Design of Concentrated Flux Type Ferrite Magnet Motor for Dual Clutch Transmission

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1. Introduction

Dual Clutch Transmissions (DCTs) are providing the full shift comfort of traditional step automatics but offer significantly improved full efficiency and performance. With up to 15% better fuel efficiency compared to planetary-ATs, the DCTs are the first automatics to provide better values than manual transmissions. Higher top speed and, more important in everyday driving, better acceleration compared to planetary-ATs and CVTs are additional benefits [1]. Therefore, DCT system has been developed competitively on the automotive industry, then development of electric actuator(motor) for DCT system has been of importance as well.

Since the neodymium permanent magnet has relatively high energy density, it has been used for motors of various automotive systems such as electric power steering(EPS), pump, and hybrid engine. Although the price of the neodymium permanent magnet is on a decreasing trend, the magnets containing rare earth materials are still expensive and sudden price spikes may occur again. It is therefore required to develop motors that do not use rare earth magnets on the automotive industry for cost reduction [2].

Motors using ferrite permanent magnet, as one of the influential alternatives, has advantages of a high competitiveness on price and stable supply of raw materials than motors made by the neodymium permanent magnet. However, the residual magnetic flux density(Br) of the ferrite permanent magnet is lower than that of the neodymium permanent magnet. To solve this problem, a ferrite permanent magnet motor, which has a torque similar to that of a neodymium permanent magnet motor, has been developed [3]. It is the method that arranges ferrite magnets along with radial direction in order to have concentrated flux, so called “Spoke type”. Since motors for DCT system are required to minimize its size because of limited space on transmission, this concentrated flux type motor would be a breakthrough.

In this paper, design of concentrated flux type ferrite magnet motor for DCT system is presented with optimization method and finite element analysis(FEA). Then it is compared with manufactured motor in perspective of its performance. In addition, structural analysis for increasing mechanical reliability of design model is included as well.

2. Electro-magnetic design

The most important thing on design of concentrated flux type motor is to reduce leakage flux. To reduce leakage flux, it is necessary to increase magnetic reluctance of leakage flux path. But there is limitation to reduce leakage flux on a single body type rotor core. Accordingly, segment type rotor core is required for maximization of motor performance. Both designed rotor core models, single body type and segment type, are shown in Fig. 1. In case of segment type, it is necessary to have complex mechanical structure to maintain circular rotor shape and fix to shaft. Since those additional structures deteriorate productivity seriously, segment type rotor core inserted aluminum casting is suggested in this paper to solve the problem as shown in Fig. 2.

For the stability on operation and control of DCT system, optimization in order to reduce cogging torque and torque ripple using Response Surface Method(RSM) is performed as well.

3. Structural analysis

Durability and safety are of importance and highly required to motors for automotive system. Hence, structural analysis of designed model is executed to verify and analyze structural rigidity against centrifugal force at high speed rotation near 5,000 RPM and structural safety between aluminum casting part and shaft when maximum torque applied.

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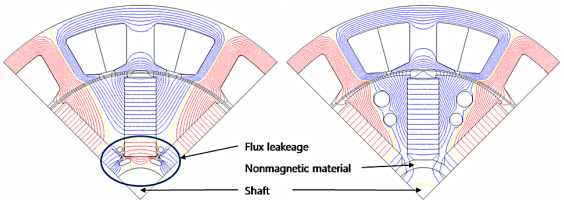

a) Single body type rotor b) Segment type rotor

Fig 1. Flux path of designed models

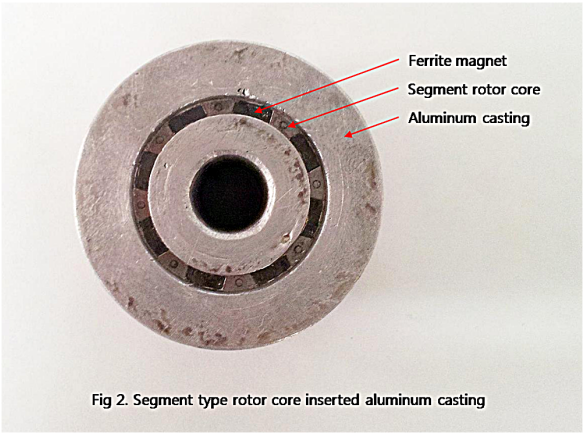

Fig 2. Segment type rotor core inserted aluminum casting