ICME design of functionally graded materials for enhanced space components

Stockholm, Sweden, September 2023 – QuesTek Europe is working with the European Space Agency (ESA) to develop new materials and processes for next-generation spacecraft. The FunGradS project, fully funded via the ESA GSTP de-risk program, under contract number 4000141768/23/NL/GLC/rk, focuses on functionally graded materials for additive manufacturing of space components.

Specifically, QuesTek's team of engineers is developing an ICME framework to be used for efficient design and development of functionally graded materials (FGM). To demonstrate feasibility, a novel FGM will be designed that is intended for rocket nozzle extensions, based on a material combination proposed by GKN Aerospace, a key subcontractor of Ariane rocket engine subsystems. The computationally designed FGM is to be produced by direct energy deposition (DED) at University West.

Additive manufacturing (AM) technologies can significantly reduce the lead time and cost of fabricating space components, e.g., 2/3 reduction for rocket combustion chamber fabrication as demonstrated by NASA[1]. However, printing bimetal structures is complicated, and no reliable material solutions are available on the market. Issues in bimetal printing such as geometrical instability due to residual stresses, or cracking at the interface due to the formation of detrimental phases make joining extremely difficult and time-consuming.

FGMs have been proposed as a solution to these technical issues, with graded transitions replacing the sharp interface between dissimilar materials. The options for graded transition could be many, covering vast composition spaces and a complex AM process parameter space. Finding high-quality solutions by trial-and-error would be very expensive and time-consuming. To avoid this, QuesTek is utilizing ICME models and tools to design an optimized composition path and deposition strategy for a robust FGM / joint structure. In addition to resolving the known challenges of bi-metallic AM, custom-designed FGMs are expected to provide additional benefits such as increased thermal cycling stability, and reduced residual stresses and thermal expansion mismatch for better part geometry control. Computational FGM design and development using QuesTek's ICME technologies will accelerate the insertion of multi-material AM in the space industry, enabling sustainable, lower-cost and higher performance rocket propulsion for next generation spacecraft. The established design framework and the developed FGM solutions may also be adapted for broader space applications and other industry sectors, such as energy and aerospace.

[1]Fabio Kerstens, Angelo Cervone, Paul Gradl. "End to end process evaluation for additively manufactured liquid rocket engine thrust chambers". Acta Astronautica, 182 (2021) 454-465.