FEA Mechanical Modeling of Torque Transfer Components for Fully Superconducting Rotating Machines

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Abstract

Because of their very high specific torque, fully superconducting rotating machines are considered as enabling technology for future turbo-electric propulsion for transportation aircraft. NASA is funding the development of a high fidelity fully superconducting machine sizing tool able to generate optimized designs based on thrust requirements and design constraints. Several mechanical challenges need to be overcome during the design of the torque transfer components; the amount of heat conducted through the shaft and torque tubes represents a large contribution of the total heat load at cryogenic temperature and as a result needs to be minimized while keeping adequate margin on the peak stress in different materials composing the shaft as shown in figure 1. Reducing the conducted heat load requires the use of different materials in the torque path; stainless steel is used for the winding support at cryogenic temperature and for the room temperature end of the shaft supporting the vacuum seals and bearings. Composite materials such as G10 or carbon fiber composites are used the carry the large temperature gradient from the cryogenic temperature at the rotor winding and the drive end of the shaft at room temperature. The use of different materials requires special cares to prevent damages due to thermal stress during cool down. The model developed includes a realistic fully parameterized 3D geometry representation of the rotor shaft and winding support. COMSOL Multiphysics® has been used to investigate the impact of the shaft components dimensions and shapes on the thermal stress, strain, displacement and torque induced stress and deformation as well as validate the mechanical design of the shaft. This parametric model allows us get the relationship between stress/strain and series of geometric parameters. The presented analysis helped determining the most proper design parameters for different working conditions of the superconducting machine. The simulations allowed for a full characterization of the superconducting motor composite shaft and successfully validated the stress and deformation of the shaft induced by heat transfer and applied torque. Figure.1 shows the geometry of the composite shaft implemented in COMSOL, and Figure.2 shows the temperature distribution of the composite shaft for a design example.

Figures used in the abstract

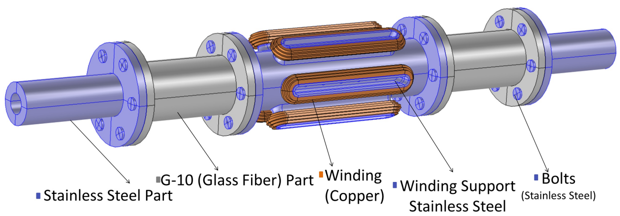

Figure 1: Geometry of the Composite Shaft in COMSOL Multiphysics®.

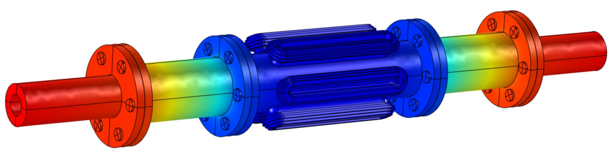

Figure 2: Temperature Distribution in the Composite Shaft.