Induction Machine Design Method for Aerospace Starter/Generator Applications and Parametric FE Analysis

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Abstract : The More-Electric-Aircraft concept in aircraft industry levies an increasing demand on the embedded starter/generators (ESG). The high-speed and high-temperature environment within an engine poses great challenges to the operation of such machines. In view of such challenges, squirrel cage induction machines (SCIM) have shown advantages due to its simple rotor structure, absence of temperature-sensitive components as well as low torque ripples etc. The tight operation constraints arising from typical ESG applications together with the detailed operation principles of SCIMs have been exploited to derive the mathematical interpretation of the ESG-SCIM design process. The resultant non-linear mathematical treatment yielded unique solution to the SCIM design problem for each configuration of pole pair number p, slots/pole/phase q and conductors/slot zq, easily implemented via loop patterns. It was also found that not all configurations led to feasible solutions and corresponding observations have been elaborated. The developed mathematical procedures also proved an effective framework for optimization among electromagnetic, thermal and mechanical aspects by allocating corresponding degree-of-freedom variables. Detailed 3D FEM analysis has been conducted to validate the resultant machine performance against design specifications. To obtain higher power ratings, electrical machines often have to increase the slot areas for accommodating more windings. Since the available space for embedding such machines inside an engine is usually short in length, axial air gap arrangement appears more appealing compared to its radial gap counterpart. The aforementioned approach has been adopted in case studies of designing series of AFIMs and RFIMs respectively with increasing power ratings. Following observations have been obtained. Under the strict rotor diameter limitation AFIM extended axially for the increased slot areas while RFIM expanded radially with the same axial length. Beyond certain power ratings AFIM led to long cylinder geometry while RFIM topology resulted in the desired short disk shape. Besides the different dimension growth patterns, AFIMs and RFIMs also exhibited dissimilar performance degradations regarding power factor, torque ripples as well as rated slip along with increased power ratings. Parametric response curves were plotted to better illustrate the above influences from increased power ratings. The case studies may provide a basic guideline that could assist potential users in making decisions between AFIM and RFIM for relevant applications.

Keywords : axial flux induction machine, electrical starter/generator, finite element analysis, squirrel cage induction machine
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