Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 04, April -2018

EXPERIMENTAL ANALYSIS AND OPTIMIZATION OF MAGNETIC GEAR

Varunkumar D Nagar[1], Mr. V P Singh [2] and Dr.Vina D Chauhan[3]

[1]*Research Scholar,* [2]*Assistant Professor,* [3]*Professor*
[1,2,3]*Mechanical Engineering Department, BVM Engineering College, V.V. Nagar, Anand, India*

Abstract —*Magnetic gears are one of the latest and most eccentric innovation in mechanical gear technology. Due to this reason a lot of consideration is shown in magnetic gear research in the recent period. This paper represents experimental analysis of magnetic gear. The analysis is done by collecting experimental data which is obtained by creating experimental set-up consisting of an external magnetic gear pair taken under consideration. The set-up is then utilized to perform number of experiments to generate data & analyse them further to get better understanding of the magnetic gear. Further this data is then used to study magnetic gear and its working parameters. At the same time learning issues regarding the magnetic gear and then improve the working of the magnetic gear by varying effective parameters to g optimize the performance of the experimented magnetic gear pair.*

Key word — *Magnetic gear, Magnetic force analysis, Rare-earth permanent magnet, Pole slip, Gear box*

I. INTRODUCTION

The first magnetic gear (MG) can be traced back to 1901 when Armstrong designed an electromagnetic spur gear. Early magnetic gear development mainly focused on spur type and worm type topologies. Essentially, a magnetic gear can be designed according to each available topology of its mechanical counterpart [3].

There is little success during the early development of MG. For most early MG topologies, their torque densities simply cannot compete with that of their mechanical counterparts. Studies on the magnetic coupling indicated that a higher torque transfer can only be realized when engaging a large number of magnet poles this implies that the MGs derived from a simple analogy of mechanical gears mostly lead to inferior designs [3].

Magnetic gear is an attractive alternative technology, which offers significant advantages over conventional mechanical gear such as bi-directional and contactless power transfer, oil-free operation, inherent overload protection, high torque density, potential for high efficiency and little or no maintenance [5].A magnetic gear resembles in part with the traditional mechanical gear. All cogs of each gear component of magnetic gears act as a magnet with periodic alternation of opposite magnetic poles on mating surfaces. A magnetic gear is composed of magnets of the type permanent, electromagnetic or otherwise magnetically induced fields. It consists of two or more elements that are usually rotating but can be linear or curve linear in nature. The working is fairly simple with the magnetic poles "pulling" & "pushing" the poles present in the other rotor. Each rotor is made up of permanent magnets with a radial field. The shaft which has to rotate slower and provide higher torque has a greater number of poles. The principal of operation of the magnetic gear is the effect attraction & repulsion of the magnetic field created by the magnet pole pair of the magnetic gear [9].

A magnetic gear is also a transmission device that can transform low torque and high rotational speed to a high torque low rotational speed. Magnetic gears can also achieve high efficiency, but a high torque capability can be hard to achieve unless carefully considerations are made regarding magnetic gear technology and design. That is why torque density is a major issue for the magnetic gear technology. Cost and amount of magnetic material is also rightly linked. Many of the known magnetic gear technologies are documented through patents, and only a few of these technologies are well documented in scientific papers [13].

Magnetic gear technology is still in its infancy and more practical validation is desired to firmly establish its readiness to the industrial world. The relatively complex structure and design process of MGs, together with the price of Permanent magnets (PMs), imply high manufacturing costs. The advantages that this technology could bring are significant and warrant further development. [11]

II. BACKGROUNG

The first magnetic gear can be traced back to 1901 when Armstrong designed an electromagnetic spur gear. The fundamental operating principle of this magnetic gear is very similar to that of conventional mechanical gears except that the force/torque transmission exerted by tooth meshing is replaced with the contactless magnetic interaction [11].Magnetic gear made of ferrite magnets & another hybrid gear with NdFeBon inner ring & ferrite magnet at outer ring, Air gap for both set-up is studied & optimized, At the time of the experiment and calculated performance were observed and these discrepancies are believed to be due to the material properties of the ferrite magnets & 416 steel magnetic properties not being as expected.

And as expected hybrid gear performed better [1].The unique advantages of the magnetic gear compared to mechanical gears are very beneficial especially in renewable energy applications, A magnetic gear is proposed to reduce the size of the propulsion motor and achieve similar torque amplification provided by a mechanical gearbox, without the maintenance and breakdown issues [2]An effort to increase torque density, have moved into the arena of rare-earth permanent magnets as well as High Temperature Superconducting coils. Design for a magnetic planetary gearbox (MPG) is exercised (with physical planet gear)The construction is then analysed on the basis of transmitted torque & pole slip limit & It is shown by experimenting that by increasing the no of planet gears transmission torque can also be increased. Also work to reduce cogging torque has been pursued [3].It can be said that with increasing the magnetic field area for example using more no. Of gear will result in higher torque transfer &by using stronger permanent magnet &/or hybridising them with ferrous magnet results in increase in efficiency [4].A cycloid magnetic gear could therefore be a possible choice for future applications where, for example, a motor or generator is integrated together with the cycloid-gear design & The proposed configurations might also be used as power-split devices for hybrid cars or wind turbines with a fixed-speed synchronous generator [5].A practical dual-stage implementation of the magnetic harmonic gear, which exhibits a gear ratio that is greater than the product of the ratios of the individual stages and a torque density of up to 75 kN m/m3, has been described [6].The performance of the magnetic gearbox is compared when utilizing ferrite and NdFeB and also a hybrid design, in which ferrite magnets are used in the inner rotor and NdFeB magnets are used in the outer rotor & Experimental results for ferrite, NdFeB, and hybridflux-focusing MGs(FFMGs) have been presented, Significant discrepancies between the calculated and measured torque values for the ferrite and hybrid FFMGs was observed, and this was due to the ferrite magnets not having the magnetic properties expected [7].Magnetic gear-boxes (MGBs) are preferably employed in high speed applications and compact harsh environments subjected to severe shock and vibration & The conventional planetary magnetic gearbox is equipped with a three-phase winding to provide additional magnetic levitation capabilities besides torque transmission, thus creating a bearingless MGB configuration so this was achieved by adding a three-phase winding in the space between the ferromagnetic pieces [9].Magnetic gearing may offer significant advantages such as reduced maintenance and improved reliability, inherent overload protection, and physical isolation between input and output shafts & despite these advantages, it has received relatively little attention, to date, probably due to the poor torque transmission capability of proposed magnetic gears but by using rare-earth magnets, a high torque density can be achieved, with efficiencies in excess of 97% for transmitted torque values higher than 75% of the pull-out torque[12].

III. EXPERIMENTAL ANALYSIS

For the purpose of performing the analysis an experimental setup is to be created which consist of a magnetic gear pair. This magnetic gear pair is an external type of magnetic gear & in comparison to the conventional mechanical it is set of a gear & pinion. The magnetic gear are made by arranging the magnets in alternate polarization over the gear wheel which is made of aluminium & the magnets used are NdFeB rare earth metal magnets of required grade are used. So an appropriate dimension of magnet from market availability is chosen to design & manufacture the magnetic gearsas a solid body is needed for fixing the permanent magnets over the circumference of the gear base so that it can act as magnetic gear but unlike the conventional mechanical gear ferrous material cannot be used. As the ferrous material have the material property of getting magnetized with time under the contact of the magnetic field it effects the working of the magnetic gear as the whole working is dependent on magnetic action.

Along with this a gear casing is required for the magnetic gears & to improve the performance of the magnets the body of casing is also made up of non-metallic material aluminium. As a power source a 3-phase motor is used. This all components are assembled on a base plate to create a setup for the experiment analysis.

Figure 1. NdFeB magnet

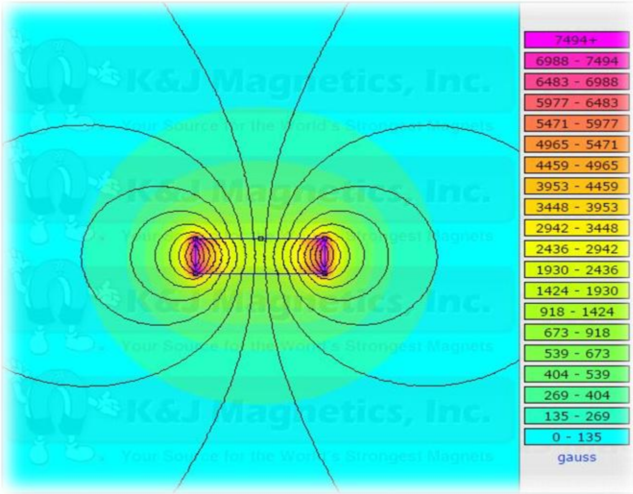

Figure2. Magnet force for magnet

The Figure 1 represents a typical NdFeB rare earth metal while the Figure 2 is indicating the magnetic force with different area zone with indication of colour and the resulted values are shown in terms of Gauss (G).

After the setup is created the experimental analysis is to be carried out. The setup is run at different parameter conditions like varying airgap and input rpm.

Table 1. Torque & pole slip at 1440rpm

SR.NO.	AIR GAP (mm)	TORQUE (Nm)		POLE SLIP (Nm)
		PINION	GEAR	
1	6	1.2334	<2	<5/5
2	4.5		2.3	9
3	3		3.07	15
4	1.5		3.09	18

Table 2.Torque & pole slip results at 700rpm

SR.NO.	AIR GAP (mm)	TORQUE (Nm)		POLE SLIP (Nm)
		PINION	GEAR	
1	8	1.2334	<2	<5
2	6		2.3	<5/5
3	4.5		3	11
4	3		3.5	15
5	1.5		3.8	18

Table 3.Torque & pole slip at constant airgap

SR.NO.	PINION (rpm)	TORQUE(Nm)		POLE SLIP (Nm)
		PINION	GEAR	
1	1440	1.2334	3.17	18
2	1220		3.1	18
3	1005		3.34	18
4	775		3.8	18
5	700		3.8	18
6	435		3.8	18

The Table 1 and 2 shows the result torque & pole slip for the experimented setup by varying the airgap. The Table 3 is showing the results for a condition where the airgap is kept constant but the rpm is changing.

There are different parameters which can affect the working of magnetic gear like Effective Magnetic Area (EMA); in our case it is the outer periphery which is to be considered as per our mg type. For the experimental gear & pinion it is 80% & 75% respectively. Similar value results in less cycle fluctuation. Higher the EMA area % the less it will effect at the same time high rpm neglects its effect but EMA % should be acceptable. Also the magnetic field contact period which is the amount of the time period for which the no of magnets are coming in contact it varies with rpm, size, dimension, etc. With every respective change. Due to this for each change in value there is possibility of change in fluctuation of velocity in a revolution. This can effect at the starting considerably & also for torque transmission. Fluctuation/Ripple in rpm & torque: if given sudden high speed input. Effect of air gap (infinite variation under the sliding range)

The optimization for the magnetic gear is done by increasing the thickness of magnets, increasing the effective magnetic area, controlling demagnetization, reducing eddy field generated & also the temperature can be maintained for the optimum conditions.

IV. RESULTS AND DISCUSSION

From the experiment several facts were observed.According to theoretical value for the air gap of 1.5mm at 1440rpm the rpm at output should be around 576rpm.From experiment we verified that the rpm is at 610rpm which is higher. Also the 610 is an average reading of the 4 trial readings & during the experiment the value is found to be fluctuating from 570 to 650.This can be considered as a huge fluctuation in output. This behaviour is can be said an example of as inertia running / leap toggle. Its presence should increase with weight as inertia increases.

The thickness of magnet in the direction of contact field directly effects the transmission power & also the change in number of pole pairs effects output.

While it is hard to maintain a 1mm airgap in created setup & at the same time at high rpm of 1440 at 8mm airgap there was zero transmission but at the same situation when rpm is lowered the power transmission is possible.
The highest poll slip value of 18Nm is found at 1.5mm airgap & is not effected by the change in rpm at input. But at the same condition the gear ratio is not maintained by the magnetic gear pair.

V. CONCLUSION

Unlike the initial expectation the gear pair didn't showed much of rippling as the experiment value of rpm change was negligible (rpm stayed constant most of the time) except the sudden variation at the starting.

The Magnetic Gears were design with a specific gear ratio & the experiment data value resulted in a gear ratio value which is very near to the design value. Sudden/abrupt change in rpm produces ripple, pole slip, and vibration. At slow rpm the start is not abrupt & with consistent torque but the result obtained is according to the current Magnetic Gear design & the result may change.

At high rpm no running condition occurs at 8 mm air gap due to sudden increase in rpm & very low Field contact period.
Highest torque & pole slip occurs at 1.5 mm air gap which is low compared to the software data & this shows that the MGs working are not as simple it seems as many other parameters also effect it. As air gap increases the pole slipping & torque transmission value decreases.

For the constant air gap of 1.5mm at different rpm the value of torque is found to be varying. At lower rpm the resulted torque is high in comparison withthe other air gaps.

As it can be seen from the results the magnetic gears have huge potential & require more attention at the practical behaviour the magnetic gears.

REFERENCES

[1] Nicolas W. Frank Hamid A. Toliyat, Gearing Ratios of a Magnetic Gear for Marine Application, Advanced Electric Machines and Power Electronics Laboratory Department of Electrical and Computer Engineering Texas A&M University, Electric Ship Technologies Symposium, 2009. ESTS 2009. IEEE

[2] Krishna K. Uppalapati, Walter Bomela, Jonathan Z. Bird, Matthew Calvin, Jason Wright, Construction of a Low Speed Flux Focusing Magnetic Gear; Laboratory for Electromagnetic Energy Conversion and Control Department of Electrical and Computer Engineering University of North Carolina at Charlotte, NC, USA, Energy Conversion Congress and Exposition (ECCE), 2013 IEEE

[3]Brönn, r-j wang and M J kamper, Development of a shutter type magnetic gear; University of the Witwatersrand, Johannesburg, Proceedings of the 19th Southern African Universities Power Engineering Conference SAUPEC 2010,

[4] Cheng-Chi Huang1, Mi-Ching Tsai1, David G. Dorrell2, and Bor-Jeng Lin3, Development of a Magnetic Planetary Gearbox, IEEE TRANSACTIONS ON MAGNETICS, VOL. 44, NO. 3, MARCH 2008

[5] Frank T. Jørgensen, Torben Ole Andersen, and Peter Omand Rasmussen, The Cycloid Permanent Magnetic Gear, IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 44, NO. 6, NOVEMBER/DECEMBER 2008

[6] Jan Rens, Kais Atallah, Stuart D. Calverley, and David Howe, A Novel Magnetic Harmonic Gear, IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 46, NO. 1, JANUARY/FEBRUARY 2010

[7] Walter B. Bomela,Krishna K. Uppalapati, Experimental Evaluation of Low-Speed Flux-Focusing Magnetic Gearboxes, IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 50, NO. 6, NOVEMBER/DECEMBER 2014

[8] Hassan Zaytoon and Ayman S. Abdel-KhalikShehab Ahmed Massoud, Cogging Torque Reduction of Axial Magnetic Gearbox Using Pole Pairing Technique; Qatar National Research Fund ©2015 IEEE 978-1-4799-7800-7/15

[9] A.S. Abdel-Khalik, S. Ahmed b, A. Massoud ,A bearingless coaxial magnetic gearbox; Department of Electrical Engineering, Faculty of Engineering, Alexandria University, Alexandria 21544, Egypt Department of Electrical and Computer Engineering, Texas A&M University at Qatar, 23874, Doha, Qatar Department of Electrical Engineering, Qatar University, Doha, Qatar Received 27 November 2013; revised 5 May 2014; accepted 1 June 2014

[10]Torben Ole Andersen, Frank T. Jørgensen, and Orla Nielsen, Development of a High-Performance Magnetic Gear; Peter Omand Rasmussen, INDUSTRY APPLICATIONS, VOL. 41, NO. 3, MAY/JUNE 2005

[11] Tlali, R-J. Wang, S. Gerber, Magnetic Gear Technologies: A Review P.M. RET innovation 2010

[12] Kais Atallah*, Stuart D. Calverley, David Howe, High-performance magnetic gears, Department of Electronic and Electrical Engineering, The University of Sheffield, Mappin Street, Sheffield S1 3JD, UK, Journal of Magnetism and Magnetic Materials 272–276 (2004)

[13] Jorgensen, Frank Thorleif , Design & Construction Of Permanent Magnetic Gear, Department Of Energy Technology, Aalborg University, 2010