DD05

Effect of the Incomplete Magnetization of Permanent Magnet in the Characteristics of BLDC Motor

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Recent years, the BLDC motors are getting popular in area of precision control applications because of their advantages of low noise and vibration, long lifetime and easy controllability, Also, the Nd-magnets(neodymium permanent magnets) are adopted in the motors due to their high coercivities(Hc) and remnant magnetic flux densities(Br) as the BLDC spindle motors in HDDs or ODDs need several aspects like high precision, fast responsibility, high torque density, etc[1].

However, the high Hc of Nd-magnets also becomes the cause of the incomplete magnetization of the rotor magnets sometimes because full magnetization of Nd-magnet requires high peak-current value and large capacitance of a magnetizer. Moreover, the BLDC spindle motors used in HDDs and ODDs usually use outer-rotor type structures, which have one ring magnet instead of segmented magnets. The ring magnets have dead zones between poles inevitability where the incomplete magnetization areas are.

Conventionally, in the finite element analysis, these areas are neglected or approximated as having less Br values. But according to recent research, the incomplete magnetization affects more on the recoil permeability than Br. In the incomplete magnetization areas, the recoil permeability is higher than in the full magnetization areas[2].

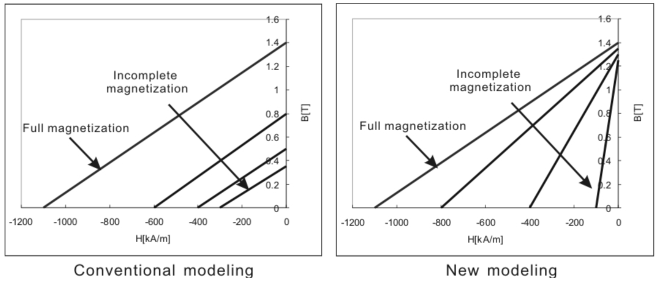

Fig. 1. Demagnetization curve modeling.

In this study, the characteristic of BLDC motor which has incomplete magnetization area is investigated. In the modeling of the incomplete magnetization area, both the recoil permeability and the Br value are considered. With this method, the characteristics like cogging torque, torque constant shows different aspects compared to the characteristics from the conventional approximation method. For the verification, the authors compared with the measured values of the BLDC motor.

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DD06

Design of a High-Performance Linear Permanent Magnet Gear

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Magnetic gear is becoming attractive due to the features such as low acoustic noise, maintenance-free, improved reliability, precise peak torque transmission capability, and inherent overload protection. A most promising magnetic gear topology was proposed in [1], which had a highly competitive torque transmission capability and a very high efficiency. A linear tube magnetic gear was analyzed in [2]. However, the proposed tube linear gear cannot be applied in transmitting force through a nonmagnetic separating wall without mechanical contact between the two movers. In this paper, a linear permanent magnet (PM) gear is proposed, Fig. 1, which can transmit force to a closed space conveniently.

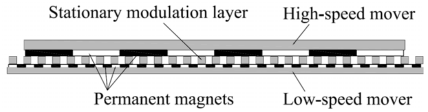

Fig. 1. Cross section of -5.5:1 linear magnetic gear.

Both the high and low-speed movers are equipped with sintered NdFeB magnets, and the stationary modulation layer is made of silicon steel laminations. According to [1], the gearing ratio N is given by $N=|m P_h + k N_s|/m P_h$, where m=1,3,5,⋯, ∞, k=0, ±1, ±2, ±3, ⋯, ∞, P_h is the number of pole-pairs of the high-speed rotor, and Ns is the number of steel segments in the stationary modulation layer between the high-speed mover and the low-speed mover. In order to transmit force at a different rotational speed, the number of pole-pairs of the low-speed mover Pl must be equal to the number of pole-pairs of the space harmonic for which $k\neq 0$. Since the combination of m=1 and k=-1 results in the highest asynchronous space harmonic, the gear ration can be determined as $N=(P_h-N_s)/P_h$. Since the high-speed mover has 4 pole-pairs ($P_h=4$), the low-speed mover is designed with 22 active pole-pairs ($P_l=22$), and the modulation layer hsa 26 steel segments ($N_s=26$). Thus, the gear ratio is -5.5:1.

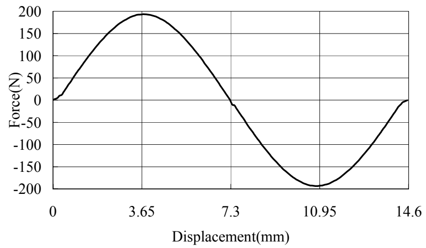

Fig. 2. Force on low-speed mover while high-speed mover being fixed.

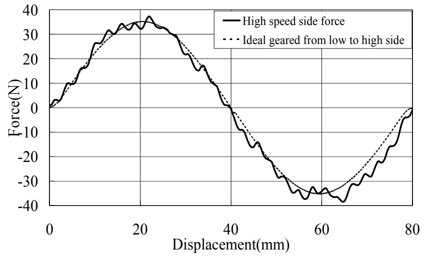

Fig. 3. Force on high-speed mover and ideal geared force while low-speed mover being fixed.

The relationship of force versus displacement is obtained by using 2-D finite element analysis (FEA) on both the high and low-speed movers with the opposite side fixing. Fig. 2 shows the simulated force on the low -speed mover when it moves by 1 pole-pair whilst the high-speed mover is fixed with the stationary modulation layer. It can then be delivered that the maximum transmit force on the low-speed mover will be about 200 N. On the other hand, Fig. 3 shows the simulated force on the high-speed mover when it moves by 1 pole-pair and the low-speed mover is fixed. Furthermore, an ideal torque curve, which is obtained from the FEA result in Fig. 2 and the gear ratio, is also given in Fig. 3, which agrees with the simulated torque very well.

More simulation results, such as the vertical magnetic pull on the movers, and the cogging torque, will be presented in the full paper.

A high-performance linear PM gear has been presented and analyzed with 2-D FEA. It is shown that, by employing rare-earth magnets, the linear permanent magnet gear with a gear ratio of 5.5 can provide maximal transmit force of 200 N, which is rather high.

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