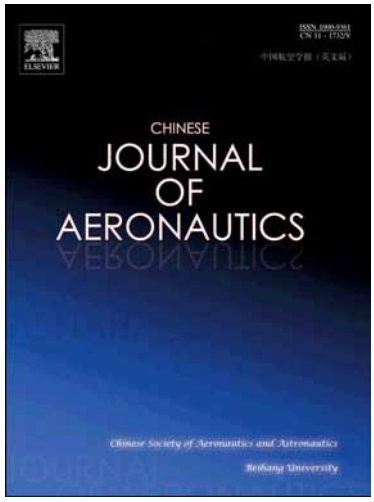

Analysis and control of the compaction force in the composite prepreg tape winding process for rocket motor nozzles

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Abstract

In the process of composite prepreg tape winding, the compaction force could influence the quality of winding products. According to the analysis and experiments, during the winding process of a rocket motor nozzle aft exit cone with a winding angle, there would be an error between the deposition speed of tape layers and the feeding speed of the compaction roller, which could influence the compaction force. Both a lack of and over compaction related to the feeding of the compaction roller could result in defects of winding nozzles. Thus, a flexible winding system has been developed for rocket motor nozzle winding. In the system, feeding of the compaction roller could be adjusted in real time to achieve an invariable compaction force. According to experiments, the force deformation model of the winding tape is a time-varying system. Thus, a forgetting factor recursive least square based parameter estimation proportional-integral-differential (PID) controller has been developed, which could estimate the time-varying parameter and control the compaction force by adjusting the feeding of the compaction roller during the winding process. According to the experimental results, a winding nozzle with fewer voids and a smooth surface could be wound by the invariable compaction force in the flexible winding system.

Keywords: Winding processes; Composite material; Rocket nozzles; Compaction; Voids; Parameter estimation

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1. Introduction[1]

Resin matrix fiber reinforced composites have been widely used in aerospace engineering and other fields for their advantages such as high specific strength, high specific modulus, and thermal stability. Resin prepreg tape winding is a major method to manufacture a rocket motors nozzle's aft exit cone[1]. The aft exit cone is used to provide the internal contour to expand the exhaust gases in solid rocket motors. Because of the high-temperature and high-speed exhaust gases, the aft exit cone is eroded during motor firing[2]. According to the high-temperature thermo-mechanical behavior of composites, Mcmanus and Springer investigated a model of voids formation rates caused by vapor and volatile, stress and strain, and damage of carbon fiber resin matrix composites with certain ply angle at high temperature[3]. Mouritz et al. analyzed the fire structural response of fiber–polymer laminates[4]. Bianchi et al. researched the thermo-chemical erosion behavior of a carbon-phenolic material in solid rocket motor nozzles[5]. McGurn et al. developed a thermal model for the response of carbon-epoxy composite laminates in fire environments, which includes porosity, mass fractions, and volume expansion ratio[6]. According to the researches, a low-porosity and intimately bonded winding product could have a better performance in high-temperature environments.

In order to decrease voids, Costa et al. showed the influence of the porosity in carbon fiber/epoxy resin, carbon fiber/bismaleimide resin composites on material performance[7]. Madsen and Lilholt built a theoret-