

Curing Response Analysis of Solid Motor Propellant Considering Heat Transfer Size Effect

Baoshi Yu^{1,2}, Dapeng Zhang^{1,2}, Wenqin Zhang^{1,2}, Zijian Fan^{1,2}

¹ College of Aerospace Science and Engineering, National University of Defense Technology,
Changsha 410073, China

yubaoshi2020@163.com; zhangdapeng@nudt.edu.cn

² Hunan Key Laboratory of Intelligent Planning and Simulation for Aerospace Missions,
Changsha 410073, China

zhangwenqin22@nudt.edu.cn

Extended Abstract

Complex chemical reactions and heat conduction between multiple media exist in the curing process of composite solid propellant, which further leads to the change of its mechanical properties and stress state, including the temperature and curing degree distribution after solidification, as well as the formation and accumulation of cure-induced residual stress. However, the curing response of this process is different in different sizes of solid engine propellant column, which is called '**Curing Heat Transfer Size Effect**' in this paper.

In this paper, the typical cylindrical structure of the solid rocket motor is taken as the research object, and the size characteristics of the solid motor propellant are characterized by the m number (the ratio of the outer diameter to the inner diameter of the motor propellant) and the aspect ratio (the ratio of the axial height to the outer diameter). Based on Exponential distribution and Weibull distribution, the size effects of the maximum temperature and cure-induced residual stress of the solid motor propellant during the curing process were described respectively, and then a theoretical prediction model of the cure-induced residual stress considering the heat transfer size effect was proposed. The prediction accuracy of the theoretical model was verified in simulation calculations and experiments. Furthermore, according to the typical curing process and common working conditions in engineering, the cure-induced residual stress and strain of the solid motor propellant were calculated, and the structural integrity of the solid rocket motor was evaluated.

The results show that the m number of the solid motor propellant mainly changes the convective heat transfer efficiency of the propellant grain at the shell interface, and the aspect ratio mainly changes the heat transfer efficiency of the grain at the interface of the internal mandrel. Increasing the m number will increase the maximum temperature and the thermal expansion strain of the propellant grain at the curing stage, which will lead to a greater temperature difference in the vulcanization cooling stage, and ultimately lead to a greater residual strain and stress accumulated at the end of the overall curing process. The continuous distribution function can accurately describe the size effect of curing response, and the prediction accuracy of the theoretical model of cure-induced residual stress is above 98%.

Based on the summarized 'Curing Heat Transfer Size Effect' of the solid rocket motor propellant and the proposed cure-induced residual stress-strain theory prediction model, the structural integrity of solid rocket motors with different sizes with the same configuration can be quickly evaluated, which saves the cost of experiments in the research and provides references for the design and development of large solid rocket motor.