TEXURING CARBON-CARBON COMPOSITE RADIATOR SURFACES UTILIZING ATOMIC OXYGEN

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Future space nuclear power systems will require radiator technology to dissipate excess heat created by a nuclear reactor. Large radiator fins with circulating coolant are in development for this purpose and an investigation of how to make them most efficient is underway. Maximizing the surface area while minimizing the mass of such radiator fins is critical for obtaining the highest efficiency in dissipating heat. Processes to develop surface roughness are under investigation to maximize the effective surface area of a radiator fin.

Surface roughness is created through several methods including oxidation and texturing. The effects of atomic oxygen impingement on carbon-carbon surfaces are currently being investigated for texturing a radiator surface. Early studies of atomic oxygen impingement in low Earth orbit indicate significant texturing due to ram atomic oxygen. The surface morphology of the affected surfaces shows many microscopic cones and valleys which have been experimentally shown to increase radiation emittance. Further study of this morphology proceeded in the Long Duration Exposure Facility (LDEF). Atomic oxygen experiments on the LDEF successfully duplicated the results obtained from materials in spaceflight by subjecting samples to 4.5 eV atomic oxygen from a fixed ram angle. These experiments replicated the conical valley morphology that was seen on samples subjected to low Earth orbit.

Previous Monte Carlo computer simulations of atomic oxygen impingement on such surfaces predict the conical morphology of experimentally derived surfaces. A particular two-dimensional computer model developed at NASA Glenn simulates the arrival of atomic oxygen onto a polymer substrate through a defect zone in a protective coating. This model is analogous to a Kapton substrate covered by a glass-fiber matrix with microscopic defect zones. The model is completely adjustable to simulate any kind of substrate geometry, physical behavior, and atomic oxygen impingement characteristics that the operator desires. Arrival of atomic oxygen can be from a fixed ram angle, isotropic to simulate an oxygen plasma environment, or sweeping to simulate arrival on a solar oriented surface. Energies of the incoming atoms can be selected to match low Earth orbit conditions, any other fixed energy, or energy based on a Maxwellian distribution for thermospheric atoms with respect to the orbital velocity and angular inclination. Impingement surface characteristics allow the modeler to change the reactivity and recombination probabilities for atomic oxygen on that particular surface, be it polymer or protective coating.

Modeling parameters that lead to simulated surface textures obtained experimentally in the LDEF were identified when the Monte Carlo simulator was first used. Optimal vales for these parameters were obtained and simulations using these values continue to agree with the surface morphology obtained experimentally on the LDEF. Simulations show that impingement on a flat surface with fixed angle arrival of atomic oxygen increases surface roughness continuously during impingement but at a decreasing rate (non-linear.) Isotropic impingement leads to a negligible surface roughness due to the breakdown of tall cones by atomic oxygen arriving from all angles.

The model is currently being updated with a statistics package to analyze the morphology of the surface during its growth. Measurements of the cones on the eroded surface allow the operator to identify an "aspect ratio" for the cones, which may be a good indicator of surface roughness. The cone statistics algorithm looks for cones across the entire surface of the erosion area and attempts to identify cones that have a similar aspect ratio and overall size, since experimentally the overall size of the cones and valleys of a particular morphology are relatively constant at any given time. The total surface area of the eroded polymer is also calculated. These statistics are then graphed and can be visualized immediately following the simulation, or saved for later use. Another addition to the model includes an automation feature to allow the operator to input parameters for many different simulations and let them proceed without operator intervention. Through the cone analysis and automation package developed it is hoped to identify which parameters in the model to adjust to increase and decrease cone aspect ratio, surface roughness, and surface area.

Experimental study of carbon-carbon surface texturing is continuing through operation of an end Hall thruster to impinge atomic oxygen on carbon-carbon composites. By varying the operational parameters, it is hoped that a procedure for texturing surfaces optimal for radiators can be achieved. While the Monte Carlo simulation allows for variation in many different parameters for atomic oxygen introduction, surface characteristics, and atom / surface interactions, the variables most likely to be of parametric importance are initial atomic oxygen energy and impingement time. The Monte Carlo model will be used to mimic the workings of the end Hall thruster and allow researchers to determine how best to operate it to achieve maximum surface roughness. Through computer modeling and experiment the goal is to find an optimum surface roughness for heat dissipation in future space power systems.