Novel Ultra High Temperature Composites for Extreme Space Applications

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Space exploration requires materials with extreme properties and capabilities. Materials used in exploratory spacecraft have to display high strength and toughness at minimum mass and with very high reliability. The craft have to operate flawlessly after extended periods in vacuum, exposed to both extreme cold (close to absolute zero) and extreme heat (e.g. when close to the sun), all the while bombarded by high energy charged particles.

Among all capabilities that spacecraft sub-systems need to demonstrate, two stand out by their thermal superlatives. Firstly, an exploratory spacecraft, on its return to earth, needs to be able to withstand the extreme heat fluxes generated by friction during high speed entry into the atmosphere. Such heat fluxes can reach as much as 15MW/m^2 (at a speed of about 12km/sec) and induce a high temperature plasma in the shock wave in front of the craft. By way of comparison, the earth receives only about 300-700W/m^2 from the sun at best. All "earth-return capsules" need to be protected by a "heat shield" (Figure 1) otherwise they would explode and/or evaporate in seconds!

Significantly, the heat fluxes though the wall of a rocket combustion chamber (Figure 2) can also reach levels approaching 10MW/m^2 and temperatures well in excess of 3000^{o}C. Usually all rocket engines use dynamic cooling, but what if cooling is only by radiation to space?

Extreme conditions require extreme materials systems and creative solutions. What materials can we use for a heat shield? What materials can we use for a combustion chamber if we are restricted to cooling by radiation only? This brief review will introduce these two challenges and discuss the possible solutions used worldwide. In particular, some of the results obtained from the ESA (European Space Agency) project "HybridTPS" and the EC/FP7 projects "RastasSpear" (2010-2013) and "Pulcher" (2013-2015) will be presented and discussed.

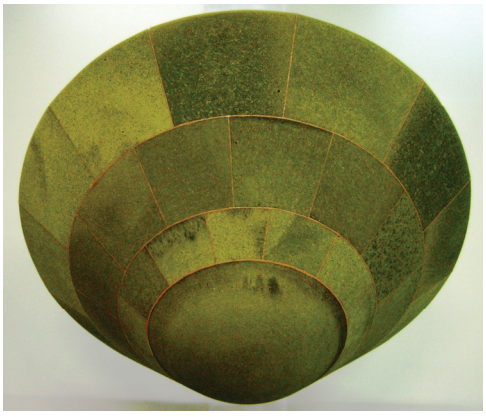

Figure 1. The Heat-shield demonstrator tested and built for FP7/RastasSpear

Figure 2. A satellite rocket combustion chamber (glowing) undergoing static tests