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Design and Construction of a Power Transmission System

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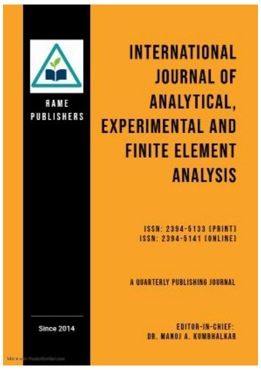

Abstract: The design and fabrication of power transmission systems play a crucial role in ensuring efficient energy transfer across mechanical components. This paper presents a comprehensive study on the conceptualization, design, and manufacturing of a robust power transmission system tailored for industrial and automotive applications. The methodology includes material selection, system modelling, stress analysis, and performance evaluation to optimize efficiency and durability. Various transmission mechanisms, such as belt drives, chain drives, and gear systems, are analysed based on load-bearing capacity, frictional losses, and maintenance requirements. The fabricated system is tested for operational efficiency and reliability under different working conditions. Experimental results validate the design's effectiveness in reducing power losses while ensuring smooth mechanical transmission. This research contributes to advancing power transmission technology by integrating innovative materials and manufacturing techniques, leading to improved mechanical efficiency and sustainability.

Keywords: Power transmission, mechanical design, gear system, belt drive, chain drive, fabrication, stress analysis, efficiency, industrial applications, automotive engineering, material selection.

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1. Introduction

Power transmission systems are fundamental in mechanical and automotive engineering [1], ensuring the efficient transfer of energy from a power source to a driven mechanism. These systems are widely used in industrial machinery, vehicles, and various mechanical applications where controlled motion and torque distribution are essential [2]. The effectiveness of a power transmission system directly impacts the overall performance, energy efficiency, and longevity of mechanical systems [3].

The design and fabrication of a power transmission system involve selecting appropriate components such as gears, belts, chains, shafts, and couplings to achieve optimal efficiency with minimal power losses [4]. Key design considerations include load capacity, torque requirements, material selection, frictional losses, and durability [5]. Advanced computational tools, including finite element analysis (FEA) and computer-aided design (CAD), are employed to refine system parameters and predict performance under different operating conditions [6].

Fabrication techniques play a crucial role in ensuring the reliability of the transmission system. Precision machining, material treatments, and quality control measures are implemented to enhance mechanical strength and reduce wear and tear. The integration of modern manufacturing techniques [7], such as 3D printing and CNC machining, has further improved the accuracy and performance of fabricated components [8].

This paper focuses on the systematic approach to designing and fabricating a power transmission system, emphasizing performance optimization, cost-effectiveness, and sustainability[9]. The study includes an analysis of different transmission mechanisms [10], experimental validation, and performance evaluation, providing valuable insights for engineers and researchers in the field [11].

Power transmission systems play a significant role in automotive and mechanical engineering applications by transferring power efficiently from the engine or motor to the driving wheels. In recent years, go-karts have gained considerable attention in the field of automobile engineering due to their simple construction, lightweight structure, and high maneuverability. The performance of a go-kart mainly depends on the efficiency of its transmission system, which directly influences acceleration, torque transmission, speed, and overall vehicle performance. Therefore, the design and fabrication of an efficient power transmission system has become an important area of research [12].

Several researchers have worked on different types of transmission systems used in go-karts. A comparative study on manual transmission, continuously variable transmission (CVT), and industrial engine transmission systems analyzed parameters such as velocity, acceleration, torque, sprocket ratio, and slipping conditions. The study reported that the CVT system provides smoother driving characteristics and better acceleration performance compared to conventional transmission systems [13].

Research has also been carried out on the economical design and fabrication of go-karts with the objective of reducing manufacturing cost while maintaining structural safety and reliability. Various components such as the roll cage, shaft, and brake system were designed and analyzed to ensure safe operation. The study demonstrated that low-cost go-karts can be successfully developed without compromising safety and performance [14].

With the advancement of electric mobility, studies on electric go-kart transmission systems have also increased. Researchers have focused on the design of chain drive systems, sprocket ratio selection, motor specification optimization, and speed analysis to improve the efficiency and output performance of electric go-karts. Simulation tools and analytical methods were utilized to optimize transmission design and maximize vehicle performance.

Further studies on transmission system analysis mainly focused on rear axle design, shaft diameter calculations, and reduction of power losses in drivetrain systems. Researchers emphasized the importance of lightweight construction, improved torque transmission, and high transmission efficiency. Virtual modeling and simulation techniques were widely adopted to optimize component design and reduce manufacturing cost.

Although significant research has been conducted in the field of go-kart transmission systems, several challenges still remain. Most existing studies primarily focus on theoretical calculations and simulation-based analysis, while practical experimental validation is limited. Detailed analysis of power losses, transmission efficiency under varying operating conditions, maintenance requirements, and reliability of transmission components has not been extensively explored. In addition, limited work has been carried out on lightweight and energy-efficient transmission systems with improved durability and reduced maintenance requirements.

Therefore, there is a need to develop an efficient, lightweight, cost-effective, and experimentally validated power transmission system capable of minimizing power losses while improving torque transmission and overall system performance. The present work aims to address these research gaps through the design and fabrication of an optimized power transmission system suitable for automotive applications such as go-karts.

Table 1. Key gaps & Challenges

Aspect	Challenges	Gaps
Efficiency	Energy losses, friction	Optimized designs, energy recovery
Durability	Wear, frequent failures	Advanced materials, coatings
Maintenance	High lubrication needs	Self-lubricating, predictive systems
Adaptability	Load inconsistencies	Smart adaptive transmission
Cost	Expensive fabrication	Cost-efficient materials, 3D printing
Sustainability	Lubricant waste, emissions	Eco-friendly solutions

1.1 Problem definition

Conventional power transmission systems often suffer from inefficiencies due to energy losses, misalignment, wear and tear, and maintenance challenges. Existing designs may not adequately address specific load requirements, speed variations, or compactness needed for specialized applications. Hence, there is a need to develop an optimized power transmission system that enhances efficiency, minimizes energy losses, and ensures durability while being cost-effective and easy to fabricate.

1.2 Objective

1. Design and fabricate a power transmission system (Go-kart).
2. Conduct experimental analysis to compare the torsional stress on the axel rod.
3. To study design and fabrication of chain sprocket to the it's optimal use.
4. To study Minimize energy losses due to friction and mechanical inefficiencies.

1.3 Methodology

The methodology focuses on designing, analysing, fabricating, and testing an efficient power transmission system. The approach includes literature review, system modelling, material selection, prototype fabrication, and performance evaluation.

1. *Literature Review* – Study of existing power transmission methods.
2. *System Design & Simulation* – CAD modelling and structural analysis.
3. *Material Selection & Fabrication* – Choosing high-strength materials and manufacturing the prototype.
4. *Prototype Testing* – Evaluating efficiency, durability, and load performance.
5. *Data Analysis & Optimization* – Refining the system for better reliability.
6. *Conclusion & Future Scope* – Suggesting improvements and sustainable solutions.

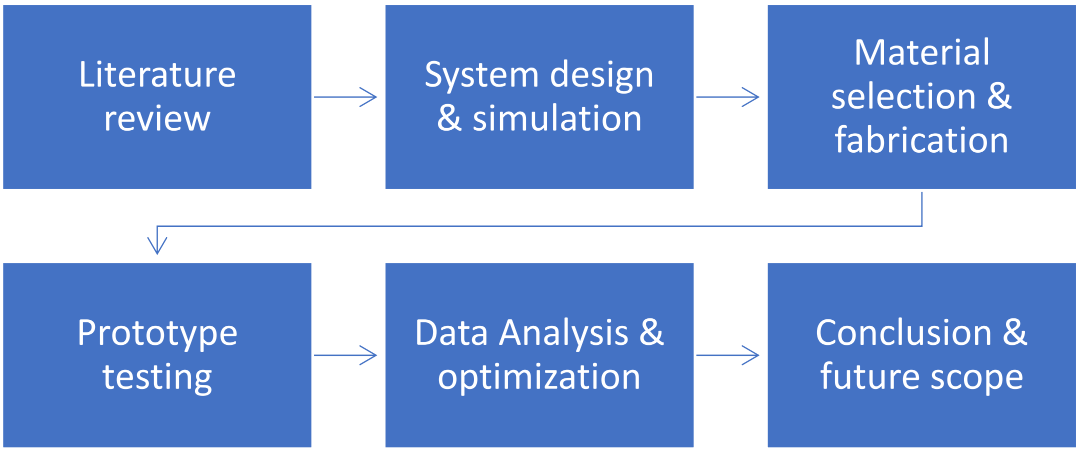


Figure 1: Methodology Flowchart for power transmission system

1.4. Operations

The design and fabrication of the chain sprocket and axel rod play a crucial role in enhancing the efficiency of the Power transmission system. This operation focuses on optimizing the sprocket and axel rod structure to improve to get max power, reduce losses, and maximize energy conversion efficiency.

Material Selection:

Materials are chosen based on strength, durability, and efficiency. High-strength alloys (steel, titanium) are used for gears and shafts, while composites and polymers reduce weight in belt and chain drives. Wear-resistant coatings and self-lubricating materials enhance longevity and performance.

Geometric Optimization & CAD Modeling:

Geometric optimization ensures efficient power transfer by refining component shapes, reducing friction, and minimizing weight. CAD modelling (using tools like SolidWorks or AutoCAD) helps visualize and simulate system performance, ensuring precise alignment and load distribution. Finite Element Analysis (FEA) further optimizes strength, durability, and efficiency before fabrication.

Fabrication Process:

Implementing advanced manufacturing techniques such as metal forming, lathe machine for high precision. Ensuring proper welding and assembly to maintain structural integrity and heat retention.

Quality Control & Structural Testing:

Quality control ensures the reliability and efficiency of the power transmission system through material inspection, precision manufacturing, and performance validation. Structural testing involves load testing, stress analysis, and durability checks using FEA tools like ANSYS. Prototype testing evaluates torque transmission, vibration, and thermal stability. Non-destructive testing (NDT) methods help detect defects without damaging components. These processes ensure safety, longevity, and optimal performance before final implementation.

1.5. Key Components and Functions

Engine: - An engine converts energy (fuel) into mechanical energy. It performs key functions like compression, combustion, power generation and exhaust removal, and cooling to ensure efficient operation.

Chain Sprocket: - A chain sprocket transmits mechanical power by engaging with a chain, regulating speed, direction and load distribution in a vehicle, ensuring efficient motion transfer and synchronization in chain drive system.

Shaft: - A shaft transmits power and rotational motion, supports rotating parts, maintains alignment, absorbs vibrations, and bears mechanical loads in a vehicle.

Engine Mount: - Secures the engine, absorbs vibrations, reduces shocks, and maintains proper alignment of the powertrain, ensuring smooth operation and protecting components from damage.

Shaft Bearing: - A shaft bearing supports and aligns a rotating shaft, reduces friction, absorbs loads, improve efficiency, and extends equipment life.

Wheel Hub: - Connects the wheels to the axle, houses bearings for smooth rotation, supports the brake system, secures the wheel with lug studs.

Carburettor: - Mixes air and fuel in the right ratio for combustion, regulates fuel flow atomizes fuel for smooth burning, controls engine speed, and aids cold starts.

Exhaust: - Removes harmful gases, reduces noise, controls emissions, improves engine performance, and helps dissipate heat.

Clutch: - Connects and disconnects the engine from the drivetrain, allowing smooth gear shifts, preventing stalling, and reducing wear, ensuring controlled power transmission and protects against overloads

2. Design Calculations

When selecting the Bajaj Avenger 150cc Street engine for a go-kart, you need to check its feasibility by considering power, torque, weight, and gearing. Below are the key formulas and selection criteria to determine its suitability.

2.1. Engine Specifications (Avenger 150cc Street)

- Power (P) = 14.54 HP (10.8 kW) @ 9000 RPM
- Torque (T) = 12.5 Nm @ 6500 RPM
- Weight = ~140 kg (motorcycle weight, engine weight ~30-40 kg)
- Top Speed (Motorcycle) = ~110 km/h

2.2. Power-to-Weight Ratio Check

A go-kart typically weighs 100-150 kg (including driver). The power-to-weight ratio determines acceleration capability:

$$Power - to - weight\ ratio = \frac{Power(kw)}{Total\ kart\ weight(kg)}$$

For a 150 kg kart (with driver):

$$0.072kW/kg = \frac{10.8}{150}$$

Comparison:

- Standard rental go-karts: 0.03 - 0.05 kW/kg (sufficient)
- Racing go-karts: 0.1 - 0.15 kW/kg (lower than ideal)

Verdict: The Avenger 150cc engine is suitable for a recreational or low-performance racing kart.

2.3. Final Drive Ratio Selection

Since the motorcycle's top speed is ~110 km/h, gearing must be adjusted for a go-kart (~60 km/h max).

Gear Ratio Formula

$$GR = \frac{Ne}{Nw}$$

where:

- Ne=9000 RPM (engine max)
- Nw = Wheel RPM

Wheel speed is calculated using:

$$Nw = \frac{60V}{\pi Dw}$$

For a 10-inch (0.254 m) diameter kart wheel and desired speed V=60V = 60 km/h (16.67 m/s): -

$$Nw = \frac{60\times16.67}{\pi\times0.254} = 1257RPM$$

Now, calculate gear ratio: -

$$GR = \frac{9000}{1257} \approx 7.16$$

2.4. Sprocket Selection

- Motorcycle Front Sprocket: ~14T
- Kart Axle Sprocket: Should be 14T × 7.16 ≈ 100T
- Use a 100T rear sprocket for optimal performance.

2.5. Acceleration Check

Force at the wheels: - $F = \frac{Tw}{rw}$

where:

- Wheel Torque = $Tw = GR \times Te = 7.16 \times 12.5 = 89.5Nm$
- Wheel Radius = $rw = 0.127m$ (half of 10-inch wheel)

$$F = \frac{89.5}{0.127} \approx 705N$$

Acceleration: -

$$a = \frac{F}{m} = \frac{705}{150} \approx 4.7m/s2$$

0-60 km/h time:

$$t = \frac{V}{a} = \frac{16.67}{4.7} \approx 3.55s$$

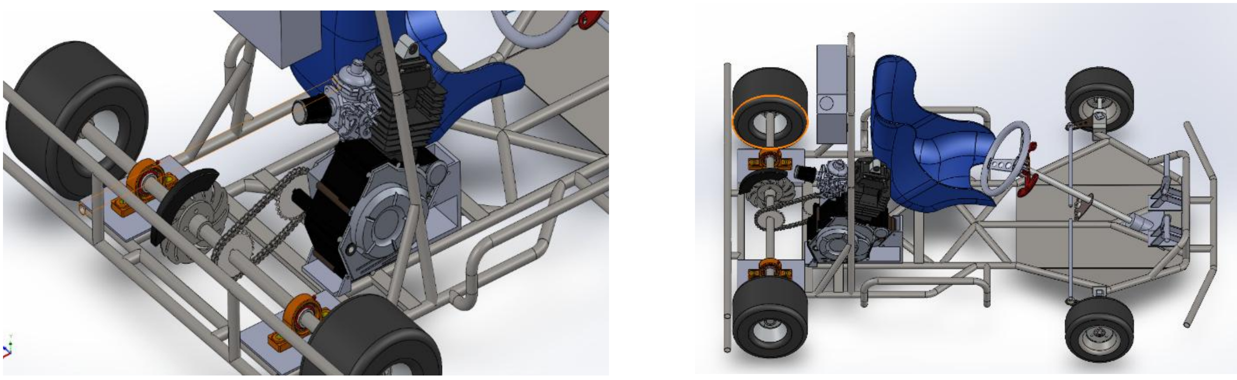
This is suitable for a performance go-kart.

2.6. Summary of Key Design Choices

Parameter	Value
Engine Power	14.54 HP (10.8 kW)
Engine RPM	9000 RPM
Wheel Diameter	10 inches (0.254 m)
Sprocket Ratio	17T: 30T
Chain Type	#35 or #40
Acceleration	~4.7 m/s²
0-40 km/h Time	~3.55 s

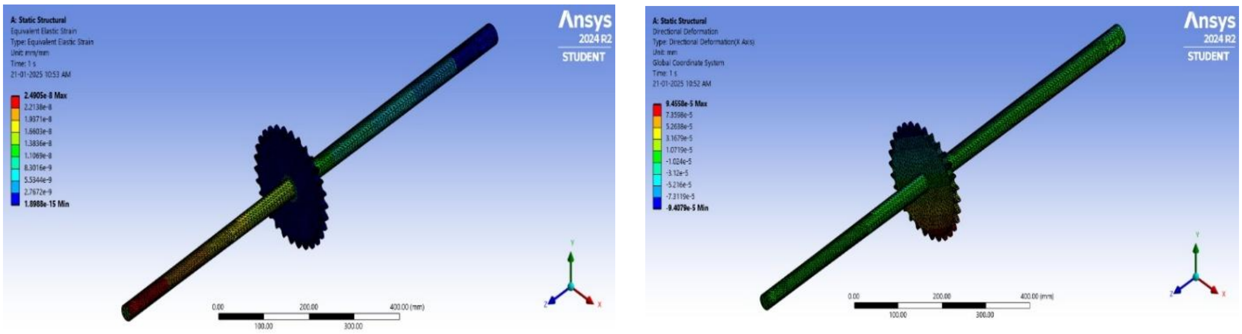
3. Design and Modeling

The design and modelling of a power transmission system involve selecting the appropriate transmission type based on efficiency, load capacity, and application requirements. Using CAD software like SolidWorks or AutoCAD, the system is modelled to ensure optimal gear ratios, belt or chain configurations, and material selection. Finite Element Analysis (FEA) tools such as ANSYS or MATLAB are used to simulate stress distribution, torque transmission, and energy losses. This approach helps in optimizing the design for durability, performance, and minimal maintenance before fabrication and testing.

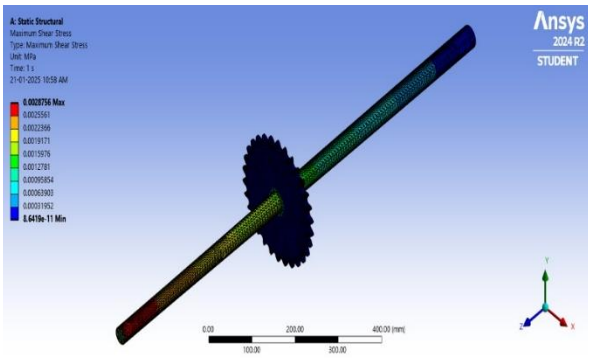


(a) (b)

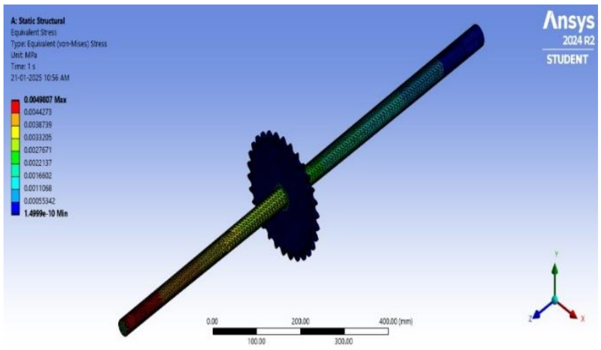
Figure2. CAD Modeling of GO-Kart Vehicle



(a) Equivalent Elastic Strain (b) Directional Deformation



(c) Maximum Shear stress



(d) Equivalent (Von-Mises) Stress

Figure 3. ANSYS results for the analysis of shaft

4. Conclusion

The power transmission system in a go-kart engine plays a crucial role in determining performance, efficiency, and reliability. Proper selection and design of transmission components—such as the clutch, sprockets, chain, and gearbox—significantly impact speed, acceleration, and overall drivability. A well-optimized system ensures efficient power delivery from the engine to the wheels, minimizing energy losses and enhancing vehicle dynamics. Factors such as gear ratios, torque transfer efficiency, and material durability must be carefully considered during design and implementation.

Different types of transmission systems, including direct drive, centrifugal clutch, and CVT, offer distinct advantages and should be selected based on application needs. Regular maintenance and precise calibration further enhance longevity and performance. Future advancements in lightweight materials and electronic control mechanisms may lead to improved efficiency and adaptability in go-kart transmission systems. Continued research and innovation will help refine power transmission technologies for better racing and recreational experiences.

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