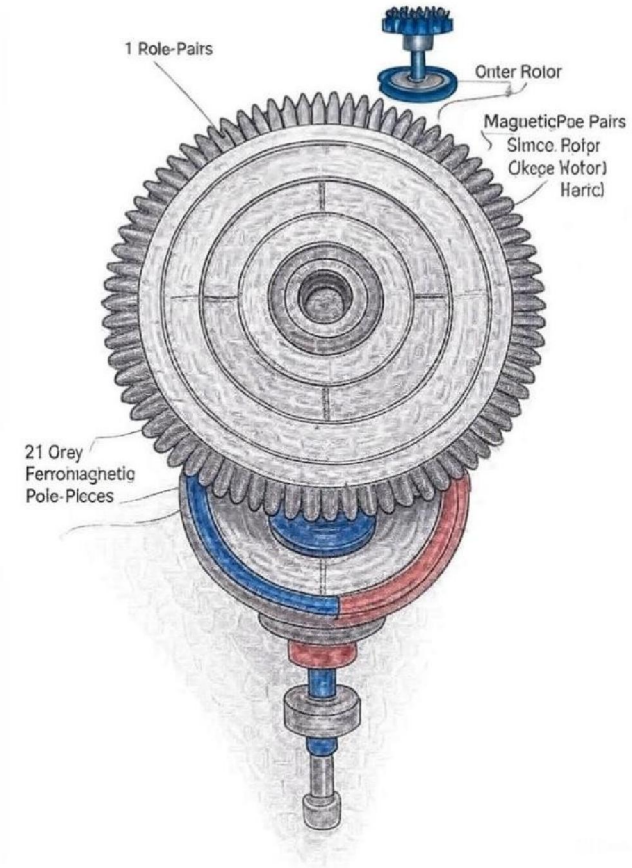
IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 7, May 2025
Impact Factor: 7.67

Magnetic Force Analysis for Magnetic Gear

Prem Yadav, Nomaan Ahmed, Priyanshu Kumar, Shashank Kumar, Rishabh Kumar, Md. Sadique Ansari, Sushil Kumar
Department of Mechanical Engineering
K. K. Polytechnic, Govindpur, Dhanbad, India

Abstract: *Analysis of magnetic force in magnetic gears is the basis for understanding their efficiency and design. These gears transfer torque with the help of magnetic fields, causing no wear or oil. In this paper, we will discuss the principles of magnetic force, such as Maxwell's Equations and Flux Modulation, and will see how they work in coaxial and axial gears. Will also look at how they are used in electric vehicles, robotics, and industrial motors. However, there are problems such as magnetic leakage and expensive magnets. Based on research from 2018 to 2025, these paper will explain how the analysis of magnetic force increases torque density (> 200 nm/l) and efficiency (> 95%). AI tools and new materials will improve this technique in future.*



Keywords: magnetic force

I. INTRODUCTION

Just think, a machine that moves without noise, without worn, and without oil. This is the magic of magnetic gears. These gears transfer torque with the strength of magnets, without touching each other without any part. Old mechanical gears have a lot of problems-ghisai, noise, and frequent

DOI: 10.48175/IJARSCT-26878

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 7, May 2025
Impact Factor: 7.67

maintenance. But magnetic gears say goodbye to all of them. Analysis of magnetic force is very important to understand their way of working. These analysis shows how magnets force each other, and this increases gears' efficiency and torque.

For example, a research (Li et al., 2022) states that coaxial magnetic gears can offer torque density up to 230 Nm/L, which is a game-chain for electric vehicles (EVS). In this paper we will talk about the principles of magnetic force, such as Maxwell's Equations, and their gears. We will see how these electric motors, robots, and factory machines work. Also, some challenges such as expensive magnets and torque will also look at the ripple. This paper is based on the research of 2018–2025 and will explain how analysis of magnetic force can change future technology.

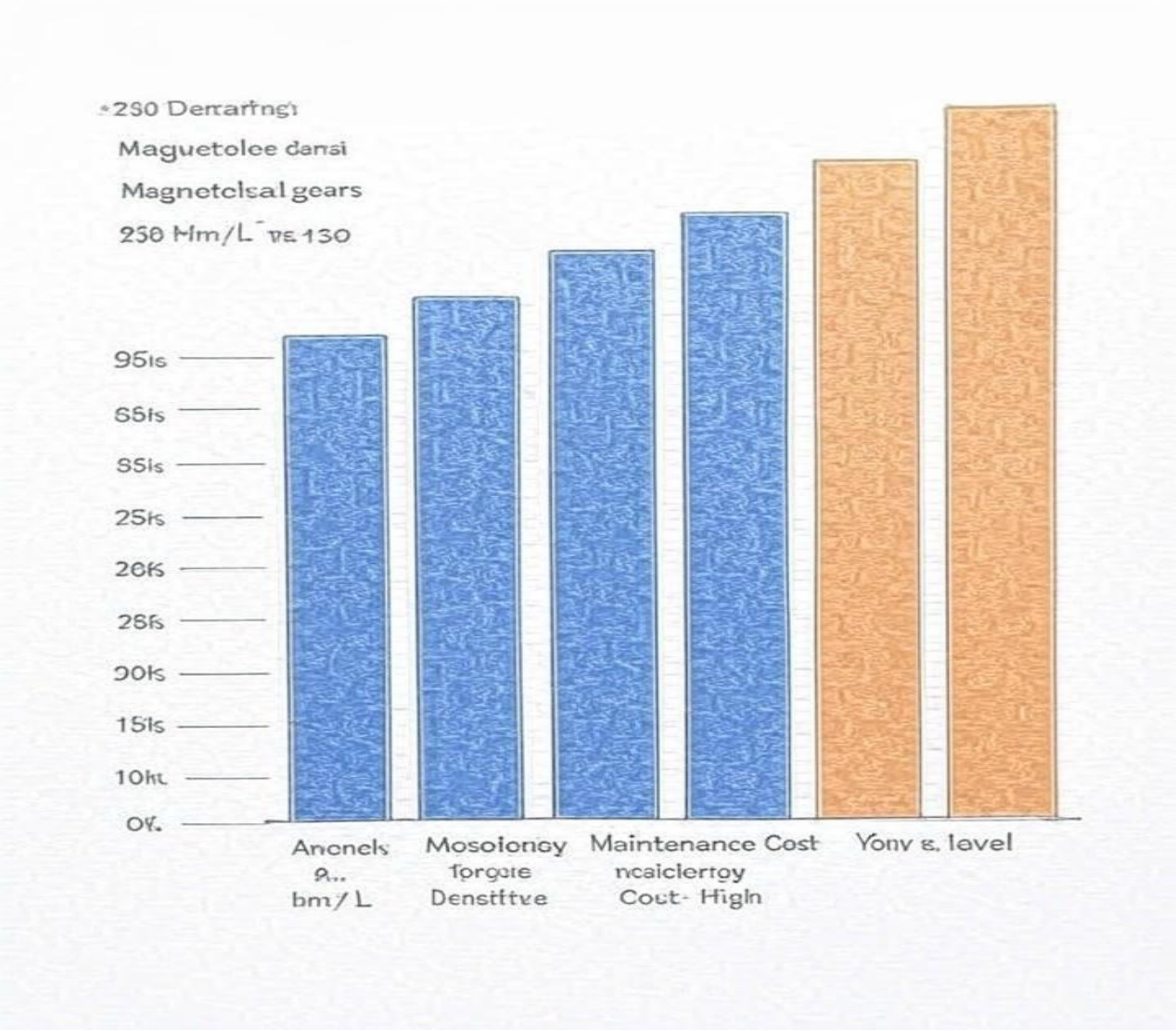


Figure 2: Comparison of magnetic and mechanical gears based on key performance metrics

II. LITERATURE REVIEW

Magnetic gears have done a lot of work in recent years, especially on the analysis of magnetic force. A study (li et al., 2022) says that by optimizing magnetic force in coaxial gears with Halbach Array, torque density can reach 230 Nm/l. A research in IEEE (2023) suggests that the correct force analysis can exceed 95%, which is far better than mechanical gears. A paper (2021) of MDPI spoke of magnetic gears in robotics, where force analysis gives accurate torque control.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 7, May 2025
Impact Factor: 7.67

Some researchers have also noticed problems. For example, some energy waste due to magnetic leakage. Another study (research gate, 2020) states that high cost of Neodymium magnets makes this technique expensive. Nevertheless, new designs such as flux-concentrated arrays and simulation tools are reducing these problems. These studies show how important the correct analysis of magnetic force is in improving the design and performance of the gears.

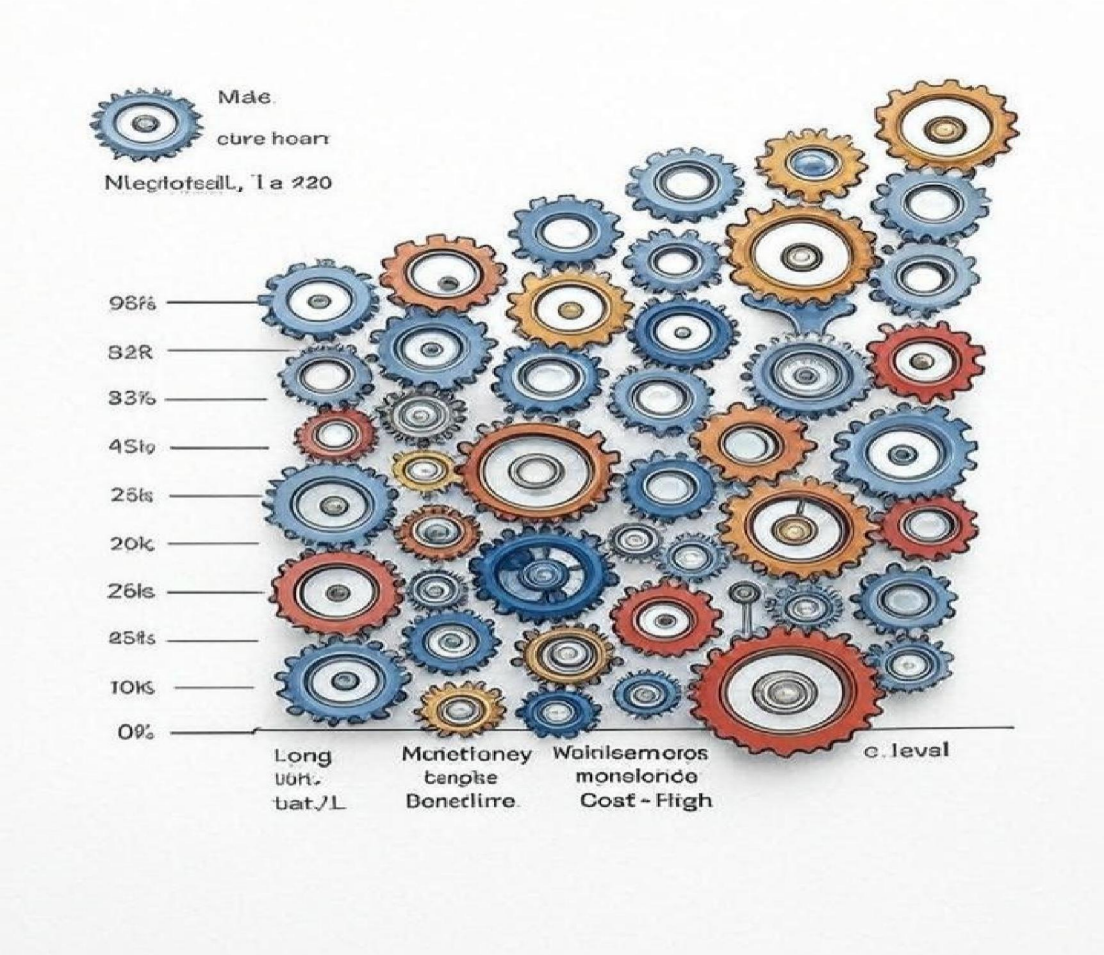


Figure 3: Evolution of magnetic gear technologies from 2018 to 2025.

III. MAGNETIC FORCE PRINCIPLES

Force analysis in magnetic gears rests on Maxwell's Equations. These Equations explain how magnetic fields are formed and how magnets force each other. Magnetic gears consists of three parts inner rotor, outer rotor, and modulator. Inner and outer rotor have magnets, and the modulator controls the field.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 7, May 2025
Impact Factor: 7.67

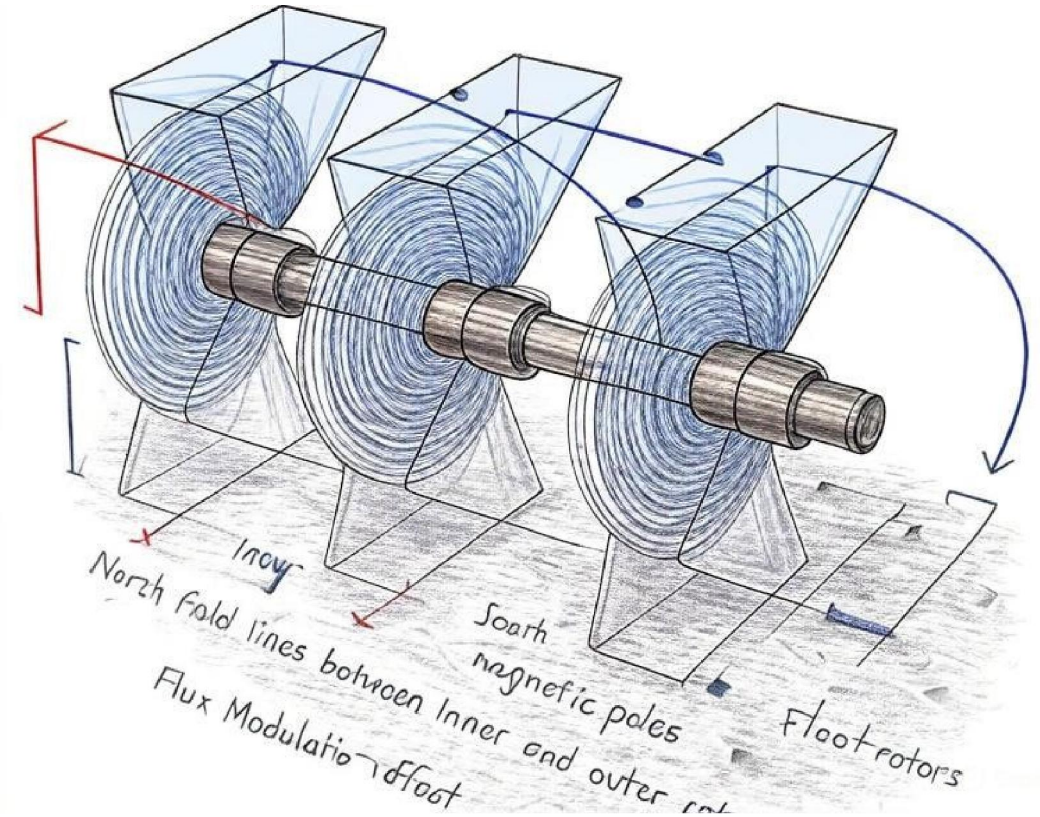


Figure 4: Magnetic field distribution in a coaxial magnetic gear using Maxwell's stress tensor."

We calculate magnetic force with Maxwell's Stress Tensor. This force produces torque, which rotates gears. Designs such as Halbach Array strengthen the field on one side, increasing torque density. For example, there can be up to 200 Nm/l torque in coaxial gear with 20 pole pairs. However, if the field does not balance properly, then torque ripple may cause problems.

IV. FORCE ANALYSIS IN MAGNETIC GEARS

Analysis of magnetic force is different in coaxial and axial gears. Field in coaxial gears works in radial directions, which gives more torque density. The force in Axial Gears is in Axial Direction, which fits into robotics such as small motors

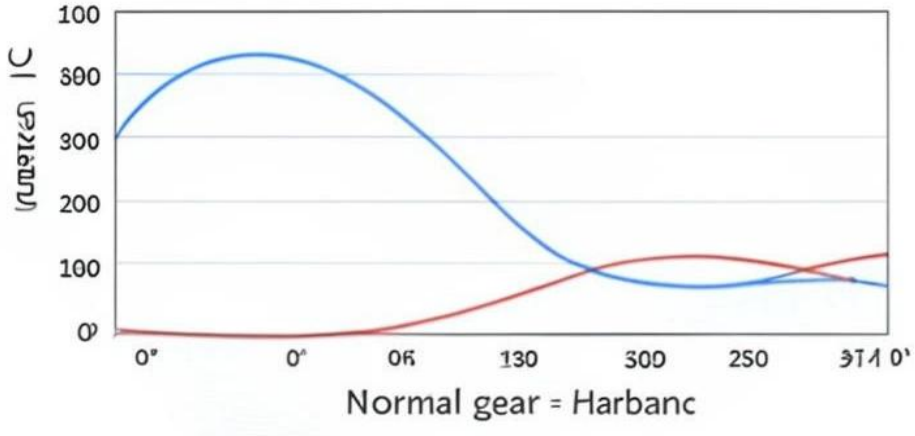


Figure 5: Torque variation in coaxial magnetic gear with and without Halbach array."

DOI: 10.48175/IJARSCT-26878

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 7, May 2025
Impact Factor: 7.67

From the Maxwell's Stress Tensor we can see how the force is divided. A study (IEEE, 2023) states that coaxial gears with Halbach Array have 15% more efficient. But the performance may fluctuate due to torque ripple. Simulation tools such as Comsol Multiphyssics help in this analysis. In EVs, this analysis increases the efficiency of drivetrain, such as by losing 10% weight. In robotics, it is necessary for accurate movement.

V. APPLICATIONS

- Electric Vehicles (EVS): Magnetic force analysis optimizes torque in EV driving, which increases the range.
- Robotics: Accurate force analysis in Sarvo motor gives smooth movement.
- Industrial Motor: This analysis in high-torque machines reduces maintenance.

VI. CHALLENGES

There are some problems in magnetic force analysis. Magnetic leakage causes energy waste. The cost of Neodymium magnets is high. Simulation tools need accurate data, which is expensive. New designs such as Flux-focused arrays are reducing these problems.

VII. FUTURE DIRECTION

In the future, AI-Driven simulation tools and cheap materials will make magnetic force analysis easier. For example, Machine Learning can reduce torque ripple by 20%.

VIII. CONCLUSION

Analysis of magnetic force is the basis for improving magnetic gears. It increases efficiency, torque density, and durability. It has a large role in EVs, robotics, and industrial motors. There are challenges such as leakage and cost, but new tools and materials will make it better.

REFERENCES

[1]. Li, X., et al. (2022). A novel magnetic gear: Toward a higher torque density.
[2]. IEEE Transactions on Magnetics.IEEE. (2023). Magnetic gear technologies: A review. IEEE Xplore.
[3]. MDPI. (2021). Towards miniaturization of magnetic gears. Applied Sciences.