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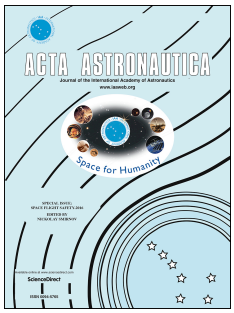

Aging constitutive model of hydroxyl-terminated polybutadiene coating in solid rocket motor

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Aging constitutive model of hydroxyl-terminated polybutadiene coating in solid rocket motor

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Abstract: To accurately describe the tensile mechanical properties of aged hydroxyl-terminated polybutadiene (HTPB) coating, the aging constitutive model was studied. The single-step and multi-step relaxation tests were performed on the unaged samples, and the tensile mechanical properties of the aged HTPB coating were tested, while the crosslink density was obtained by nuclear magnetic resonance (NMR) experiments. The model parameters were solved using the experimental data. The crosslink density was used to characterize the aging degree of the HTPB coating, and combined with the modified Arrhenius equation, a model of crosslink density variation with aging time was built. Multiply the hyper-elastic model with the aging characteristic function, an aging constitutive model of HTPB coating was established, which can be used to describe the tensile mechanical properties of aging HTPB coating. The verification tests show that the predicted value of the crosslink density under the test of 313.15K is in good agreement with the test value. The aging constitutive model can predict the tensile mechanical behavior of HTPB coating well, which is of important engineering significance.

Keywords: HTPB coating; constitutive model; accelerated aging test; crosslink density; uniaxial tension; NMR

1 Introduction

HTPB coating is a polymer composite material, in which hydroxyl-terminated polybutadiene rubber is loaded with functional fillers such as corrosion-resistant and anti-abrasive fillers [1]. As a buffer part of the propellant and thermal insulation layer of the solid rocket motor, HTPB coating must maintain good mechanical properties in order to effectively mitigate the external shock during storage and transportation time [2, 3]. In the storage process, the material of the coating will fail due to the effects of radiation, stress, and thermal-oxygen environments, resulting in the destruction of the structural integrity of the rocket engine. The thermo-oxidative aging is considered to be the main reason for the deterioration of the coating performance, and the performance prediction of materials under thermo-oxidative aging condition has always been the focused research in the field [4]. Studying the mechanical properties of the coating and establishing an accurate aging constitutive model will provide an important reference for the structural integrity assessment of solid rocket motors [5].

In recent years, the study of the constitutive model of rubber materials has attracted extensive attention. Zhang FF et al. studied the constitutive model of rubber composites and described the vulcanization and damage effects of the materials well [6]. Taking the influence of stress and strain into account during the aging process, Deng B et al. established the thermo-oxidative aging constitutive model of solid propellant, and verified the model with Abaqus [7, 8]. Zhu XH et al. used the Mooney-Rivlin model and the Yeoh model to study the aging constitutive behavior of the stator rubber, and the model considered the temperature effect [9]. The work above provides guidance for the study of aging constitutive model. The references compared the performance differences before and after aging, but didn't specifically show the effect of aging time and temperature in the constitutive model. Due to the large deformation ability and hyper-elastic properties, it is difficult to accurately predict the mechanical properties, and the study of the aging constitutive model of HTPB coating has not been reported.

A large number of studies have shown that changes like the oxidative polymerization and the

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