Simulation Analysis of Steady State Characteristics of a Novel Permanent Variable Transmission

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Abstract —The steady state characteristics reflect the main transmitting capability of the permanent variable transmission (PVT). The static and following-up characteristics of a novel PVT were analyzed with the help of Flux3D. The simulation result of static torque validated the feasibility of the novel PVT. During the process of actual operating, the driving torque on the low speed rotor is a fluctuating quantity and the fluctuation amount is directly related to the starting angle of the active part.

I. Introduction

Mechanical gearbox is a kind of transmitting device which has been widely used in our daily life due to its merits of high transform torque and good reliability. However, their mechanical impact, serious abrasion, whilst noise and bulky size are significant issues. As a new type of magnetic mechanism, permanent variable transmission (PVT) which adopts electromagnetic principle to generate the coupling force has the great advantages compared with the mechanical gearbox, such as non-contact and flexible transmission, no noise and lubrication, inherent overload protection[1-4]. Therefore it is getting more and more applications in military and industry areas in the last two decades. Besides, because of its non-contact advantage, PVT is especially suitable for the transmission between different mediums, such as the movement transform between vacuum or sealing environment and outside, and so on.

Generally the research on PVT focuses on the output of the peak value of the static torque which implies the potential capability of the transmitting device. However, the low speed rotor follows the rotation of the high speed rotor instead of remaining still during the virtual operating process. Therefore it is the following-up characteristics that reflect the actual capability of the transmitting torque in the PVT. In this paper the working principle of a novel PVT was analyzed and steady state characteristics including static and following-up characteristics were studied with FEM. The simulation results supply a useful reference for the design and utilization of this novel PVT.

II. Structure and Principle of the Novel PVT

The structure of the novel PVT is shown in Fig. 1. An axial magnetic circuit is adopted to realize the magnetic coupling of high speed and low speed rotor, and radial air gap is used to realize the movement transformation, as show in Fig. 2.

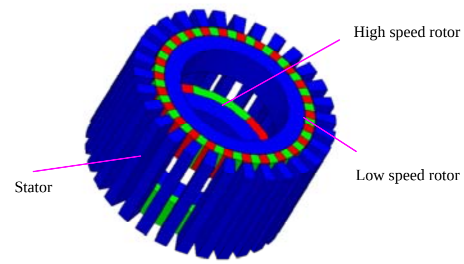

Fig.1. Schematic structure of the novel PVT

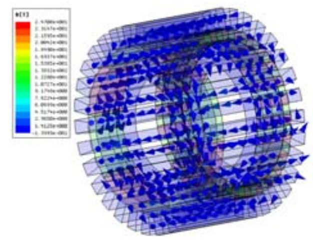

Fig.2. Whole distribution of the flux density

III. Static Characteristics of the PVT

A finite element model of the novel PVT is set up in FLUX3D. The pole pairs of the high speed rotor and low speed rotor are 4 and 26 respectively, and the number of stator cores is 30.

The characteristics that the PVT shows out in the situation of rotating the high speed rotor while keeping the low speed rotor are defined as the static characteristics. The static torques are shown in Fig.3. Torques on both sides are sinusoidal with the rotating angle, amplitudes are 29Nm and 185Nm, respectively. The ratio of the amplitude of low speed torque and high speed torque is about 6.4 which is approximately equal to the designed gear ratio 6.5.

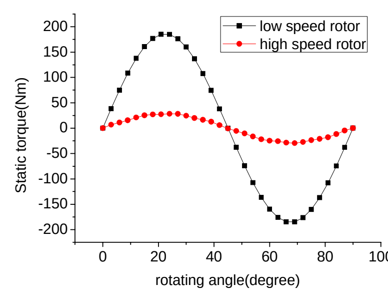

Fig. 3. Static torques on two rotors

IV. Following-up Characteristics of the PVT

During the actual working process of the PVT, the low speed rotor follows up the rotation of the high speed rotor instead of being kept still. According to the static characteristics of the PVT, the magnetic torque on the low speed rotor increases with the included angle between the low speed rotor and high speed rotor. The low speed rotor remains still as long as the magnetic torque is smaller than the load torque. Once the magnetic torque reaches to the load torque, the low speed rotor tends to follow up with the rotation of the high speed rotor. The angle of the high speed rotor at which the low speed rotor starts to rotate is defined as starting angle. In the ideal operating process, the low speed rotor follows up with rotation of the high speed rotor, keeping the ratio of low speed and high speed equal to the gear ratio of the PVT.

Following-up characteristics were studied with the same finite element model in part III. In this process we suppose the starting angle of the transmitting system to be a certain value and keep the high speed rotor and low speed rotor rotates synchronously. Similar as the cause of cogging torque in BLDC motors[5], the interaction of the permanent magnets and the stator cores would result in the torque ripple in PVT. The following-up torque on the high speed rotor with certain starting angle is shown in Fig.4. It can be seen that the following-up torque fluctuate around a mean value. The maximum torque and minimum torque are 20.3Nm and 21.7Nm, respectively, and the fluctuation amount of the following-up torque is about 3.32%.

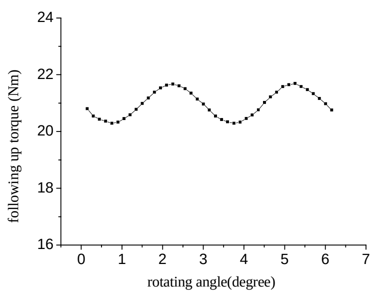

Fig. 4. Following-up torque on high speed rotor with certain starting angle

As to different load on the low speed rotor, the starting angle of the transmitting system varies. We investigated the influence of starting angle on the following-up torque exerted on the high speed rotor.

Fig.5 shows the following up torques on the high speed rotor with different starting angle. Fig.6 shows the fluctuation amount of the following up torque on the high speed rotor with different starting angle. It can be seen that the fluctuation amount reduces with the increase of the starting angle which means that the PVT operates steadily with large starting angle.

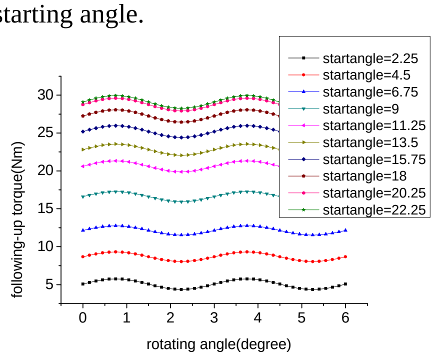

Fig. 5. Following-up torque with different starting angle

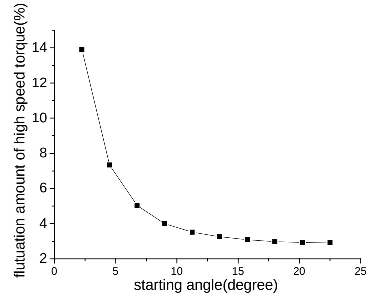

Fig. 6. Fluctuation amount of following-up torques on the high speed rotor with different starting angle

We compared the static torque and the following-up torque on the high speed rotor in Fig.7. The variation of mean value of following-up torque and static torque are the same which validate the simulation results.

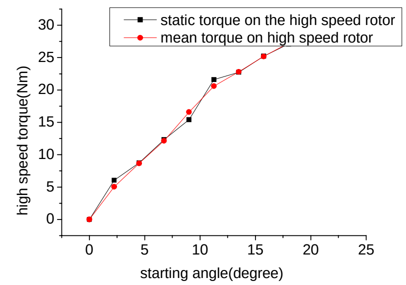

Fig. 7. Comparison of static torque and following-up torque

V. CONCLUSION

The feasibility of the structure of the novel PVT was verified with the simulation results of steady state characteristics. During the process of actual operating, the driving torque on the high speed rotor and low speed rotor were fluctuating quantities instead of remaining as constants. The fluctuation amount is directly related to the starting angle of PVT.

ACKNOWLEDGEMENT

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VI. REFERENCES

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