Finite Element Transient Analysis of Induction and Permanent Magnet Motors for Aerospace Applications

Themistoklis D. Kefalas[1] and Antonios G. Kladas[1]

[1]School of Electrical and Computer Engineering, National Technical University of Athens
9 Iroon Polytechneiou Street, Athens 15780, Greece
thkefala@central.ntua.gr

***Abstract*—The purpose of the present paper is the development of numerical techniques for the reduction of the computational cost of the 3D finite element (FE) transient analysis. The specific methodologies were applied for the electromagnetic and thermal transient analysis of a permanent magnet synchronous motor (PMSM) and an induction motor (IM) specifically designed and optimized for aerospace actuation applications.**

***Index Terms*—Aerospace industry, finite element methods, induction motors, permanent magnet motors, thermal analysis.**

I. Introduction

This paper concerns the electromagnetic and thermal analysis of two actuators, a permanent magnet synchronous motor (PMSM) and an induction motor (IM), designed for demanding environmental conditions encountered in an aerospace application [1]-[3]. The solution of the aforementioned problem requires a detailed 3D finite element (FE) transient analysis due to the extreme loading conditions and the high integration of the actuators. For that purpose, a FE package for electromagnetic and thermal analysis was assembled, which incorporates a number of numerical techniques specifically developed for the reduction of the computational cost of the 3D FE analysis [4], [5].

II. Description of Prototype PMSM and IM

A. Permanent magnet synchronous motor (PMSM)

A surface mounted PMSM was designed and optimized for two different modes of operation encountered in a demanding aerospace application. Under normal mode of operation the torque and rotating speed are equal to 1.2 $N \cdot m$ and 180 rpm. Under the extreme mode of operation, torque and rotating speed are equal to 6.0 $N \cdot m$ and 6,000 rpm. High temperature, samarium cobalt permanent magnets and non-overlapping, fractional slot winding configuration were used.

B. Induction motor (IM)

An IM was also designed for the aforementioned aerospace application. A non-overlapping winding was not the optimum choice for the IM. As a result, a conventional winding configuration was used. For the rotor bars the NEMA design class A was adopted due to the high torque capacity and efficiency at low slip frequencies.

III. Results and Discussion

A number of transient and steady state FE electromagnetic and thermal analyses of the PMSM and IM, were carried out using the FE package integrating the developed methodologies. Figs. 1, 2 show respectively the temperature distribution of the PMSM and IM running under maximum load.

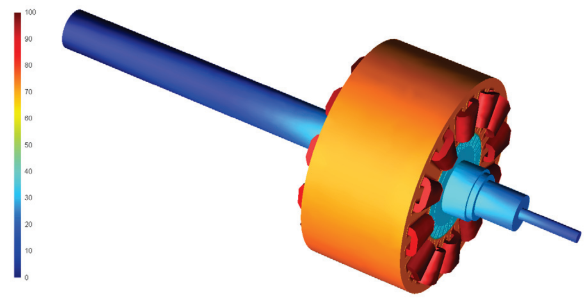

Fig. 1. PMSM temperature distribution, 2607 s.

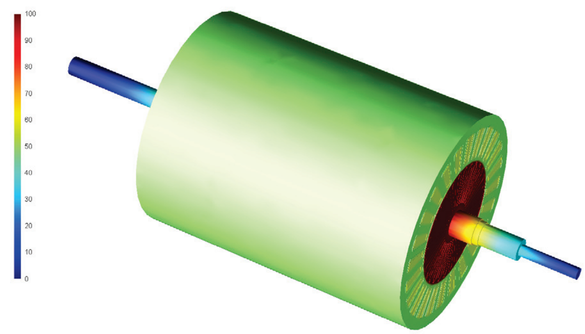

Fig. 2. IM temperature distribution, 2607 s.

IV. Acknowledgment

The research leading to these results has received funding from the European Commission, in the frame of "Clean Sky" Programme, Topic Nbr: JTI-CS-2009-1-SGO-02-010 under grant agreement 255811EMAS.

References

[1] W. Cao, B. C. Mecrow, G. J. Atkinson, J. W. Bennett, and D. J. Atkinson, "Overview of electric motor technologies used for more electric aircraft (MEA)," *IEEE Trans. Ind. Electron.*, vol. 59, no 9, pp. 3523-3531, Sep. 2012.

[2] P. E. Kakosimos, E. M. Tsampouris, A. G. Kladas, and C. Gerada, "Aerospace actuator design: A comparative analysis of permanent magnet and induction motor configurations," *Proc. ICEM*, 2012.

[3] E. M. Tsampouris, M. E. Beniakar, A. G. Kladas, "Geometry optimization of PMSMs comparing full and fractional pitch winding configurations for aerospace actuation applications," *IEEE Trans. Magn.*, vol. 48, no. 2, pp. 943–946, Feb. 2012.

[4] T. D. Kefalas and A. G. Kladas, "Finite element transient thermal analysis of PMSM for aerospace applications," *Proc. ICEM*, 2012.

[5] T. D. Kefalas and A. G. Kladas, "Thermal investigation of permanent magnet synchronous motor for aerospace applications," *IEEE Trans. Ind. Electron.*, vol. PP, no 99, 2013.