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Reluctance Network Model for the In-wheel motor of a Series-Hybrid Truck using Tooth Contour Method

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***Abstract*—Recently, series-hybrid drivetrains are given more emphasis over parallel-hybrid drivetrains due to their simplicity, freedom in implementation and higher efficiency. However, the modeling phase of such machines takes either long calculation time with numerical methods such as Finite Element Analysis (FEA) or produces low accurate results with Magnetic Equivalent Circuit (MEC) models. In this paper a method is used to build a reluctance network where high accuracy is obtained yet still with acceptable calculation time.**

I. INTRODUCTION

Hybrid vehicles, which employ a technology combining gasoline and electric motors, are a hot item these days for transporters looking for ways to cut their fuel bills. However, commercially available high torque motors are limited in their speed envelope which prevents the truck to attain maximum velocity. Hence, it is requested to design an in-wheel motor. This is a very challenging task, since the space envelope is limited (power requirement is approximately 2.3 MW/m^3) and an extended field weakening capability of almost five times base speed is essential [1].

The limited space envelope in combination with the high power requirement calls for an accurate model with acceptable calculation time. This model can be constructed using the Tooth Contour Method (TCM).

II. TOOTH CONTOUR METHOD

The TCM is based on dividing the ferromagnetic bodies of the machine in parts and calculate their mutual permeances in the air space between the separate bodies for different rotor positions [2] [3]. The permeance is calculated by exiting one part called contour with an arbitrary scalar potential and place all the other contours at zero potential, illustrated in Fig. 1.

The permeance between two contours can be calculated from the amount of flux entering the contour at zero potential as illustrated in Fig. 2. The distribution of the electrostatic field entering the contours on 3 magnets for different rotor positions is shown in Fig 2(a-c). From this electric field, the magnetic field distribution and thus the permeance between two parts can be calculated. The resulting permeance for different rotor positions is shown in Fig. 2(d). The permeances are used to construct a reluctance network model of the machine.

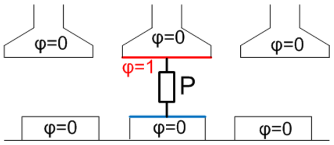

Fig. 1. Illustration of the TCM

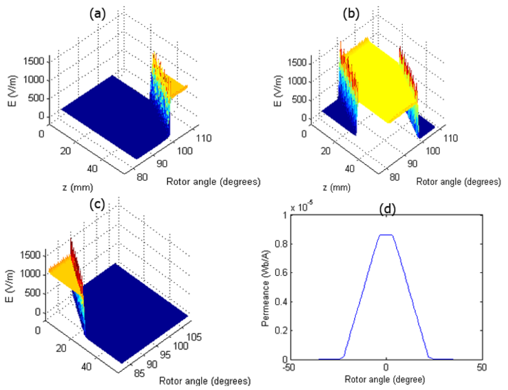

Fig. 2. (a)-(c) Electric field distribution on various magnets, (d) Resulting permeance function

III. CONCLUSION

Flux tubes, which are used for MEC, are spatially bounded and therefore the flux outside the tube is neglected. The permeances calculated with the TCM are not spatially bounded and thus more accurate. Furthermore no knowledge about the flux distribution in the machine is required to calculate the permeances. At the same time the number of elements in the reluctance network is much lower than the number of elements used in the FEA. This results in a significant shorter calculation time.

Electromagnetic quantities such as magnetic flux density, torque and back-EMF can be calculated of the model constructed with the TCM and verified with 2D FEA and MEC.

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