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RESEARCH ON EPDM INSULATION ABLATION BY PARTICLE FLOW BASED ON STRENGTH FAILURE MODEL FOR POROUS CHARRING LAYER

Abstract

Ethylene-Propylene-Diene Monomer rubber (EPDM) is capable of forming the charring-pyrolytic-virgin three-layer structure when heated, providing effective thermal protection to SRM chamber walls. However, severe erosion problems often occur on the surface of ablatives due to particles impact from propellant combustion in SRM with high lateral acceleration. Ablation of insulation is generally caused by two distinctly different factors, i.e. particles erosion and thermo-chemical ablation. Although frangibility is usually used to describe structure strength of it, the charring layer is essential to protecting the inner insulation from extremely combustion environment. Once the charring layer is damaged, the pyrolytic and virgin layers are exposed to high temperatures boosting heat transfer to the rocket cases. Therefore, the charring layer is the key to effective SRM thermal protection systems.

The structure of the charring layer formed during ablation is porous, as can be observed by SEM images. However, the charred layer was usually considered as solid in analyzing the erosion problem in some studies. Ignoring the significant porosity characteristic led to disagreement between calculation and the actual blockage rule of the charring layer. In fact, when the impact force of the particle flow exceeds the bearing capacity of porous structure, cracks emerge and the erosion effect becomes increasingly intensive. Therefore, accurate analysis of the strength of the charring layer is the key to predicting particle erosion.

A new charred layer failure strength model with porous structure was developed from extensive structure analyses of charring layer. In this model, the structure of charred layer was described by porosity, and the mathematical relation between tensile strength, compressive strength and porosity for the material has been derived. The parameters needed by the model can be obtained by the basis of tensile and compressive tests. Predicted critical values showed good agreement with the particles impinging experimental results. At the same time, a thermo-chemical ablation model of ablative materials based on porous structure of charred layer was developed. Both of them were used to predict the ablation results of insulation which eroded by particle flow. The results were also proved by the insulation ablation experiments with particle erosion and thermo-reaction.

In this paper, a new model of strength failure which was based on porous skeleton structure was established to analyze the charring layer. The model is used to predict the critical conditions of failure of charred layer. It was verified though experiments, in which pleasant agreement was founded.