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Heat Transfer in a Torus Electromagnetic Coupler Subjected to Cooling

F.Z. Boudara[1], H. Bouzekri[1], Y. Benhammadi[1], P.-H. Cocquet[1], M. Rivaletto[1], L. Pécastaing[1], A. Silvestre de Ferron[1], S. Paquet[2], J-P. Brasile[2], Y. Le Guer[1]

[1] UNIV PAU & PAYS ADOUR/ E2S UPPA, LABORATOIRE DES SCIENCES DE L'INGÉNIEUR APPLIQUÉES À LA MÉCANIQUE ET AU GÉNIE ELECTRIQUE – Fédération IPRA, EA4581, 64000, PAU, FRANCE

[2]EFFITECH, PAU, FRANCE.

Extended Abstract

The increase of greenhouse gases observed during the last decades mainly caused by non-renewable energy sources has led to the rise of renewables ones such as solar, wind, or fuel cell. For their implementation, these sources require mastering the power they deliver by adequate and intelligent flow management. In particular, the fast charging of autonomous systems will lead to the transfer of electrical power far greater than the capacities of the products currently on the market.

In this logic, an air-core toroidal coupler which is able to transfer 400kW with a promising efficiency of 95% in the overall volume of 13 litters was developed. But mastering compactness at such a level of power also requires simplifying cooling systems. Hence, the magnetic core of the coupler was delated to avoid the magnetic losses and to deal only with the joule losses due to the AC resistance of the Litz wire used in the conception of the prototype. Besides, to prevent a high additional eddy current loss, the use of metals for the cable holder is not permitted. Hence, the PLA material was chosen to support the 3D printed cable holder because of its low-loss tangent and high-volume resistivity. This material has thus an operating temperature limit which must not be exceeded, forcing the torus coupler to be cool down. For this purpose, we carried out a theoretical thermal modelling of the hollow torus subjected to a parietal heat flux (the Joule losses) and external and internal convective cooling.

The heat equation is solved in a torus coordinate system for the appropriate boundary conditions. The steady-state thermal problem is first solved and then the transient one. To our knowledge this problem with these boundary conditions has never been studied analytically in the literature. The only works found for the transient study of the temperature field within a torus geometry are those of Wiesche [1] Alassar and Abushoshah [2] [3] but they concern other types of boundary conditions.

Our results show the evolutions of the temperature field inside the torus for internal convective heat transfer coefficients of 5 $W/m^2/K$ and external convective heat transfer coefficients of 211 $W/m^2/K$. The maximum temperature reached respects the maximum thermal limits supported by the Litz wire, which is 120 °C, and the PLA, which is 60 °C.

References

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