

DRAG COEFFICIENTS OF SIMPLE-GEOMETRY ROUGH BODIES

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This paper considers the effect of the surface roughness of Kapton-H polyimide, a typical structural material for the outer surfaces of spacecraft, on the drag coefficients of bodies with simple geometric shapes (a sphere, a cylinder, and a cone). Kapton-H is a benchmark material used in testing polymers for resistance to long-term exposure to the near-satellite environment. The Kapton-H roughness is low. However, during the operation in very low Earth orbits (VLEOs), the roughness of polymers significantly increases. When polymers interact with atoms and molecules of the near-satellite environment, their momentum and energy accommodation coefficients change. As a result, the spacecraft component drag coefficients change too.

The need for studying the drag coefficients of rough bodies with simple geometric shapes stems from the current trends in space research, in particular the need for a long operation of spacecraft in VLEOs at altitudes from 170 km to 300 km, where spacecraft are exposed to hypersonic atomic oxygen (AO) flows with an annual fluence from 1×10^{22} atoms O/cm² to 1×10^{23} atoms O/cm². These conditions significantly affect the service performance of spacecraft, especially those of the structural materials of their outer surfaces, among which polymers play an important role. Exposure to atomic oxygen degrades polymer materials, which manifests itself in changes in the surface structure, roughness, and erosion depth. This, in turn, leads to changes in the aerodynamic and thermal characteristics and the processes of polymer surface – AO interaction.

In particular, changes in the surface roughness of materials change important parameters, such as the solar absorptance and the AO-to-surface momentum and energy transfer coefficients. At the same time, these coefficients depend on the AO fluence, the surface roughness, and the angle between the oxygen atom velocity and the normal to the body surface. All these factors govern changes in the thermal conditions and aerodynamic characteristics of spacecraft in VLEOs, which is crucial for a long-term spacecraft operation.

Changes in the drag coefficients and thermal conditions of spacecraft surfaces affect the service life of spacecraft. The presented results are of practical importance in selecting polymer materials for spacecraft's outer surfaces at the design stage.

Keywords: drag force coefficients, polyimide, roughness, spacecraft.

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