DESIGN OPTIMIZATION AND EXPERIMENTAL ANALYSIS OF AXIAL FIELD MAGNETIC COUPLING.

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Abstract : The paper deals with the study of effect of Cogging torque and eddy current losses in Induction type magnetic Coupling which causes undesirable vibration and heat generation leading to decrease in torque transmission for which Maxwell torque equation in different sub- domain is used for an desired problem condition and further size optimization is done to obtain required solution.

IndexTerms **- Magnetic Coupling, Eddy current, Electro Magnetism.**

I. INTRODUCTION

A mechanical device which helps to connect two shafts at there ends to transmit the power is called Mechanical Coupling. For a efficient output it is important for a coupling to transmit maximum torque from driving to driven shaft. Normally shaft doesn't disconnect in normal operating condition, however there are some coupling which do disconnect or slip away beyond a particular torque limit is reached. To avoid this Magnetic Coupling are used where torque is transmitted without any mechanical contact. It has the ability to protect system against overload condition as well as transfer torque even in misalignment. Magnetic coupling are of two types synchronous and induction type. In Synchronous type magnetic coupling the two disc, each consists of sector shaped permanent magnet separated with small air gap while in Induction type magnetic coupling one disc is mounted with sector-shaped permanent magnet while the other disc is mounted with copper plate, separated by a small air-gap. The magnets are axially magnetized to obtain alternate north and south poles. Soft-iron yoke are used to close the flux and due to the magnetic induction the torque is transferred through an air-gap from one disc to other disc.

II. LITERATURE

Thierry Lubin and Abderrezak Rezzoug studied the magnetic field distribution in the permanent-magnet motors under load conditions. A magnetic vector potential expression is derived in Permanent magnetic region.[1]

Bastien Dolisy et al. propose an analytical method for modeling a permanent magnets axial field magnetic coupling.[2]

Romain Ravaud, et al. Presented a For the computation of the torque transmitted in synchronous coupling with radially polarized permanent magnet three dimensional analytical approach is used..[3]

Cetin and Ferhat Daldaban et al. analyzed the performances of the different rotor poles characteristics for the reduction of torque ripple, and flux density distribution by using finite element analysis in permanent magnetic machine.[4]

J.Torres and E. Hincapie, F.Gilart et al. studied distribution of the magnetic flux density was determined for the passive sources of magnetic field most used in magnetic stimulation of biological systems, toroidal dipole magnets and cylindrical dipole magnets[5]

M.I. Tsindlekht et al. states that the magnetic field distribution in a finite thin-walled Nb conducting cylinder in an axial magnetic field is analyzed. The magnetic field and current density exhibit strong force on the cylinder edges. As soon as the external magnetic field reaches threshold value, the flux jump is observed in the hollow cylinder. And same is experimentally observed in wide range. The field at which the jumps appear is temperature dependent. And it has been observed that with increase in wall thickness the singularity of the current density and magnetic field on the edges decreases.[6]

A.Radkovskaya et al. states that Magnetic metamaterials made of non-magnetic resonators meta-atoms are an essential part of meta-material world reacting to the ac magnetic field. Have described local permeability distribution in the vicinity of the resonant frequency. [7]

Thierry Lubin et al. presented a theoretical analysis of an axial magnetic coupling, leading to a simple expression of the electromagnetic torque.[8]

Thierry Lubin et al. Also presents an approach for quick calculation of steady-state and transient performances of an axial-field eddy current coupling.[9]

Jang-Young Choi et al. Based on analytical magnetic field calculations, they presents the torque analysis and measurements of air-gap considered in permanent magnet couplings. they have also obtained the total magnetic fields produced by using a magnetic vector potential and a 2-D analytical model with two polar coordinate system. further analytical torque solution is derived using obtained magnetic field solution.[10]

Noboru Niguchi et al. Described the torque and speed characteristics in a magnetic geared motor with permanent magnets at high speed rotor end. This motor have overload protection characteristics and the rotor slips under overload condition.[11]

R. Ravaud et al. Presented a comparison of cylindrical and plane air gap magnetic couplings in which the tile permanent magnet polarizations can be either radial or tangential or axial. Determined the expressions for the torque transmitted between the two rotors of coupling .[12]

S.Mohammadi and M Mirsalim presented design optimization of double sided radially fluxed permanent magnet eddy current coupling. By using Faraday and ampere law with conventional magnetic equivalent circuit technique they have developed an analytical model the obtained model is capable of easily dealing with complex geometries and material properties and the permanent magnet characteristics as well as the associated design constraints so that to obtain realistic designs result.[13]

Fakhreddine Habib et al. Have presented a finite element formulation of thermo mechanical problem observed in crack bodies. And also a new thermo mechanical crack propagation model of cracked body to ensure the safety due to generated thermal stress.And nature of crack produced due to mechanical and thermal factors and associated stress intensity factor were studied.[14]

Yunpeng Wei et al. Studied the temperatures and dynamic characteristics of wheel/rail at different creep ratios, and introduced a thermal mechanical coupling model of 3-D wheel/rail-foundation contact system and its experimental device .with the increase of creep ratios the temperature also increases, Because of the thermal effects, the accelerations of wheel/rail decreases gradually with the rise of creep ratios.[15]

Chun-Yu Hsiao et al. studied the existence and effects of cogging torque. Have used half magnet pole pair technique for evaluation of developed cogging torque.[16]

O.de la Barriere et al. Presented a 3-D analytical model of an axial flux permanent-magnet synchronous machine, based on formal resolution of Maxwell equations. The mathematical procedure used to compute the machine no-load flux. This method is 3-D, and then takes into account the radial edge effects of the machine, as well as the curvature effects by a resolution in cylindrical coordinates. results are verified using 3-D finite elements, and compared with simpler analytical models of axial flux machines.[17]

Hyeon-Jae Shin et al. Studied in Magnetic couplings torque is transmitted across a separation wall, axial permanent magnetic couplings (APMCs) are well suited for use in isolated systems such as vacuums or high-pressure vessels. They have designed and carried out analysis of APMCs based on 3D finite element analysis.[18]

L. Belguerras et al. An exact 2-dimensional analytical method for calculating the magnetic field distribution in a Flux Concentration Permanent Magnet Machines (FCPMM) with sector magnets is developed and validated. The ability of the model to determine the performances of rectangular magnets FCPMM is then analyzed.[19]

R.V. Rao and K.C. More : To obtain refined optimization results they have studied self-adaptive Jaya algorithm for optimal design of thermal devices. Four different optimization case studies of the selected thermal devices are presented [20]

Di Zheng et al. the eddy current loss and temperature developed at copper plate under various load is studied using three-dimensional magnetic field analytical model. Analytically they have obtained eddy current loss by calculating total magnetic flux produced, considering cylindrical coordinates of magnetic field model under multiple load.[21]

III. OBJECTIVE

1.To increase the life of the coupling, by eliminating direct contact.

2.To improve torque transmission from driver to driven shaft by studying the effect of Eddy current and thermal analysis ultimately improving the efficiency and life of the coupling.

IV. BRIEF DESCRIPTION OF THE PROJECT UNDERTAKEN

Magnetic coupling are distinct from mechanical coupling in various ways. Replacing Mechanical coupling by Magnetic Coupling is quite advantageous. Physical mechanical connection in Magnetic coupling is completely eliminated which further leads to elimination of wear and tear. Magnetic couplings also have a built in safety feature, in the event of an overload on the coupling, it will shift to the next position and keep going. Hence it allows transmission of torque through parallel and angular misalignment. Since the couplings use permanent magnets, no external power source is needed

V. METHODOLOGY:

The given topic will be analyzed experimentally as well as analytically. With reference to problem statement literature survey will be carried out. The FEA analysis will be conducted based on problem statement and further optimization will be done based on that FEA analysis results, and based on best obtained optimized and FEA result further fabrication will be done. For Experimental Analysis the following model of magnetic coupling will be fabricated considering permanent Magnets and Copper plate.

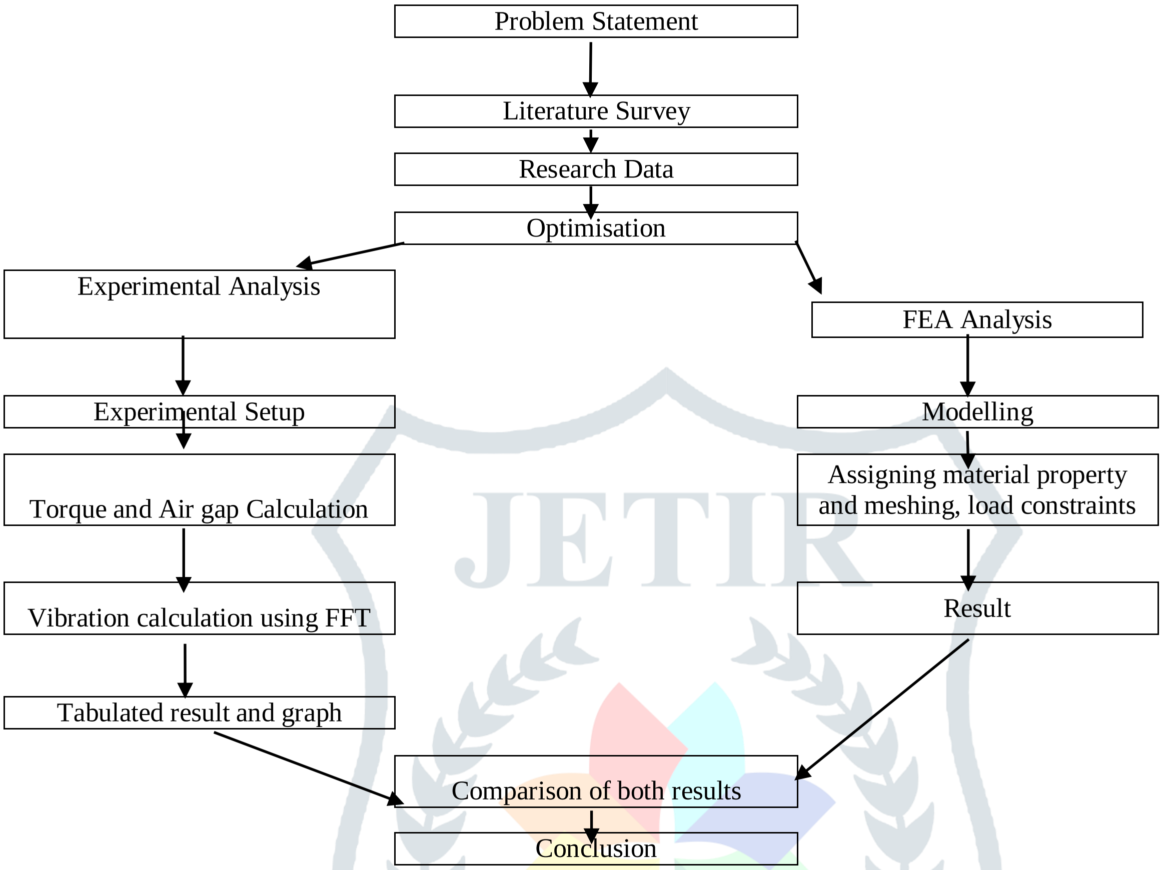

Fig1 Methodology Flow Chart

VI. MAGNETIC COUPLING

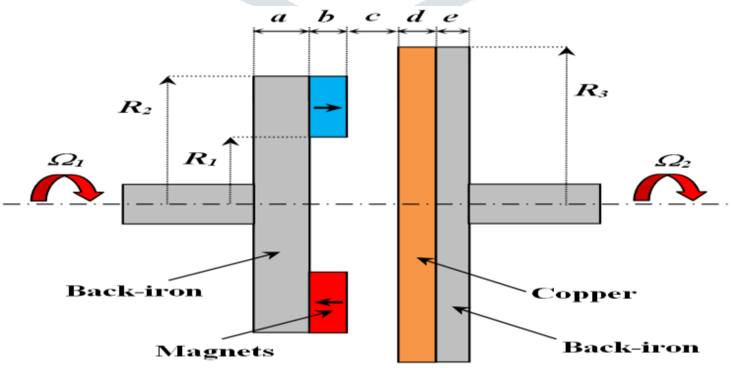

Fig. 2 Geometry of the axial magnetic coupling [8]

The permanent magnet coupling is for contact-free torque transmission through any non-ferrous wall, with the benefit of slipping when the maximum torque is exceeded, protecting mechanical components in the drive line from damage. They can transmit a torque from a primary driver to the driven counterpart without any mechanical contact.

Here the Working parameter to obtain Torque (T) of 50Nm would be:

Table 1: Initial Design variables to be considered:

Sr.no	Variables	Units	Values
1	Inner Radius of disc R1	Cm	9.10
2	Radius of copper disc R3	Cm	15
3	Magnet Thickness b	mm	4.33
4	Copper plate thickness d	mm	4.21
5	Pole arc to pitch ratio (α)	-	0.71
6	Number of poles (p)	-	10

Axial field magnetic couplings are well suited for use in isolated systems as it can transmit the torque through separation wall and hence can be used in vacuum or high pressure vessels. They present a maximum transmissible torque giving an intrinsic overload protection.

Nomenclature:
1.Permanent magnets: A permanent magnets is an object made from a material that is magnetized and creates its own magnetic field. Mounted on iron yoke on driving shaft
2.Copper disc: Copper disc is mounted on iron yoke on driven shaft
3.Iron yoke: Soft iron yokes are used to closed the flux and hold the magnets.
4.Air-gap:Air gap is the distance between two magnetic disk. It is denoted by e
5.Inner radius of disc (R_1): Distance from the centre of shaft to the inner side of magnets.
6.Outer radius of disc (R_2): Distance from the centre of shaft to the outer side of magnets.
7.Inner radius of Copper plate (R0): Distance from the centre of shaft to inner side of the copper plate.
8.Outer Radius of Copper plate (R3):Distance from the centre of shaft to the outer side of the copper plate.
9.Radial length of the magnet (L=R2-R1): It is the difference between the Outer radius and inner radius of magnet
10.Radial length of the copper (H=R3-R0): It is the difference between the outer radius and inner radius of copper plate.
11.Copper end-lengths to magnets length λ: It is the ratio of the difference between the radial length of copper and magnet, and radial length of copper.

VII. Conclusion

For transient performance of the eddy-current coupling they have considered steady state operation where as slip speed generated impacts both eddy current density and temperature distribution. Due to slip speed there is energy loss in the form of heat which further leads in reduction of electrical conductivity of copper which decreases the output torque. Also the output torque is also affected by torque ripples caused due to cogging torque which is generated due to energy variation between magnets on driving and driven disc which causes vibration and noise during machine operation leading to loss of energy and decrease in life.

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