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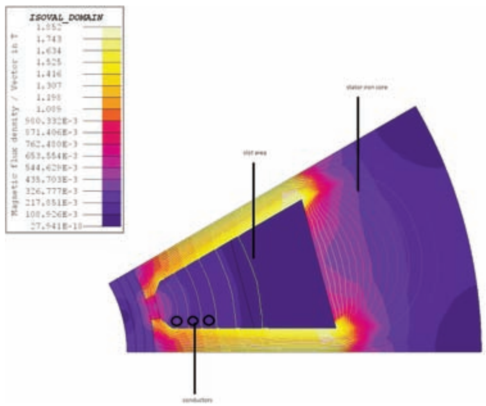

Flux density in a stator slot of the test machine

2:30

HD-06. Rotor Lamination Core Design Change to Less Harmonic Distortion in Hybrid Excitation Motor for Main Spindle Drive in Machine Tools. *S. Muthubabu*[1], T. Kosaka[1] and N. Matsui[1] *1. Computer Science and Engineering, Nagoya Institute of Technology, Nagoya, Aichi, Japan*

This paper presents rotor design analysis of the proposed permanent magnet hybrid excitation motor (HEM)[1] for high-speed main spindle drive in machine tools based on detailed analyses of experimental results obtained using prototype machine. The proposed HEM has been intentionally designed using 3D-finite-element analysis (FEA) for the target application. Although the basic working principle of HEM has been proven by the experimental results, the induced voltage distortion due to 5th harmonics has been a primary factor which has degraded the drive performances of test machine. After checking the differences between the designed drawing and the real one being taken into account of real manufacturing, design refinements are conducted to the tested HEM using 3D-FEA. And it is demonstrated that 3D-FEA analysis reconsidering the rotor design specifications as the main design parameters tends to have good improvement from the trial model. The no load experimental analysis[2] of test machine has concluded that the proposed machine has worked well according to its working principle. However, the measured characteristics have included some errors towards 3D-FEA calculations. The test model evinces about the presence of extensive harmonic distortion in both armature and excitation windings, which annihilates the performance of the machine and also deviates from target application. The motor design specifications are examined carefully using 3D-FEA analysis and a new rotor teeth design is developed to reduce the harmonic distortion significantly. The new shape of the rotor is shown in fig.1. All dimensions are in mm. The %5th harmonics is reduced to 6%. The initial trial manufacturing model experiences high distortion not only due to rotor design but also the manufacturing process[3] itself deteriorates the model performance. The magnetic laminations are stacked into magnetic cores by laser welding at the periphery. The thermal stress associated with welding can substantially influences the magnetizing behavior of the electrical steel by increasing the eddy current loss. The induced voltage waveform characteristics comparison is shown in fig.2. A new trial manufacturing will be made and experimentally validated.

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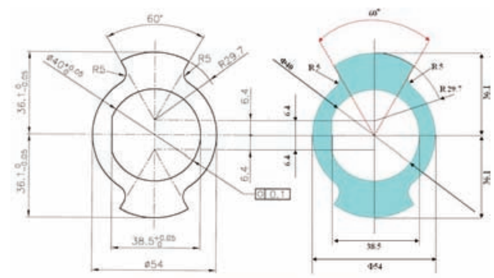

Fig. 1 Comparison of trail model and new rotor dimensions

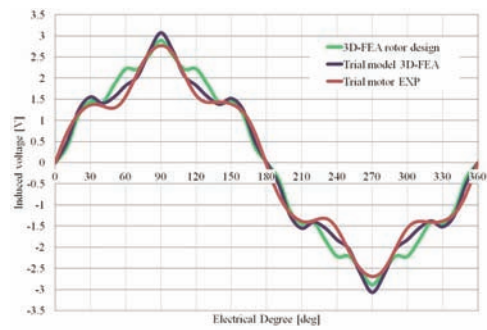

Fig. 2 Induced voltage waveforms comparison at 1200rpm of trial model and new rotor design

2:42

HD-07. Design and test of a thermomagnetic motor using a Gadolinium rotor. *V. Franzitta*[1], A. Viola[1] and T. Marco[2] *1. Dipartimento dell’Energia, Palermo University, Palermo, Italy; 2. Dipartimento di Ingegneria Elettrica, Palermo University, Palermo, Italy*

The purpose of this paper is to show that a Thermomagnetic (Curie) Motor [1-3], which can rotate continuously and has useful mechanical characteristics, is feasible. A thermomagnetic motor can directly converts thermal energy into kinetic energy. In this type of motor force is generated by a thermally induced permeability difference in two areas of the rotor, which can generate a force if the rotor is placed in a magnetic field. This force can be enhanced if the hot side temperature of the rotor is above the Curie’s temperature of the magnetic material and the cold side under this temperature Unfortunately, the traditional ferromagnetic materials have very high Curie’s temperature and therefore their ferromagnetic phase transition cannot be used. As a result Curie motors built by using traditional materials have very poor performances. Only one ferromagnetic material, Gadolinium, has a Curie temperature which allows to obtain an easily usable Curie temperature. As a result, in this paper we present the result of the use of Gadolinium as the ferromagnetic material of a thermomagnetic motor. Gadolinium powder was used in the rotor of the machine. The Curie’s temperature of Gadolinium powder is 293 K. In this paper we present a novel approach to the description and design of the Curie motor and we use the design obtained to build a prototype. The approach is based on a thermal-magnetic coupled dynamic model of the motor. The motor is modeled in terms of both its magnetic as well thermal properties (magnetic permeability and thermal conductivity) and the thermal processes are supposed to be influenced by the thermal conductivity, the convection and the advection. An analytical expression of the generated torque, which links this quantity to the magnetic, thermal and geometrical parameters of the generated torque is given. The expressions of speed and torque are derived and related to the thermal properties of the machine and used as optimization indexes in an optimization procedure. The analytical results are verified by a 3D FEM analysis. This process leads to the design of the stator and the rotor of the machine. The rotor has been built and an experimental verification of the performances is reported.

[1]Tesla N., US Patent number 396121, (1889). [2]Palmy C., "A thermomagnetic wheel", Europhysicsnews, vol.38, No 3, pp. 32-34,2007. [3]Murakami K., Nemoto M. "Some experiments and considerations on the behaviour of thermomagnetic motors", IEEE Trans. Magnetics Mag., vol. 8, pp.387-398, 1972.

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HD-08. A Flux Focusing Axial Magnetic Gear.

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A magnetic gear (MG) enables a contactless mechanism for speed amplification to be achieved. MGs do not require gear lubrication, they have inherent overload protection and they have the potential for high conversion efficiency. High torque density MGs comparable to mechanical gears have been reported in the literature [1]. A MG, as shown in Fig 1, consists of p1 pole-pair permanent magnets (PMs) on an inner ring rotating at ω1, a p3 pole-pair PM outer ring rotating at ω3 and a middle ring with n2 ferromagnetic steel poles that can rotate at ω2. The inner and outer rings that contain PMs interact with the middle steel poles to create space harmonics [2]. If the relationship between the steel poles is chosen to be p1=|p3 n2| then the rotors will interact via a common space harmonic component [2], and the angular rotational velocities for each ring is related by ω1=(p3/(p3-n2)ω3+(n2/(n2-p3)ω2 Current MG designs use large quantities of rare-earth magnet material and unfortunately the high cost of rare-earth material makes the MG uncompetitive with alternative technology. This paper investigates a novel axial flux focusing MG (AFFMG) using ferrite magnets. The AFFMG topology is shown in Fig 2. In this design ω3=0 and therefore the gear ratio is 4.25. The flux focusing is achieved by changing the area of the magnet relative to the area of the steel pole. The initial geometric parameters for the design shown in Fig 3 is given in Table 1. The flux focusing ratio is defined as the ratio between the magnet area, Am, facing the steel pole and steel pole area, Ag, facing the air gap. Since there are two magnets facing each steel pole the flux focusing ratio is defined as Cf=Bg/Bm=2Am/Ag The flux focusing ratio for both the inner and outer steel poles has been initially chosen to be 5.5 and 5.6 respectively. The geometric variables are shown in Table 1. Initial torque performance for the FFMG is shown in Fig 4. The full paper will investigate the performance of different parameters on the torque density characteristics. A comparisons with a traditional radial MG design will also be given.

[1] E. Gouda, S. Mezani, et al., "Comparative study between mechanical and magnetic planetary gears," IEEE Trans. Magn., vol. 47, pp. 439-450, 2011. [2] K. Atallah and D. Howe, "A novel high performance magnetic gear," IEEE Trans. on Mag., vol. 37, pp. 2844-2846, 2001.

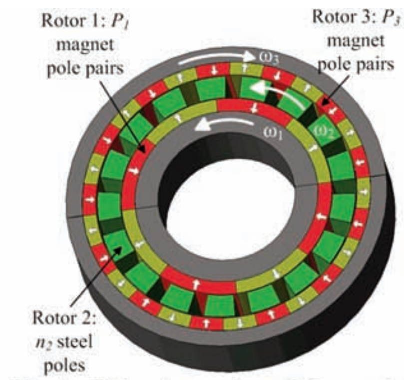

Fig. 1. MG using surface PMs. p_1=4 pole-pairs, n_2=17 steel poles and p_3=13 pole-pairs on outer rotor.

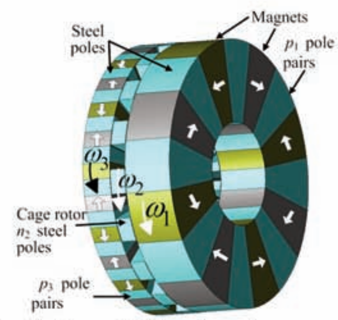

Fig. 2. An axial flux focusing magnetic gear with p_1=4, n_2=17 and p_3=13 pole pairs.

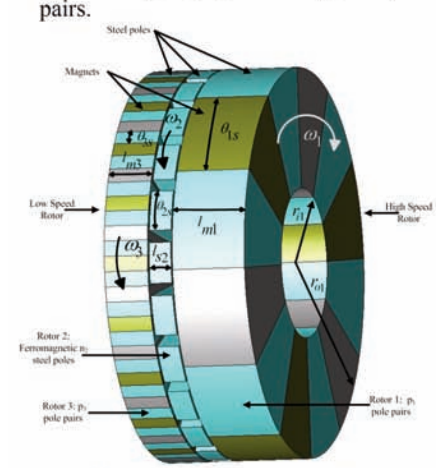

Fig. 3. MG geometric parameters