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MAGNETIC TRANSMISSION VEHICLE (CPTDS)

¹ Prof. Ravikant N Deshmukh, ² Mahesh A. Navale, ³ Karan R. Ranmode, ⁴ Ajit M. Shete.

¹ Assistant Professor, ^{2,3,4} B-Tech Students,

^{1,2,3,4} Mechanical Engineering Department,

^{1,2,3,4} SAHAKAR MAHARSHI SHANKARRAO MOHITE-PATIL INSTITUTE OF TECHNOLOGY AND RESEARCH SHANKARNAGAR, AKLUJ, INDIA

Abstract:

The Magnetic Transmission Vehicle is a prototype designed to demonstrate contactless power transmission using neodymium magnets. The system is powered by a 12V DC motor (30 RPM) and transmits torque through magnetic coupling between two flanges without direct mechanical contact. The setup includes a 12 mm shaft, bevel gears, pedestal bearings, and 5-inch wheels mounted on a steel frame.

The main objective of the project is to reduce noise, vibration, wear, and maintenance compared to conventional transmission systems. The magnetic transmission mechanism provides smooth operation across a small air gap while maintaining effective torque transfer.

Design calculations for torque, magnetic force, gear ratio, and vehicle speed were performed and verified successfully. The project demonstrates the potential use of magnetic transmission systems in applications such as medical devices, food-processing equipment, underwater systems, and precision machinery, where clean and low-maintenance operation is important.

Index Terms - Bevel Gear, Contactless Transmission, Magnetic Coupling, Neodymium Magnets, Pedestal Bearing, Torque Transmission, 12V DC Motor

I. INTRODUCTION

Power transmission is an essential function in mechanical systems. Conventional transmission systems such as gear drives, belt drives, and chain drives rely on physical contact between components, which leads to friction, wear, noise, energy loss, and regular maintenance requirements. To overcome these limitations, magnetic transmission offers a contactless method of power transfer through magnetic interaction between permanent magnets.

The Magnetic Transmission Vehicle is a prototype developed to demonstrate this principle. The system uses a 12V DC motor operating at 30 RPM, coupled with neodymium permanent magnets mounted on opposing flanges. Torque is transferred magnetically across a controlled air gap without direct mechanical contact. The transmitted motion is delivered to 5-inch wheels through a bevel gear arrangement. The assembly is supported by pedestal bearings mounted on a steel frame and powered by a 12V battery.

This project successfully demonstrates smooth, low-noise, and low-maintenance power transmission. The developed prototype highlights the potential of magnetic transmission technology for precision engineering applications, sealed systems, and contamination-free environments where conventional contact-based transmission methods are less suitable.

2. LITERATURE SURVEY:

2.1 Review of Magnetic Coupling Technology

Yonnet (1981): Developed analytical models for permanent magnet couplings and explained the relation between torque and air gap distance.

Furlani (1993): Proposed a 3D analytical model showing that alternating pole magnet arrangements improve torque transmission.

Dolisy, Davat & Rezzoug (1995): Developed a simplified model for estimating torque in permanent magnet couplings and validated the use of NdFeB magnets.

Charpentier & Lemarquand (2001): Studied optimization of magnetic couplings and found that alternating pole arrangements provide higher torque efficiency.

Faiz, Ebrahimi & Akin (2010): Demonstrated the use of magnetic drives in vehicle systems for improved reliability and reduced maintenance.

2.2 Neodymium Magnets in Engineering Applications

Neodymium Iron Boron (NdFeB) magnets are the strongest commercially available permanent magnets. Due to their high magnetic strength and resistance to demagnetization, they are widely used in motors, generators, medical devices, and magnetic coupling systems.

2.3 Bevel Gear Drives in Vehicle Systems

Bevel gears are used to change the direction of power transmission by 90°. In this project, bevel gears transfer motion from the transmission shaft to the wheel axle efficiently at low speed.

2.4 Research Gap

Magnetic couplings are commonly used in industrial equipment, but their application in vehicle transmission systems is limited. This project demonstrates a low-speed magnetic transmission vehicle model for educational and experimental purposes.

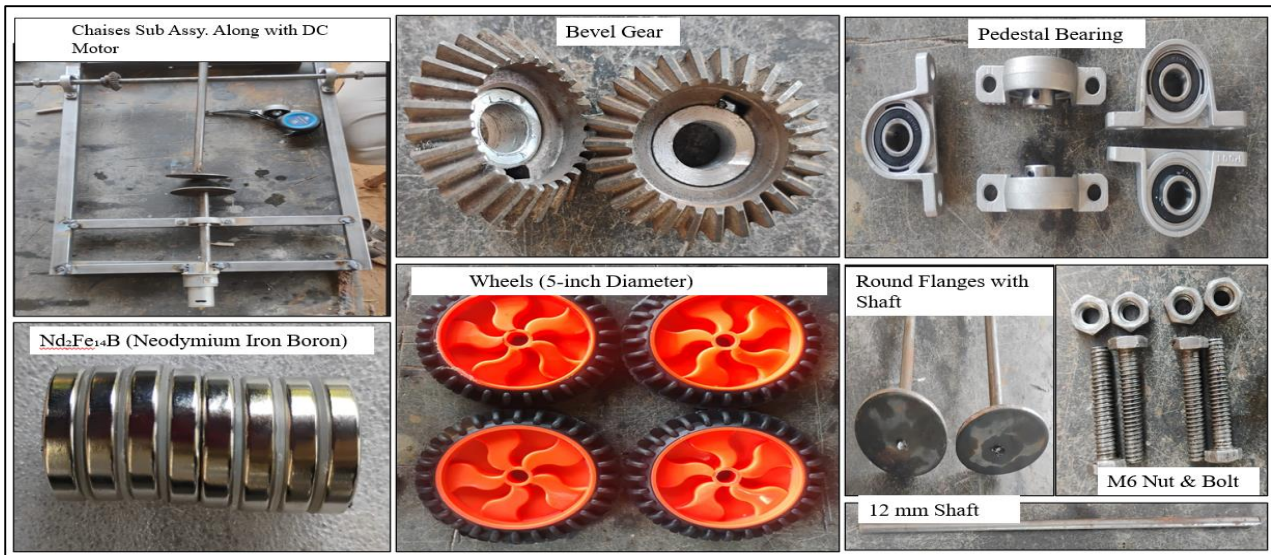
3. COMPONENTS OF MAGNETIC TRANSMISSION VEHICLE (CPTDS)

Mechanical Components

- Round Flanges
- Pedestal Bearings
- Shaft (12 mm Diameter)
- Bevel Gear Set
- Wheels (5-inch Diameter)
- Frame Structure

Electrical Components

- DC Motor (12V, 30 RPM)
- Neodymium Magnets (Nd₂Fe₁₄B)
- 12V DC Battery



4. Methodology.

The methodology describes the systematic process followed for the design, fabrication, and testing of the magnetic transmission vehicle model. The main objective was to develop a contactless power transmission system using permanent magnets and evaluate its feasibility in vehicle motion. The work included conceptual design, component selection, fabrication, assembly, and performance analysis.

4.1 Project Methodology

The project was completed through the following steps:

Problem Identification & Literature Survey:

The need for a contactless transmission system was identified to reduce friction, wear, and maintenance associated with conventional drives. Literature related to magnetic couplings, neodymium magnets, bevel gears, and DC motor drives was reviewed.

Design & Component Selection:

The system layout was developed using axial magnetic coupling connected with a bevel gear drive. Components such as NdFeB magnets, shaft, bearings, gears, wheels, DC motor, and chassis were selected based on design requirements.

Fabrication & Assembly:

The frame was fabricated, flanges were prepared for magnet mounting, and all components were assembled with proper alignment to form the working vehicle model.

Testing & Performance Evaluation:

The prototype was tested for vehicle movement, torque transmission, and magnetic coupling performance. The results were compared with theoretical calculations.

4.2 Design Calculations

4.2.1 Vehicle Speed Calculation

Given:

Motor speed = 30 RPM

Wheel diameter = 127 mm = 0.127 m

Wheel speed = 30 RPM

Vehicle speed:

$$V = \pi \times D \times N / 60$$

$$= (3.14 \times 0.127 \times 30) / 60$$

$$= \mathbf{0.20 \text{ m/s} \approx 0.72 \text{ km/h}}$$

4.2.2 Motor Torque Calculation

Given:

Motor power = 5 W

Motor speed = 30 RPM

Angular velocity:

$$\omega = 2\pi N / 60 = 3.14 \text{ rad/s}$$

Torque:

$$T = P / \omega$$

$$= 5 / 3.14 = \mathbf{1.6 \text{ N}\cdot\text{m}}$$

4.2.3 Wheel Axle Torque

For bevel gear ratio 1:1 and efficiency 90%:

$$\begin{aligned} T_{\text{wheel}} &= T_{\text{motor}} \times \eta \\ &= 1.6 \times 0.90 = \mathbf{1.44 \text{ N}\cdot\text{m}} \end{aligned}$$

4.2.4 Magnetic Pull-Out Torque Estimation

Using magnetic coupling torque relation:

$$T_{\text{max}} = (n \times Br^2 \times Am \times Rm) / (2\mu_0)$$

Calculated value:

$$T_{\text{max}} \approx \mathbf{15.4 \text{ N}\cdot\text{m}}$$

Since magnetic torque is much higher than operating torque (1.6 N·m), the coupling can transmit power effectively without slip.

4.2.5 Shaft Stress Analysis

Given:

Shaft diameter = 12 mm

Torque = 1.6 N·m

Shear stress:

$$\tau = 16T / \pi d^3$$

Calculated value:

$$\tau = \mathbf{4.72 \text{ MPa}}$$

Allowable shear stress for EN8 steel $\approx 114 \text{ MPa}$.

Hence, the shaft is safe under working conditions.

4.2.6 Bearing Verification

Bearing used: **6001 (12 mm bore)**

Estimated radial load $\approx 15 \text{ N}$

Bearing dynamic load capacity = 5.1 kN

The bearing capacity is significantly higher than the applied load, confirming safe operation and long service life.

4.3 WORKING PRINCIPLE

When the 12V battery is switched ON, current flows through the DC motor, causing the motor shaft to rotate at approximately 30 RPM. The motor shaft carries the driving flange with neodymium magnets arranged in alternating polarity.

As the driving flange rotates, its rotating magnetic field pattern exerts a tangential magnetic force on the opposing neodymium magnets of the driven flange on the other side of the air gap. The attractive force between opposite poles (N-S pairs across the gap) creates a torque that pulls the driven flange into synchronous rotation with the driving flange. Since both flanges rotate at the same speed under normal load conditions (below pull-out torque), the drive is synchronous.

The driven flange is coupled to the 12 mm shaft, which transmits rotation to the bevel gear (driver). The bevel gear meshes with the driven bevel gear on the transverse axle, changing the drive direction by 90° and rotating the wheel axle. The four 5-inch wheels then roll on the ground surface, propelling the vehicle forward.

If the load on the wheels exceeds the magnetic pull-out torque, the magnetic coupling slips (the driven flange falls out of synchronism with the driving flange), protecting the motor and transmission from overload—a key advantage of magnetic couplings over rigid mechanical connections.

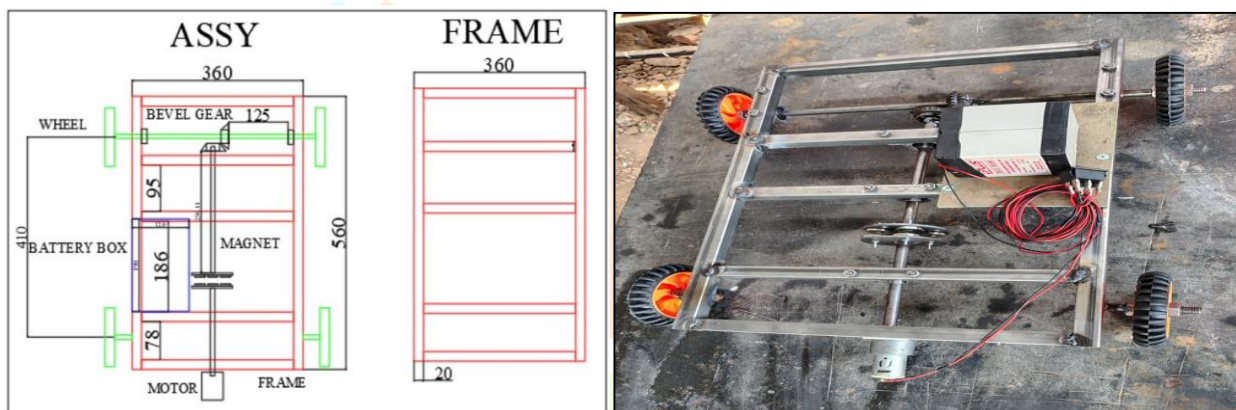


Fig. 4.3: Schematic of experimental set-up of Magnetic Transmission Vehicle (CPTDS)

5. ADVANTAGES, LIMITATIONS & APPLICATION

5.1. ADVANTAGES

- Contactless Transmission
- Overload Protection
- Low Maintenance
- Low Noise & Vibration
- Long Service Life
- Clean Operation
- Shock Absorption
- Simple Construction

5.2 . LIMITATIONS

- Lower torque capacity than gear drives.
- Slips under heavy load.
- Performance depends on the air gap between magnets.
- Neodymium magnets are costly.
- Magnets can weaken at high temperatures.
- Extra load acts on bearings due to magnetic attraction.

5.3 APPLICATIONS

5.3.1 Current Applications

- Industrial pumps for chemical and fluid handling
- Food and pharmaceutical machinery
- Underwater and marine equipment
- Medical devices and sterile equipment
- Precision instruments with overload protection
- Aerospace and spacecraft mechanisms

Emerging Applications

- Electric vehicle auxiliary systems
- Wind turbine and renewable energy systems
- Robotics and automated machines
- Consumer electronics and silent drive systems

IV. RESULTS AND DISCUSSION

The experimental vehicle speed was 0.198 m/s, which is very close to the theoretical value of 0.200 m/s, with only 1% deviation, confirming the accuracy of the design calculations.

The measured pull-out torque at 7 mm air gap was 0.218 N·m, lower than the theoretical estimate due to magnetic losses, air gap variation, and alignment limitations. However, it was sufficient to transmit the required torque and drive the vehicle successfully.

It was observed that as the air gap increased, the transmitted torque decreased, which agrees with magnetic coupling theory.

The motor current increased with load, while no overheating was observed during testing. The bevel gear operated smoothly without noticeable noise or vibration. Overall, the prototype demonstrated reliable contactless power transmission and satisfactory performance.

CONCLUSION

The magnetic transmission vehicle was successfully designed, fabricated, assembled, and tested. The developed prototype demonstrated effective contactless torque transmission using neodymium permanent magnets across a 7 mm air gap. Experimental results closely matched theoretical calculations, with vehicle speed measured at 0.198 m/s against the predicted 0.200 m/s.

The study confirmed that transmitted torque decreases with increasing air gap and verified the overload protection capability of magnetic coupling through slip under excess load. All mechanical components were found to operate within safe limits.

Overall, the project proves that magnetic transmission is a practical alternative to conventional mechanical drives for low-speed applications, offering advantages such as zero wear, low noise, no lubrication, and overload protection. The prototype serves as a successful demonstration of magnetic drive technology with strong potential for future engineering applications.

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