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Design of magnetic gear

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Abstract—*This thesis deals with design and simulation of planetary magnetic gear. The goal of this thesis is to calculate output torque and magnetic field in FEMM software. We can use strong NdFeB rare earth magnets as magnetic gear as a serious alternative of classical mechanical gears. The new planetary magnetic gear will have more advantages than classical mechanical gear like high torque density relationship –high efficiency, no lubrication, contactless and are maintenance free.*

Index Terms—*FEMM, NdFeB, Iron core, inner magnetic rotor, outer magnetic rotor.*

I. INTRODUCTION

Magnetic gears offer plenty of potential benefits, including: physical isolation between the driver and the receiver, reduction of noise and vibration levels, protection against overload and contactless torque transmission. They do not require periodic inspections or maintenance checks, which significantly helps reduce operating costs. It consists of a low and high-speed rotor, on which permanent magnets are mounted. It should be noted that the rotor contact interface is reduced significantly, this causes heavy losses in the magnetic circuit. Therefore, the gear efficiency decreases, as well as, the transmitted torque density is not sufficient for practical application, and it does not exceed 10 kNm/m3 for this type of designs.

II. RELATED WORK

It can be short yet detailed enough, or if it's critical to take a strong defensive stance about previous work right away. Give citations of all the papers referred.

It is literature survey of the work closely related to your project done by the various authors.

III. MAIN BODY OF THE PAPER

Magnetic planetary gear consists of two permanent magnet rotors and one rotor with iron segments. The inner rotor is the high speed rotor and the outer rotor is the low speed rotor in this simulation. Flux paths in the iron parts are illustrated on Figure1). This illustration is fixed in an instant where there is no load applied to the rotors. The iron segments are mechanically fixed and magnetic flux paths in these segments have the freedom to rotate as input shaft rotates. The main flux path directions in iron segments are illustrated with bold arrow in Figure 1). The individual main flux path directions in the iron segments will rotate counter clockwise as the inner rotor is driven clockwise and the outer rotor is driven counter clockwise. The angular velocity of inner rotor is 5.5 times higher than the velocity at outer rotor. This gear simulation is therefore a reduction gear with a gearing relationship of 5.5 when the input shaft is connected to the inner rotor and the output shaft connected to the outer rotor.

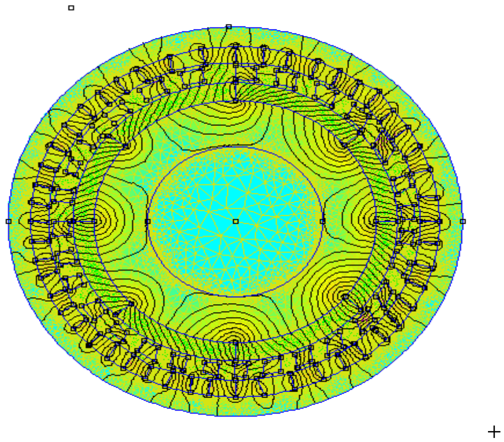


Figure 1): Magnetic flux direction in FEMM

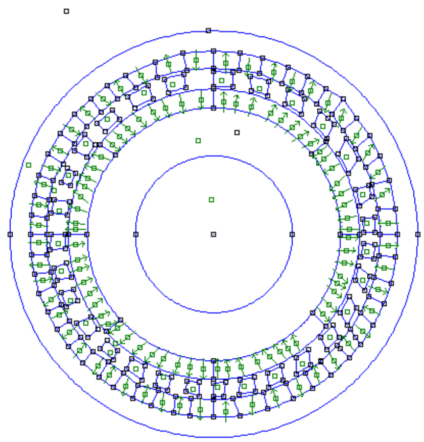


Figure 2): Design of magnetic gear

IV. PERFORMANCE AND EXPERIMENT

Magnetic planetary gear used in 3 configuration:
Inner rotor fixed 2) outer rotor fixed 3) iron core segment Fixed.
Iron core segment fixed:
Gearing relationship of planetary magnetic gear when Iron core segment is fixed is represented as:

$$G_{ra} = (n_s - p)/p$$

$$n_s = no\ of\ iron\ segment\ in\ iron\ core$$
$$p = no\ of\ pole\ pair\ on\ high\ speed\ rotor$$

If n_s = 28, p = 6
Then G_{ra} = 5.5

This combination result in a gearing relationship of G_{ra} = 5.5. This gearing relationship equation expresses the absolute value of gearing relationship and does not take account for rotation direction shift.

$$w_l = angular\ velocity\ of\ low\ speed\ rotor$$
$$w_h = angular\ velocity\ of\ high\ speed\ rotor$$
$$w_l = \frac{1}{-G_{ra}} w_h$$

If magnetic gear configuration is operating at constant angular Velocity then there is no losses in the system and total mechanical power of whole system must be equal to zero hence

$$p_l + p_i + p_o = 0$$
$$T_l . w_l + T_i . w_i + T_h w_h = 0$$
Iron core is fixed hence angular velocity of iron core=w_i =0
$$T_l . \frac{1}{-G_{ra}} w_h + 0 + T_h w_h =$$
$$T_l = G_{ra} . T_h$$

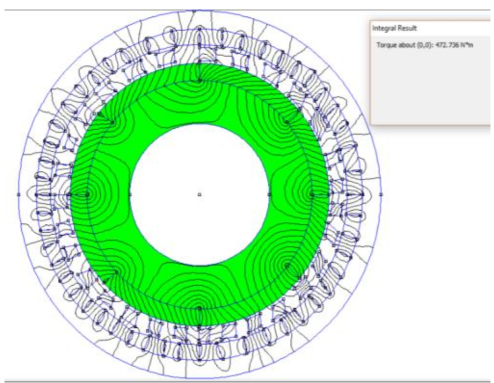
Torque and rpm is transfer through magnetic field lines inner rotor rotates with high speed as compared to outer rotor. Iron core segment is used between two rotors because iron core does not attract the magnetic lines but it offers low resistance path to magnetic force .To provide low resistance path from input to output shaft we put iron core in between two pole pairs. correlate this analogy with electric circuit If there is 3 parallel path for current to flow from one end to other end but current only flow from that path which offers low resistance path for it.

P = V.I electric power
P=T.W mechanical power
We can correlate V & T, I&W

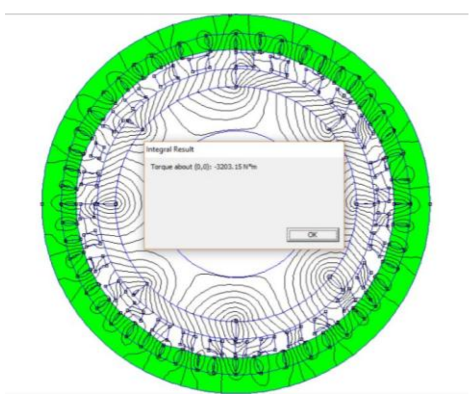
Same we can say for magnetic lines. They choose only low resistance path means they travel only from iron core i.e. from low resistance path.

V. RESULTS

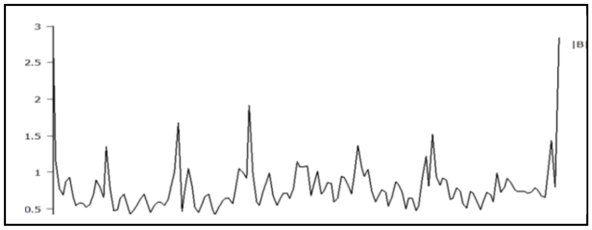
Iron core fixed segment configuration:
Inner rotor torque =472.36 N*m



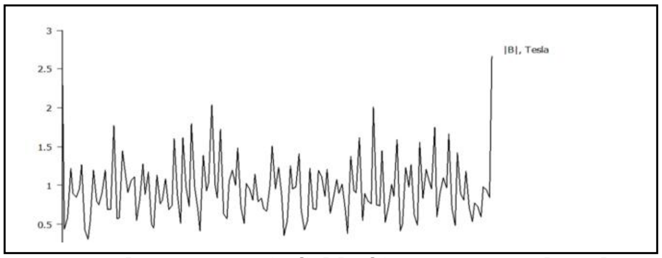
Outer rotor torque= (-3203.15) N*m



Operation of magnetic gears can be seen from above
Figure, Negative sign in outer rotor torque shows that outer rotor rotates in opposite direction of inner rotor hence this gear is reduction gear ratio example.



Graph 1): Magnetic field of outer rotor vs length



Graph 2): magnetic field of inner rotor vs length

VI. Result Analysis

Output torque at outer rotor is greater than inner rotor torque hence outer rotor rpm is less than inner rotor rpm hence it is reduction gear ratio configuration.

VII. Conclusion

Unique gear ratio can be derived using above configuration Magnetic gear can be placed within motor and wheel of vehicle. If winding is put over outer rotor then it can be act as controlling part of magnetic gear and we can obtain variable gear ratio through above configuration.

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