CHARACTERIZATION OF SPACE DEBRIS MATERIALS DURING THEIR ATMOSPHERIC ENTRY

Marianne Balat-Pichelin (1), Lucile Barka (1), Arnaud Bultel (2), Julien Annaloro (3)

(1) Laboratoire PROMES-CNRS, UPR 8521, 7 rue du four solaire, 66120 Font-Romeu Odeillo, France, Marianne.balat@promes.cnrs.fr
(2) CORIA, UMR 6614, CNRS et Université de Rouen, 675 avenue de l’Université, 76801 St-Etienne du Rouvray, France
(3) CNES, DCT/TV/PR, 18 avenue Edouard Belin, 31401 Toulouse, cedex 9, France

ABSTRACT

In order to mitigate debris in orbit and to avoid dramatic collisions on Earth after atmospheric re-entry at its end-of-life, the spacecraft missions have to take into account the influence of atmospheric re-entry conditions on the spacecraft survivability. The materials to be used in the spacecraft must take into account the different new rules, in order to be mainly or totally destroyed due to the severe aerothermodynamic and aerothermochemical conditions encountered during the re-entry phase. The non-equilibrium air plasma flow impinging the material enhances oxidation phenomena due to the presence of atomic oxygen. Oxidation, ablation and melting coupled phenomena can occur on the material leading to an important damage of the materials.

In this way, oxidation in air plasma conditions, close to those encountered during re-entry, was studied using the MESOX facility available at PROMES-CNRS on metallic alloys such as Inconel 718, TA6V, SS 316L and 304L, and Invar in order to obtain degradation kinetic laws at high temperature (up to the melting point of the alloys) and for short time duration (few minutes). Then, the measurement of the total directional emissivity – and hemispherical value obtained by integration – at high temperature using the MEDIASE facility of PROMES-CNRS was carried out on the same virgin alloys – in high vacuum to avoid oxidation – and on samples oxidized in air plasma conditions, and in situ in standard air. An increase of the total emissivity for oxidized samples by a factor 3 to 4 is obtained compared to virgin samples. This effect strongly influences the heat flux and could also act on the ablation during a trajectory and consequently on the casualty area calculation.

Some experimental results on oxidation and emissivity will be presented together with microstructural characterization of the samples using different techniques such as SEM, XRD and 3D roughness profilometry. The previous degradation kinetic parameters have been used to determine the oxidation rate coefficients expressed under Arrhenius-type laws. Since the oxidation mechanism leads to the formation of a specific type of oxide with a modification of the specific mass of the oxide layer with respect to the virgin alloy, this specific mass has been calculated. Then, equations driving the growth kinetics of the oxide layer have been derived as well as those of the energy and mass fluxes. A complete modelling of the oxidation kinetics has been therefore implemented in coupling with the thermal balance of typical objects considered as test-cases in DEBRISK (CNES code). The results clearly show that the oxidation mechanism only slightly increases the energy flux, even at high temperature. This increase does not basically modify the thermal evolution of the considered object. However, the calculations show that the relative mass decrease of TA6V objects can reach some percent, which could have some influence on their flight conditions.

Moreover, calculations have been also performed considering the change in the total emissivity due to the oxidation mechanism. Since the related change can be significant, the thermal evolution can be deeply modified. For instance, the melting of the concerned material can be avoided.

Topic: Materials and processes in extreme environments