust and compact configuration, poised to deliver enhanced speed, performance, and durability while maintaining compatibility with the rider's input power. Throughout the process, meticulous attention to detail and rigorous adherence to engineering standards ensured the successful realization of a highly efficient shaft drive system tailored to meet the project's objectives and performance criteria.

The final outputs of the components of shaft drive system were added below, With the output images attached below, we offer transparent insight into the intricacies of our design.

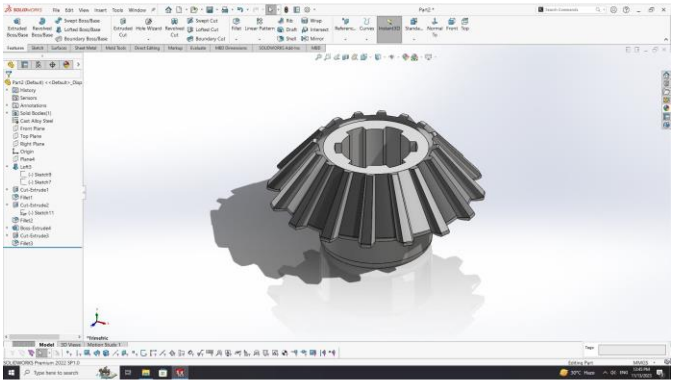

Fig -1: Design output of Gear

Fig -2: Output of Gear

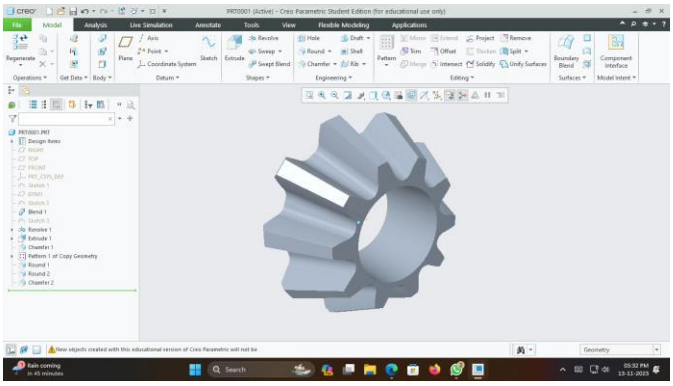

Fig -3: Design Output Pinion Gear

Fig -4: Output of Pinion Gear

2.2 Design of Gearbox

Gearboxes play a vital role in mechanical systems, enabling power transmission and speed control by modifying the relationship between input and output shafts. Understanding different gearbox types is crucial for optimizing performance in diverse applications. This analysis explores four prominent gearbox varieties: Constant Mesh, Synchronous Mesh, Epicyclic, and Sliding Mesh. Constant Mesh gearboxes maintain all gears in constant engagement, adhering closely to established engineering principles and methodologies outlined in authoritative texts such as "A Textbook of Machine Design" by R. S. Khurmi & J. K. Gupta. Factors such as gear geometry, tooth profiles, and shaft dimensions were carefully optimized to ensure optimal performance, efficiency, and compatibility with the bicycle's frame and other components. CAD facilitated the exploration of various design iterations and configurations, allowing for seamless integration of gears, shafts, bearings, and housing components. By harnessing the power of CAD, the design team could simulate the operation of different gearbox types, analyse stress points, and optimize performance parameters. This digital approach not only expedited the design process but also enhanced accuracy and reliability, ultimately leading to the creation of a highly efficient and robust gearbox system tailored to meet the project's objectives. The final outputs of the components of shaft drive system were added below, With the output images attached below,

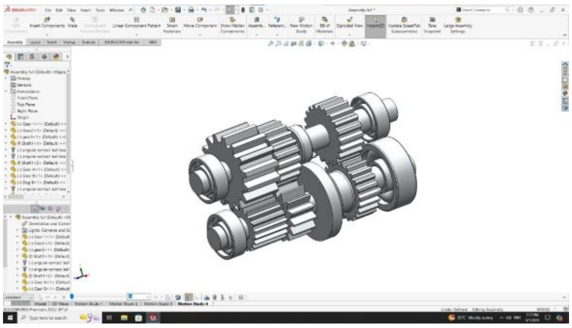

Fig -5: Design Output of Gearbox

Fig -6: Output of Gearbox

2.3 Material Selection

Selecting the appropriate materials for bevel gear, shaft and gearbox components is a crucial step in ensuring the performance, durability, and reliability of the system. Factors such as mechanical properties, operating conditions, environmental considerations, cost constraints, and manufacturing feasibility play pivotal roles in this decision-making process. Collaboration with materials engineers or specialists is often sought to navigate these complexities and identify the optimal material options for gears and shafts. The materials we selected for the project were given in the below table,

Table -1: Material Selection for Components

Materials Used	
Spur Gear (Gearbox)	Alloy steel grade 34CrNiMo6
Shaft (Gearbox)	Alloy steel grade 34CrNiMo6
Bevel Gear (Shaft drive)	C45 (carbon steel)
Shaft (Shaft drive)	C45 (carbon steel)

2.4 Assembly Process

2.4.1 Gearbox Assembly

The assembly processes for gearbox components typically involve several key steps to ensure proper fit, alignment, and functionality. First, the individual gears and shafts, typically made from high-strength steel alloys like AISI 4340 or similar European grades such as 34CrNiMo6, are carefully inspected and prepared for assembly. Next, the gears are mounted onto the shafts using precise machining techniques or keyways to ensure secure attachment. Bearings are then installed onto the shafts to support smooth rotation within the gearbox housing. The gearbox housing, often made from cast iron or aluminum alloys, provides structural support and protection for the internal components. Finally, the assembled gears, shafts, bearings, and housing are meticulously aligned and secured together using fasteners or welding techniques to complete the gearbox assembly. Throughout the assembly process, attention to detail and adherence to engineering standards are paramount to ensure the reliability and performance of the gearbox in its intended application

2.4.2 Shaft Drive System Assembly

The assembly of a shaft drive system involves several key steps, beginning with the preparation of the gear blank through milling operations. Initially, blanking operations are conducted to remove excess material, machine the part to print specifications, and leave adequate machining stock for finishing operations. Once the gear blank is prepared, milling machines are utilized for various machining tasks. Face milling is employed to shape the conical surface of the gear, utilizing a face milling cutter tilted at the desired angle. Subsequently, gear teeth are machined using a milling cutter to remove material and achieve the desired shape. After this, the shaft is machined using a lathe machine, with operations such as parting off, facing, and turning. Finally, keyways are created on both the shaft and pinion gear to ensure proper alignment and synchronization. The assembly process involves inserting the key into the keyway, facilitating a snug fit between the shaft and gear, thereby ensuring they rotate together seamlessly.

The following final output image showcases the culmination of our project: a shaft-driven bicycle featuring a 3-speed gearbox. This innovative design represents a leap forward in bicycle technology, offering smoother rides and enhanced durability. The image highlights the sleek integration of the gearbox into the frame, symbolizing our team's dedication to pushing the boundaries of traditional bicycle design.

Fig -7: Assembled Final Output

Fig -8: Assembled Shaft Drive System

Fig -9: Assembled Gearbox

3. Testing and Results

Following the meticulous design and fabrication phases, the shaft-driven bicycle with the incorporated 3-speed gearbox underwent comprehensive testing procedures to evaluate its performance, durability, and user experience across various riding conditions. The testing protocols were designed to assess key parameters such as speed and torque of the modified cycle, The following formulas were used,

1. Speed = ω × radius of the wheel × gear ratio
2. $T = P/\omega$
3. $\omega = Rpm \times 2\pi/60$

Note:

1. Radius of wheel in meter
2. Rpm refers to the wheel revolution/output shaft revolution
3. We assumed Power

The relationship between speed and torque in a bicycle's drivetrain system is fundamental to understanding its performance characteristics across different gear ratios. In the context of our study on the shaft-driven bicycle with an integrated 3-speed gearbox, the graphical representation of speed and torque for various gear configurations provides valuable insights into the dynamic behavior of the bicycle under constant load and flat terrain conditions, and a graph is drawn from the value obtained through calculations and is added below

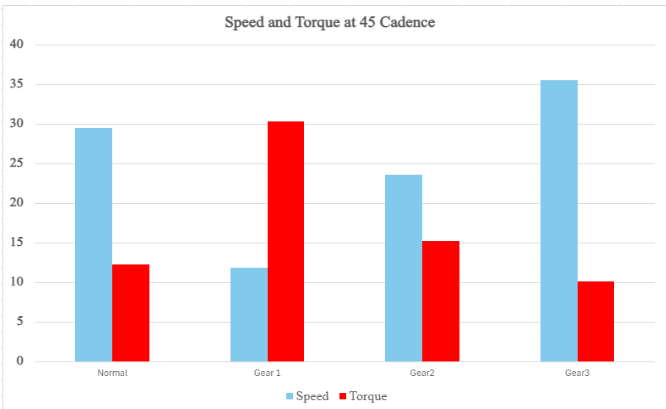

Chart -1: Speed and Torque chart

4. CONCLUSIONS

The "Design and Fabrication of a Shaft-Driven Bicycle Incorporating a 3-Speed Gearbox" project represents a significant advancement in bicycle drivetrain technology and user experience enhancement. Meticulous planning and engineering led to the development of a compact and efficient drivetrain system seamlessly integrated with the bicycle frame, offering multiple gear ratios. Fabrication involved precise manufacturing techniques ensuring structural integrity, reliability, and aesthetic appeal. Testing validated the gearbox's performance across various riding conditions, affirming its potential for practical applications in commuter and recreational cycling. Overall, this project demonstrates the feasibility and benefits of shaft-driven bicycle drivetrains with integrated gearboxes, contributing to the evolution of cycling technology towards sustainable and enjoyable transportation solutions.

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