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# Performance comparison of axial-flux switched reluctance machines with non-oriented and grain oriented electrical steel rotors

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# View Abstract

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**ABSTRACT BODY:**

**Digest Body:** I introduction

Many applications require rotating machines to deliver high torques and operate at large speeds while seeking high efficiency. In this respect, switched reluctance machines (SRM) are good candidates as they are known to operate at high torque or at exceptionally high speeds. They are also known to be robust giving the fact that they are magnet-free and have no winding at the rotor. Besides the advantages, several studies taking interest in the axial-flux SRM (AFSRM) showed that it is more compact than the radial-flux SRM (RFSRM) [1,2].

Consequently, a growing interest is directed towards AFSRM to deliver compact designs [3,4].

To increase the efficiency, Grain Oriented Electrical Steel (GOES) is full of interest as it has excellent performance regarding permeability and iron losses [5]. However, its anisotropic nature makes it difficult to use in electrical rotating machines as the performance vary depending on the magnetization direction. Therefore, few studies deal with the introduction of GOES in SRM. Authors of [6] introduced GOES at the stator and rotor teeth of a 12/8 segmented AFSRM. A configuration with the stator teeth clipped onto the stator yoke was discussed, showing a significant raise in the electromagnetic torque but with an increase of manufacturing complexity.

In this paper, an AFSRM using GOES in the rotor is presented and its performance compared to the same AFSRM with NOES rotor through 3D numerical simulations. The axial structure and the numerical model used are presented and a comparison of both inductances is given.

## II AFSRM and the numerical model

The structure considered is an 8/6 AFSRM with two external stators and a rotor in long magnetic path configuration; i.e. the magnetic flux density is crossing rotor teeth from one stator to the other. This structure is chosen for its thermal advantages, as it allows faster thermal dissipation. Furthermore, by using this topology, the rotor yoke is not useful from a magnetic point of view anymore. Therefore, it can be removed and the teeth are individually cut and encapsulated in a non-magnetic structure.

The considered axial structure, for which a simplified view of half of the structure is shown in Fig. 1, is indeed well suited for the use of GOES in the rotor since the magnetic flux density only crosses the rotor teeth from a stator to the other (Fig. 1).

The GOES is characterized by typical directions: Rolling (RD), Transverse (TD) and Normal (ND) directions. Thus, arranging GO sheets so that the RD, which corresponds to the easy magnetization, is in the direction of the magnetic flux of the rotor would increase the variation of the air gap reluctance and thus the performance of the machine. Furthermore, the steel sheets can be arranged at the rotor according to two configurations favoring either the RD and TD forming a plane or RD and ND, which may change the saliency. Previous work has dealt with the study of the contribution of GOES in the case of a configuration close to the one of a SRM but it was only in 2D case [7]. In order to compare the performance of the considered AFSRM with non-oriented and grain oriented electrical steel in the rotor teeth, the structure has been modeled using a 3D FE software. In this model, the anisotropy of the magnetic material was taken into account using a diagonal tensor with a normal permeability whose value is defined in [8]. So far, the comparison results are given for the first configuration (RD and TD in the same plane) as previous work [7] showed that although the configurations display different torque waveforms, they give similar mean electromagnetic torque values.

### III Results comparison

Two different types of electrical steel are considered: isotropic NOES 0.5 mm (M400) and anisotropic GOES 0.35 mm. To evaluate the GOES impact on the machine performance when introduced at the rotor, inductance simulations were computed. The inductance results cover a rotor position range from alignment to opposition, which represents the interest area for torque production. Fig. 2 shows a steeper inductance slope in the two studied cases. The maximum inductance value when GOES is used is improved in comparison with the NOES rotor. Around the opposition position, both NOES and GOES curves are almost overlapping. This is consistent in this case as the use of GOES does not have an impact anymore. Consequently, the slope of the self-inductance, which is a reflection of the torque capability, is steeper at the same current level. From the results shown, the performance of the studied topology is improved by replacing NOES rotor teeth by GOES ones. This shows that the use of the latter can be interesting in some given configurations while avoiding any additional manufacturing complexity.

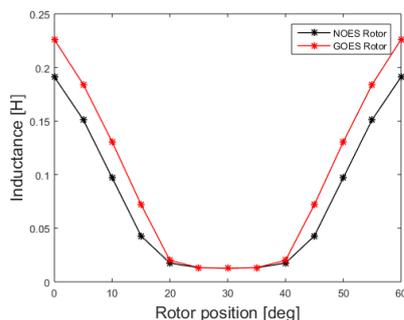
In the full paper, more details will be given related to the machine studied and the numerical model used. Furthermore, other results will be given and discussed showing the improvements of the performance in terms of electromagnetic torque waveforms.

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**KEYWORDS:** Axial flux switched reluctance machine, Grain oriented electrical steel, Non-oriented electrical steel, Electromagnetic torque.



Fig.1 Half of the AFSRM



**IMAGE CAPTION:**

Fig.1 Half of the AFSRM

Fig. 2 Inductance comparison for NOES and GOES rotors

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