High Temperature Magnetic Material with Temperature Capability Greater Than 500°C – phase I

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Purpose

Recent studies have shown that a significant reduction in fuel burn for future aircraft can be achieved by developing hybrid electric airplanes, where an electric motor drives the propeller fan. The fan will be electrically powered by generating electricity using either a gas turbine engine or an energy storage device, such as a battery. For hybrid electric application, the power density for the electric motors has to be increased by a factor of 3-4 compared to the state-of-the-art (SOA). One factor that limits the power density of the permanent magnet electric motors is the temperature capability of permanent magnets. As the motor temperature increases during operation, the SOA magnets lose their magnetic properties. The best high temperature magnetic material available today is $Sm_2(Co,Fe)_{17}$, which has a temperature limit of 400°C for long-duration operation. We propose to develop a high temperature permanent magnetic material with a high Curie temperature and with a capability for using it as a permanent magnet above 500°C for long-duration.

Background

Permanent magnets are unique in their ability to convert energy, whether mechanical to mechanical energy or electric to mechanical energy. They in themselves have no moving parts, no coolant, nor lubrication and hence, inherently a higher reliability. Currently, magnets are developed with trial, error and empirical methods. These commercial magnets are developed with design criteria specific to their application, as an example for automotive or audio service. However, for aviation, the requirements are more stringent and require the magnet to perform in extreme environments. The unique approach to this research is the use of computational methods to find potential high-performing systems, and to filter out alloy compounds, which show little promise for meeting the requirements. In addition, the computational methods also give very good predictions of the materials' properties such as the magnetic moments, its saturation, physical density and stiffness which are relevant to further fabrication.

The proposed effort will enable high power density, non-cryogenic electric motors for hybrid electric aircraft, which will help NASA achieve aggressive (greater than 70 %) fuel burn reduction goals for N+3 (for beyond Yr 2030 time frame) aircraft. The proposed concept will also enable lightweight electromechanical actuation devices for more electric aircraft in the future, with the benefit fuel burn and carbon dioxide emission reduction.