ABSTRACT – Student Speech Contest

Polymer binder-free additive manufacturing of reaction-bonded silicon carbide through laser powder bed fusion

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Additive manufacturing (AM) offers ceramic components a design freedom that conventional shaping cannot match. Yet nearly all ceramic AM processes, including vat photopolymerisation, material extrusion and binder jetting, rely on a substantial polymer binder fraction. Its removal by debinding is slow, restricts the maximum wall thickness and, combined with sintering, introduces shrinkage and possibly distortion. For silicon carbide (SiC), which is difficult to sinter and strongly absorbs UV light, these limitations are particularly severe.

This presentation discusses a binder-free alternative: laser powder bed fusion (LPBF) of a SiC–Si powder blend, in which only Si melts and bonds the SiC particles into a porous preform. Carbon is then introduced by polymer infiltration and pyrolysis (PIP), and the preform is densified by liquid silicon infiltration (LSI), forming reaction-bonded SiC (RBSC) without debinding and without shrinkage. The initial route was limited to ~50 vol% SiC, with ~40 vol% residual Si and ~10 vol% unreacted carbon, because of the low preform density (~45 vol%) and carbon "choking" by dense SiC shells.

Three key processing steps were optimised. (i) Feedstock: spherical, gas-atomised Si improved flowability and packing. (ii) LPBF: a larger laser spot (90 vs. 50 µm) smoothed thermal gradients. Together, this raised the preform density from 44.7 ± 0.8 to 55.9 ± 0.5 vol% while increasing the build rate from 0.23 to 2.40 mm^3/s, after which the processing parameters were optimised further. (iii) Carbon source: an intermediate Si-to-SiC conversion step and tuning of the resin constituents improved carbon yield and reactivity, limiting choking. Together, these steps have so far raised the SiC fraction from ~50 to ~80 vol%, with further gains expected from the latest LPBF optimisation. Already at an intermediate stage (62 vol% SiC), the material reached E = 266 ± 5 GPa, a flexural strength of 221 ± 21 MPa and a thermal conductivity of 136 W/mK.

Finally, the presentation shows how the design freedom of the route is exploited in aerospace application studies: morphing thermal protection systems tested in the VKI Plasmatron at ~1000 °C, gyroid-based heat exchangers and, prospectively, lightweight mirrors. It concludes with ongoing work on joining LPBF SiC with C/C and C/SiC composites to add damage tolerance, and with the industrial valorisation perspectives of the route.