The Design of Power Transmission system through "The Cycloid Magnetic Gear" for Hybrid Vehicles

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Abstract
Magnetic gears are magneto-mechanical devices that are widely used to replace the ordinary mechanical gears. This paper presents an application new permanent-magnet gear based on the cycloid gearing principle, which normally is characterized by an extreme torque density and a very high gearing ratio. Which is plays an important role in transmission system of vehicles.

Keywords: cycloid Magnetic gears, Power transmission

1 Introduction

Transmission system plays valuable role in the vehicles form speed, mileage, torque, velocity ratio point of view. In this fast growing world, peoples are demanding modern hybrid vehicles that should have high torque and velocity ratio but our existing approach of mechanical gears for transmission system are find unable to meet these requirements thus we need such a transmission system that can satisfy our needs. Thus here we are going to introduce a design of new permanent magnetic gear for power transmission system based on cycloid gearing principle which is normally characterized by an extreme torque density and very high gearing ratio. Permanent-magnetic gears are magneto-mechanical devices that are widely used to replace the ordinary mechanical gears and to transmit torque without any mechanical contact. The concept of cycloid magnetic gears with permanent magnets can be implemented for power transmission system to provide motive force. Purpose of this paper is to make an alternative approach for power transmission system as compared to mechanical gears for hybrid vehicles and wind turbines. This paper involves a new permanent magnetic gear based on cycloid gearing principle.

2 Motivation

Geared devices are a necessity in many tools. The primary purpose of gearing is to provide either a speed change or a force change. The space required for transmission system is large and systems are heavy. We can replace these gears by magnetic gears. Hybrid vehicles having Gasoline power and Electric power, so that weight of vehicle increases. To reduces the weight of vehicle conventional power transmission system can be replaced by magnetic gears.

The classical spur gear of permanent-magnet version can see Fig. 1. It is quite clear that a lot of the magnets are inactive and cannot assist in transferring torque between the two rings. In addition, volume taken up from the gear is quite high because the two rings are separated. In order to reduce the volume and also increase the interaction, it is therefore more suitable to use an inner type spur gear; as in Fig. 2(a). From Fig. 2, it is shown that more magnets gets active if the number of poles on the inner ring is getting closer to the number of poles on the outer ring.

This gearing principle has significant gear-reduction ability. Same example is shown in Fig. 3. Where the outer rotor part C is fixed. An eccentric B is driving the inner magnetic plate, and this plate will make a combined orbit and rotational motion. The rotational part of this motion is transferred to the output shaft A. The gear ratio is $(-21/1) = -21$, which is much higher than a simple inner spur-gear configuration [4].

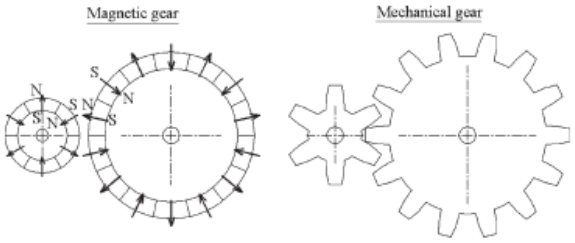

Fig. 1. Permanent-magnet and mechanical spur gear.

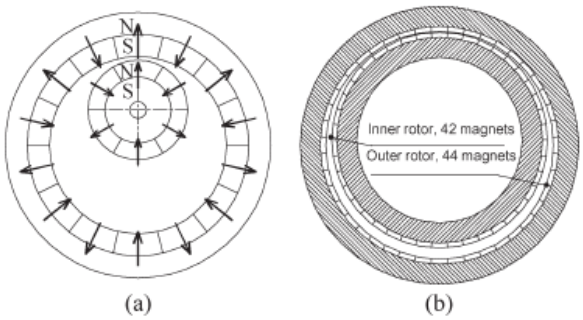

Fig. 2. (a) Inner type spur gear. (b) Inner spur gear with high magnetic interaction and low gearing ratio.

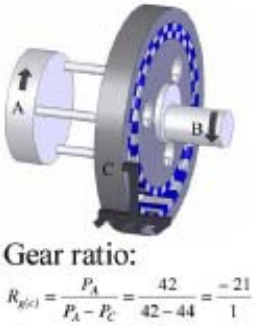

Fig. 3 Cycloid gear

3 Background

Magnetic gearing may offer significant advantages such as reduced maintenance and improved reliability, inherent overload protection, and physical isolation between input and output shafts. Despite these advantages, it has received relatively little attention, to date, probably due to the poor torque transmission capability of proposed magnetic gears. The magnetic gear significantly higher torque transmission capability and a very high efficiency [1].

The analyzed permanent-magnetic gear has a gear ratio of 5.5 and is able to deliver 27 N·m. The analysis has shown that special attention needs to be paid to the system where the gear is to be installed because of a low natural torsion spring constant. The analyzed gear was also constructed in practice in order to validate the analysis and predict the efficiency. The measured torque from the magnetic gear was only 16 N·m reduced by the large end-effects. A systematic analysis of the loss components in the magnetic gear is also performed in order to figure out why the efficiency for the actual construction was only 81%. A large magnetic loss component originated in the bearings, where an unplanned extra bearing was necessary due to mechanical problems. Without the losses of magnetic origin in the bearings and less end-effects caused by relatively short stack, an impressive efficiency estimated at 96% can be obtained. Comparison with classical mechanical gears has shown that the magnetic gear has a better efficiency and a comparable torque per volume density [2].

This paper presents a new permanent-magnet gear based on the cycloid gearing principle, which normally is characterized by an extreme torque density and a very high gearing ratio. An initial design of the proposed magnetic gear was designed, analyzed, and optimized with an analytical model regarding torque density. The results were promising as compared to other high-performance magnetic-gear designs. A test model was constructed to verify the analytical model [4].

4 Initial Results

In Fig. 4, good agreement is seen between the two calculation methods. The reason for the small deviation is mainly caused by the assumption of a unity relative permeability of the permanent magnets in the derivation of the analytical model. The FEA model uses 1.05 in relative permeability for the NdFeB magnets.

The efficiency were measured at 1500, 500, and 50 r/min. The highest efficiencies were generally obtained at low speed and high torque. The best gear efficiency measured at 50 r/min was 94%. Efficiencies of 500 and 1500 r/min were 93% and 92%, respectively.

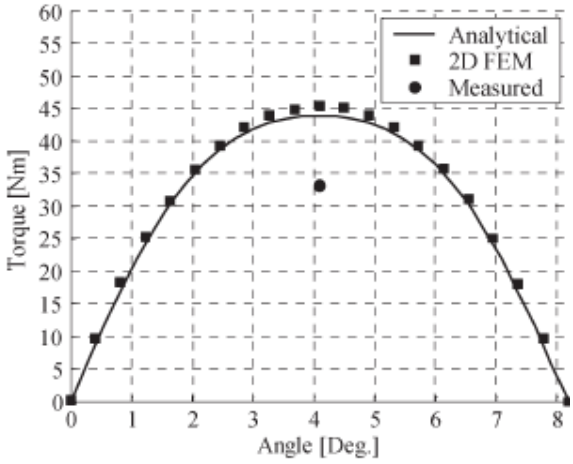

Fig. 4 Analytic and FEA-calculated torque–angle curve.

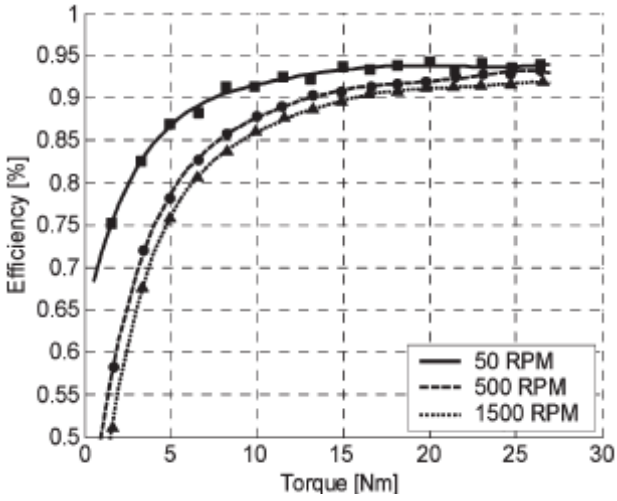

Fig.5. Measured efficiency for the cycloid magnetic gear.

A constrained nonlinear-minimization routine was performed to find the optimal dimensions for the magnetic spur gear. The initial design is very close to the computer-optimized solution. The initial design was 141.9 kN · m/m3, and the computer optimized solution was 142.5 kN · m/m3. The reason why the results are so close to each other is mainly caused by tight constrains limitations.

The last result of the torque-density optimization gave 183 kN m/m3 or 183 N m/L, which is nearly twice the capability of state-of-the-art permanent magnetic gears [4].

5. CONCLUSION

The concept of magnetic gears in power Transmission system overcomes the drawbacks in existing mechanical gears such as- need for lubrication, overload, mechanical fatigue, high torque density. This is a new cycloid permanent magnetic gear i.e. characterized by having high torque density and high gearing ratio. Design for magnetic gear is analyzed and it gives the result that Cycloid gear was able to give more than 35% torque density compared to existing planetary gears. Finally, it is concluded that the results in this paper may help to initiate a shift from mechanical gears to magnetic gears.

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