DURABILITY DESIGN FOR COMPOSITE FLYWHEEL ROTORS

Abstract

Composite flywheels have gained much interest recently as an alternative to fuel cells or acid batteries, but the great difficulties in performing spin tests have hindered their development and their subsequent applications. Because of this difficulty, very little data regarding the ultimate strength of flywheels is available, let alone fatigue or creep data. The flywheels are loaded continuously for a long period, and therefore the creep data is the most valuable information for design. It is also the most difficult to obtain, since the time to failure tends to be in the order of decades if not centuries. Predicting the fatigue life is also a difficult task, since composite materials are viscoelastic and exhibit a strong time and temperature dependence, which is not considered in the conventional S-N curve approach.

Our accelerated testing methodology is based on the time-temperature superposition principle for polymeric materials. This principle, originally developed for non-destructive material properties, has been recently shown to be applicable to failure properties of composite materials. Using this as a building block, we have developed a methodology to predict the long-term life of composite materials over various temperature ranges, time-to-failure, and loading conditions. In this methodology, series of coupon test results at different temperature and loading conditions are contracted to a single curve plotted against time to failure, which is called the master curve. Using this master curve, the life of the material for any temperature and time to failure can be predicted. By correlating this with the spin tests of the actual flywheel rotors, these master curves can be used for the design and optimization of flywheels.

In this study, we plan to (1) evaluate the long-term performance of the candidate materials, (2) create design guidelines for the flywheels, (3) perform life prediction of the actual flywheel, (4) develop a rational basis for the accelerated proof test, and (5) statistical evaluation and optimization of the methodology.

In order to accomplish these goals, we will perform the following tests for a generic candidate material system. Two types of coupon tests to create master curves, spin tests of sample flywheel rotors for correlation, and spin tests at elevated temperatures to evaluate the accelerated proof test concept.