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Design and Fabrication of Magnetic Dynamometer for Micro-power Measurement

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ABSTRACT

The torque measurement has been a challenge especially for low torques. The amplification of the torque with either pulleys or gears is one way out, but it introduces its own losses and affects the accuracy of the measurand. The magnetic force applied to the flywheel is one of the nascent options which is explored in this present work. The prime mover is low power impulse steam turbine, but a 50 W generic universal electrical motor is opted for prime mover. The speed is being reduced at 5 times with corresponding amplification in torque. The permanent magnets are applied at the circumference with predefined gap. The arrangement to vary this gap is provided on the setup. The variable gap is applied to produce magnetic force with variable magnitudes. This calibrated force in turn torque applied to steam turbine, where the torque generated is still lower. Hence, thus calibrated force i.e. torque shall enable to estimate the power developed, which is essentially useful for efficiency calculations. The results obtained through this present work are encouraging.

***Keywords*— Eddy Current, Magnetic Braking, Magnetic Field Intensity, Magneto Motive Force**

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I. INTRODUCTION

The measurement of torque has always been a challenge especially for the low torques. The torque has to be absorbed or transmitted while measurement. Out of these two alternatives, for low torque measurement, always absorption type is default option. In the present study, a low power universal electric motor is selected to be prime mover for source of low torque and the magnetic breaking is the opted way to measure the torque. The magnetic dynamometer would have been the best choice. This is limited by the size of the proposed dynamometer. Therefore magnets are applied at the circumference of the rotor, and the distance between the magnet and the rotating disc is manipulated to obtain the torque range. The non contact type dynamometers are studied by various authors:

I.Giouroudi [1] describes the practical application of development of highly sensitive torque measurement system. While designing the micro-motors the major parameters to be measured are torque and rotational speed. For this purpose the cable brake principle is implemented.. The measurements of speed were performed using a commercially available laser tachometer. Brin [2] explained the design of an eddy current brake dynamometer to determine the efficiency of wheel hub motor. Magnetic field produced is increased and the braking force is also increased when the current supply to the coils of the electromagnets is increases. The power ratting of the electric motor is known and the angular velocity is measured with tachometer then the torque that could be produced at minimum speed can be calculated.

Heinrich Ruser [3] describes principle of contactless torque measurement using the magneto-elastic effect of ferromagnetic materials. The shaft undergoes cyclic complete magnetization and re-magnetization to effectively erase its magnetic and thermal history. The assessment of the complete hysteresis curve by complete re-magnetization of the shaft material allows determining the torque-dependent parameters of the hysteresis. This enables the measurement of torque with High linearity and reproducibility for a large variety of materials. The generated eddy currents, the total eddy current power input to a rotating conductor is calculated. Then by using the correlation between the power and the torque, the braking torque is obtained by dividing the power by the angular velocity. Scheiber[4] studied the effects of a magnetic field on a moving conductor with low magnetic Reynolds number. Using the magnetic potential of Smythe [5] describes the model of eddy currents generated on a rotating disk by using Maxwell-Ampere law in order to relate the current flow on the surface of the conductor to the applied magnetic field. The induced magnetic field generated due to the eddy currents in terms of the external field is obtained by using Faraday's law and Gauss' law. An important conclusion is that the eddy currents cause demagnetizing fields on electromagnets that oppose the applied field and this result in a variation in the eddy current distribution.

II.DESIGNING THE DYNAMOMETER ASSEMBLY

In the following, the principle procedure of designing the dynamometer is outlined. The complete assembly is as shown in figure 2. This design produces a much stronger magnetic field .Disk type permanent magnets were implemented in this design, because a closer air gap could be used and controlled much more easily. This design holds the magnets such that the flywheel can rotate through the air gap between the magnets and keep the required air gap. This dynamometer design is much more stable and reliable. In this design the universal motor is coupled to the dynamometer with a open belt drive system.

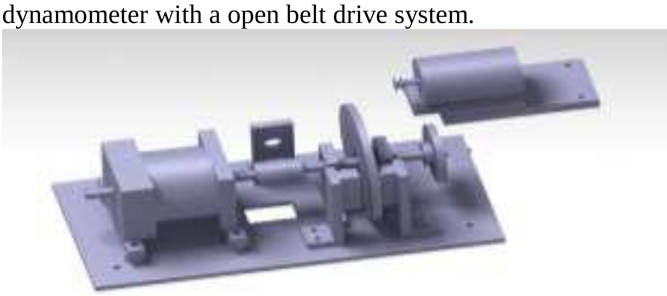

Fig. 1: 3D Model of Dynamometer Assembly

III.EXPERIMENTATION OF MAGNETIC DYNAMOMETER

The magnetic dynamometer is designed for a table top set up of steam power plant. The miniaturization of the power plant dictates the size of the turbine and mass flow rate of steam along with pressure and temperature. This compels the power of the steam turbine. Since turbine operates with less than 50 Watts, a specially designed dynamometer is required to estimate the power developed by the steam turbine and performance characteristics of the same. The turbine was designed to be operated at 24000 rpm at 50 W, thus producing a negligible torque. This actually limits the used of absorption type dynamometer as it blocks the shaft. Therefore a non contact type magnetic brake type dynamometer is being designed and implemented for the turbine.

IV.CONSTRUCTIONAL DETAILS

The figure 3 shows the constructional details of dynamometer based on magnetic brake principal. The prime aim is to estimate the power of turbine. This is achieved by measuring the speed of the rotor, while loading for known torque. Since the designing of magnetic dynamometer and design and manufacturing of steam turbine are simultaneously activities, it was resolved to design the dynamometer suitable for the low power motor. The motor is selected to be universal motor of 50 W. The motor runs at 9500 rpm at 0.05 Nm torque.

The universal motors are used where low torque at high speed is desired. The output of the universal motor is coupled to the flywheel shaft through the initial reduction of 1:5. This is implied by V-belt pulley arrangement. The dimensions of the driving and driven pulleys are 20 mm and 100 mm respectively. The thicknesses of both the pulleys are 10 mm. The centre distance between motor shaft and flywheel shaft is 140mm. The v-belt of length 350mm is used for connecting two shafts.

The permanent magnets are used to reduce the speed of the flywheel. The flywheel rotates between the gap of magnets. A coupling is used for connecting the flywheel shaft to the turbine shaft. The gaussmeter is used to measure the magnetic field density. The digital tachometer is used to measure the angular speed of the flywheel.

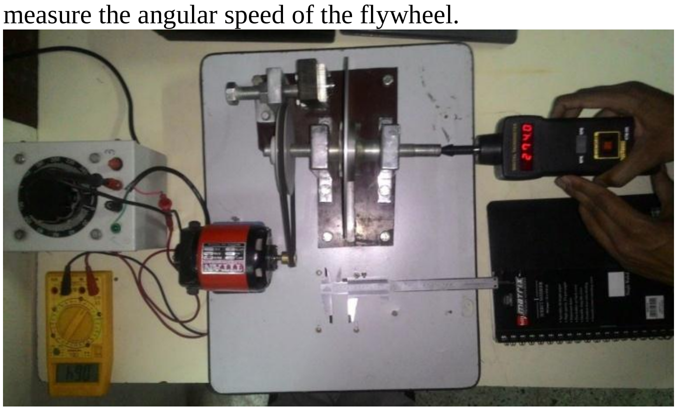

Fig. 2: Experimental Set up

V.OPERATIONAL FEATURES OF DYNAMOMETER

The magnetic dynamometer works on the principle of the magnetic braking system. The motor is operated at variable speed by varying the input voltage of the motor using dimmer-stat. The output of this motor is given to the flywheel shaft which rotates between the air gap of magnets. The varying torque is applied by changing the distance between flywheel and magnet. The speed of the flywheel is measured in presence of magnetic field.

The magnetic field intensity increases with reduction in distance and there is reduction in speed of flywheel. The speed of the flywheel is measured with the help of tachometer. The same torque is applied when the flywheel is connected with the help of universal coupling to the output shaft of turbine whose power is to be measured. As the value of applied torque and speed of flywheel are known the output power of turbine can be directly calculated.

VI.RESULT AND DISCUSSION

The experimentation is aimed to identify various parameters which influence the torque implied on the flywheel. It is illustrated earlier that the magnetic force is function of the air gap between magnet and the flywheel. Similarly the force implied on the flywheel times the radial distance of the magnets from the center amounts to the torque applied on the shaft. The voltage applied to the motor is varied from 80v to 230v. The air gap between the flywheel and the magnet is maintained as 5 mm to 15.The speed is recorded using digital tachometer. The readings are as follows.

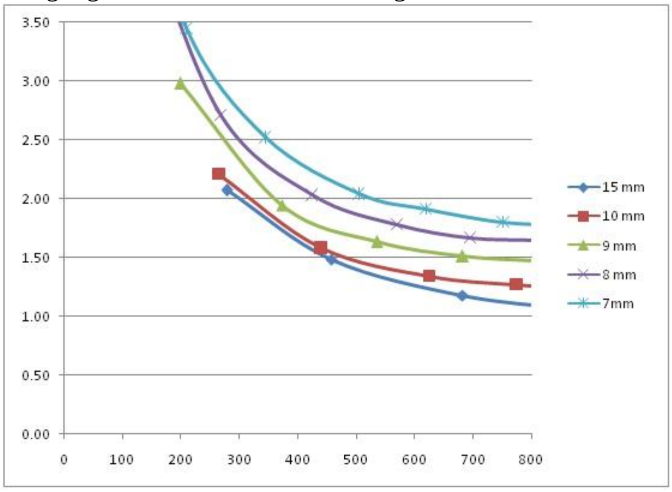

Fig.3 magnetic force as a function of air gap

A.EFFECT OF INCREASING WIDTH OF AIR-GAP

If the air gap between the magnet and disk is increased with time then, at low Speed, the change in air gap does not have much effect on the braking force But, at high speed, initially on increasing the air gap the braking force increases and after a particular point the braking force decreases At lower speeds since, the change in air-gap has negligible effect on the magnitude of magnetic field between the poles of the electromagnet. Thus, the magnitude of braking force obtained is relatively constant. As the magnets are moved at a distance which is greater than the thickness of the disc apart from each other the effective magnetic field decreases. This is because the effective magnetic field is an inversely proportional function to the distance between the poles. As the distance increases, the effective magnetic field decreases and since, the braking force is proportional to changes in magnetic field strength, the braking force also decreases.

B.EFFECT OF CHANGE IN MAGNETIC FIELD

The Magnetic field is increased from 0 to max. then it is observed that braking force increases as the magnitude of Magnetic Field increases. Since, the braking force increases, thus the brakes would work more over the disk to stop its rotation and reduce its speed efficiently and much faster than the conventional braking system. As explained by Lorentz Law, since the eddy currents induced also depend upon the magnetic field of the source producing it. As the magnetic field increases so will the eddy currents induced and hence, the increased magnitude of eddy currents would oppose the cause producing it. The interaction of the two magnetic fields of the source and that produced by induced eddy current would generate the braking torque in a value proportional to the change in magnetic field. Thus, increase in magnetic field causes increase in braking force.

VII.CONCLUSION

The air gap is increased with some increased distance from the flywheel. The variable AC voltage applied to motor. With these control variable, the torque developed i.e. the parameter to be controlled was mapped and the results are encouraging. The force ranges from 1N to 5N. Some of the important deductions are as under.

- The different gaps give different forces at the shaft of flywheel.
- The angular velocity of the electrical motor is seen to be reduced by 150 to 500 rpm for different magnitudes of magnetic force applied as discussed in the previously. But this is precisely compatible for the torque range for the proposed steam turbine.

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