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FRACTOGRAPHIC ANALYSIS OF A FLYING TEST BED UHTC NOSE TIP

Abstract

The capsule SHARK (Sounding Hypersonic Atmospheric Re-entering "Kapsule") has been designed and realized for testing in real flight conditions a ZrB2-based UHTC Nose Tip. The capsule has been instrumented with thermocouples, accelerometers, rate and pressure sensors and three thermocouples were inserted inside the UHTC Tip. The capsule was launched by the ESA rocket MAXUS-8 and, after a parabolic trajectory with an apogee at 700 km of altitude, it performed an atmospheric re-entry. The temperature profile recorded by the thermocouples inserted inside the Nose Tip has reported a discontinuity at about 760 s after the release from the rocket, revealing a probable failure of the ceramic component during the flight. The capsule has been recovered at less than 3 km from the calculated impact point. The Nose Tip has been found damaged: the fore half was missing while the inner part was fractured in three pieces all of them recovered. The fractographic analysis of the three recovered fragments has been carried out by naked eye and optical microscopy techniques. The fracture surface has been studied and the main fracture marks, such as fracture mirror, mist, hackle lines, arrest lines and Wallner lines, have been highlighted. The probable origin of the main fracture has been identified on the edge of the hole for thermocouples where the hackle lines seem to converge. The strength limiting flaw seems to be a defect caused by the electrical discharge machining used for the realization of the hole itself. The fracture dynamic has been outwardly reconstructed and the stress at fracture has been evaluated by means of a semi-empirical correlation and the measurement of the fracture mirror radius. Then, applying the Griffith equation, the flaw size has been estimated to be about equal to 85 μm. Considering the shape of the fracture surface, the thermal shock due to the hypersonic flight conditions has been proposed as the most likely failure cause. Moreover the fractographic analysis performed on the three recovered fragments of the inner part has demonstrated the fracture origin is located approximately at the bottom of the thermocouples hole. The strong analogy with a plasma wind tunnel experiment performed by the CIRA on a similar UHTC Nose Tip, with an inner hole, manufactured with the same machining technology, has induced to recognize the thermal shock as the probable failure cause. The fractographic results have been also compared with the thermo-structural rebuilding and the temperature sensors measurements.