Hybrid Excited Electric Machine with Axial Flux Bridges

Piotr PAPLICKI, Ryszard PALKA, Marcin WARDACH, Maria Evelina MOGNASCHI

Department of Power Engineering and Electrical Drives,
West Pomeranian University of Technology, Szczecin, Sikorskiego 37, 70-313 Szczecin, Poland

Maria Evelina MOGNASCHI

Department of Electrical, Computer and Biomedical Engineering,
University of Pavia, via Ferrata 5, 27100 Pavia, Italy

Abstract. The paper presents new concepts of rotor design for a hybrid excited synchronous machine with axial flux bridges. Based on a three-dimensional finite element analysis (3D-FEA) the influence of the bridges type and arrangement on the field-control characteristics of the machine is examined and compared with experimental results. Moreover, harmonic spectrum of air-gap flux density, no-load magnetic flux linkage and back electromotive force (back-EMF) for three rotor designs are reported in comparison. Finally, field-weakening characteristics versus an additional field excitation DC coil current of the machine are presented.

1 Introduction

Nowadays, due to high torque density and efficiency, permanent magnet (PM) machines have been used in many industrial applications, such as vehicle drives i.e. However, the constant PM excitation makes the air-gap flux non-adjustable. Consequently, typical PM machines suffer from restricted flux-weakening capability and constant power operating region at wide-speed-range. Therefore, variable-flux machines with hybrid excitation are extensively investigated in order to obtain a motor drive for wide speed range with high efficiency.

The purpose of this paper is to explore new axial flux bridges shown in Fig. 1 and Fig. 2a, in rotor magnetic structures of an Electric Controlled Permanent Magnet Synchronous machine (ECPMS-machine) with good (10:1) field weakening capability (Fig. 2b), which has been developed and partially tested in [1-5].

2 Influence of the flux axial bridges arrangement on magnetic flux distribution

Fig. 1a shows two active parts of the rotor structure of ECPMS-machine and three types of axial flux bridges and their arrangement as:

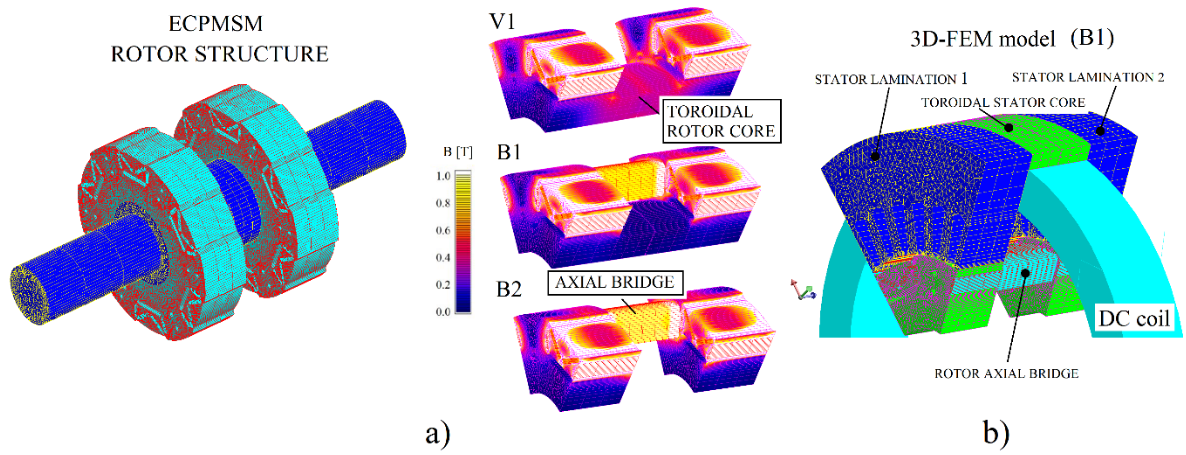

Fig. 1 Novel concepts of rotor ECPMS-machine with axial flux bridges (a) and 3D-FEA model of ECPMSM-machine with B1 rotor concept (b)

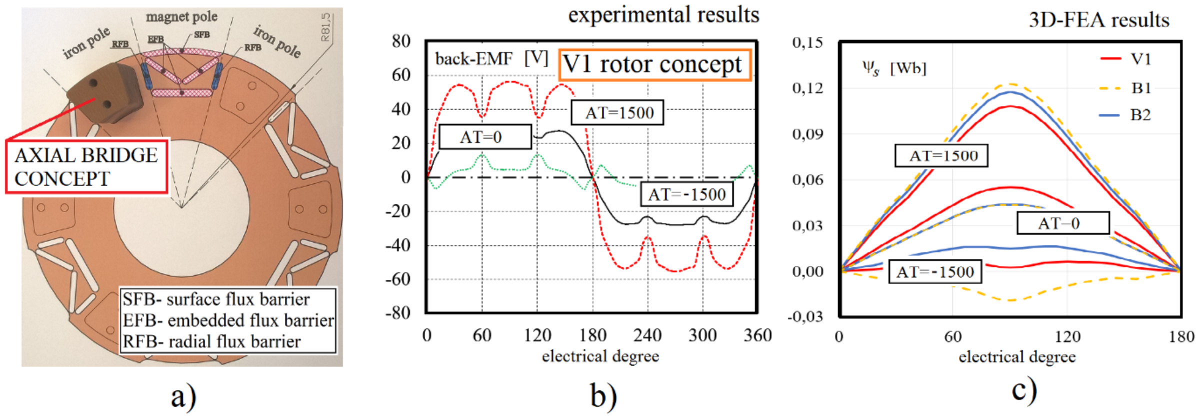

Fig. 2 Axial flux bridge concept (a), experimental results of back-EMF for V1 rotor concept (b) and waveforms of no-load magnetic flux linkage Ψ*s* with additional field excitation DC coil at three different load conditions (c)

Case 1: model V1 with a toroidal rotor core located in the middle of active parts.
Case 2: model B1 with the toroidal rotor core and the axial flux bridge.
Case 3: model B2 only with the axial flux bridge.

Fig. 2 shows 3D-FEA results of no-load magnetic flux linkage Ψ_s of the machine obtained with additional field excitation DC coil (Fig. 1c) at three different ampere-turns (AT) load operation: in flux-weakening (AT=-1500); flux-strengthening (AT=1500) and no-load (AT=0) condition, in comparison.

3 Conclusion

The main objective of presented study is to demonstrate the efficiency of active magnetic bridges in magnetic circuit of hybrid excited machine, and indicate new directions in the search of optimal design solutions for the ECPMS-machine. The results show a noticeable influence of additional axial flux bridges on the flux-control range of the machine. In B1 concept the best air gap flux adjustment by employing additional field excitation DC coil has been obtained, in comparison with the base model V1. Moreover, the results show that the starting torque for B1 concept is increased approx. 13 % and the field weakening performance is clearly improved.

Acknowledgements

This work has been supported with the grant of the National Science Centre, Poland 2015/17/B/ST8/03251.

References

[1] P. Di Barba, et al., Hybrid excited synchronous machine with flux control possibility, *International Journal of Applied Electromagnetics and Mechanics*, vol. 52, no. 3-4, 2016, pp. 1615-1622.
[2] P. Paplicki, , et al ., Simulation and experimental results of hybrid electric machine with a novel flux control strategy, *Archives of Electrical Engineering*, vol. 64, no. 1, Mar. 2015, pp. 37–51.
[3] P. Di Barba, et al., Design of Hybrid Excited Synchronous Machine for Electrical Vehicles, *IEEE Trans. Magn.*, vol. 51, no. 8, Aug. 2015.
[4] P. Putek, et al., Multi-objective topology optimization of a permanent magnet machine to reduce electromagnetic losses and cogging torqu", *International Journal of Applied Electromagnetics and Mechanics*, vol. 53, no. S2, pp. S203-S212, 2017, DOI: 10.3233/JAE-140162.
[5] P. Paplicki, Influence of Magnet and Flux-Barrier Arrangement on Flux Control Characteristics of Hybrid Excited ECPMS-machine", *Electronika ir Electrotechnika*, vol. 23, no. 2, 2017, pp. 15-20, http://dx.doi.org/10.5755/j01.eie.23.2.14461.