Heat Transfer Analysis of High Porosity Fibrous Insulation during Re-entry Space Vehicle

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Abstract

Any object entering the earth's atmosphere from vacuum of space is subject to friction caused by the movement of the object in air. This friction causes these objects to reach temperature upto 1650 ℃, at this range almost anything entering the earth surface simply burns up. The solution for this problem comes primarily in the form of Thermal Protection System (TPS). TPS consists of several sub system like Reinforced Carbon – Carbon (RCC), Low-Temperature Reusable Surface Insulation (LRSI) tiles, Flexible Insulation Blankets (FIB) and High-Temperature Reusable Surface Insulation (HRSI) tiles. This article deals only HRSI material. HRSI is mostly made up of silica fiber material in the form of tiles. This high porosity material is currently used by space shuttle for construction purpose. The knowledge of thermal conductivity of such materials like silica fiber is difficult. So we need standard theoretical approach.

The combined radiation/conduction heat transfer in high porosity fibrous silica was investigated theoretically. The effective thermal conductivity of fibrous insulation sample (silica tile) with density 200 kg/m^3 and thickness 20 mm was calculated over the temperature range of 300-1500 K & environmental pressure range of 1.33 x 10^{-5} KPa to 101.32 KPa. Radiative thermal conductivity of the material (silica tile) was modeled assuming and optically thick medium in which the spectral extinction property was calculated by utilizing the fiber medium scattering phase function and the composition of fiber material. A semi empirical model was used to calculate the fiber-matrix conduction. The gas conduction was mainly dependent upon the environmental gas pressure. The non-linear thermal conductivity was obtained by theoretical approach.

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