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IMPROVEMENTS IN PI AEROGELS FOR FLEXIBLE THERMAL PROTECTION SYSTEM - HYPERSONIC INFLATABLE AERODYNAMIC DECELERATOR (HIAD)

Abstract

Mars has always been an exciting site for scientific discovery, automation, and human exploration. To sustain NASA's long-term purpose of landing humans on Mars, hypersonic inflatable aerodynamic decelerators (HIADs) have evolved as a promising technology as the current design fails to send human-class payloads. After a long disregard, the success of Inflatable Re-entry Vehicle Experiment (IRVE)-2 and IRVE-3 projects have established the potential value of HIAD technology. Flexible HIAD circumvents geometric restrictions, unlike rigid systems fixed in size and shape. The HIAD project involves Flight Validation, Flexible Systems Development (FSD), and Advanced Entry Concepts. FSD includes an Inflatable Structures element and a Flexible Thermal Protection System (TPS) element. The F-TPS covers the inflatable structure and insulates it from the burning heat of atmospheric re-entry and aerodynamic shear forces.

The study focuses on the advancement of F-TPS for the HIAD project. Polyimide (PI) aerogel has emerged as a promising candidate for use in the insulation layer. It offers durability and strength and can reform into thin films with unprecedented flexibility. However, there is a need to modify the material to withstand re-entry conditions. The paper describes the existing challenges with PI aerogels and suggests solutions. It's well-established that standard PIs are easily degraded in atomic oxygen (AO) environments. Introducing polyhedral oligomeric silsesquioxane (POSS) moieties has been found to induce excellent AO resistance, which is crucial in a low earth orbit (LEO) oxygen-rich environment. The percentage content of POSS could also bring considerable modifications in the mechanical and thermal properties. PI-POSS aerogel further has a low decomposition temperature of about 560 degrees Celsius. Due to the low usable temperature range (0 degree to 500 degree Celsius), it gets easily charred. The study suggests a better layup, done in combination with Pyrogel 3350. Proficient works are available on materials, offering improvements in PI aerogels. In this paper, the existing literature is closely analyzed, integrated, and applied to the developing HIAD project.

The recent improvement in aerogel is expected to show significant advancement in other fields. The HIAD technology will be a breakthrough for landing humans on Mars and other atmosphere-rich planets and moons.