Improving adhesion in bonded ceramics through novel additively manufactured surface geometries

Final year PhD

DSDS24, Cranfield Defence and Security Doctoral Symposia 2024, 13-14 November 2024, STEAM Museum, Swindon, UK

1. Introduction - the problem

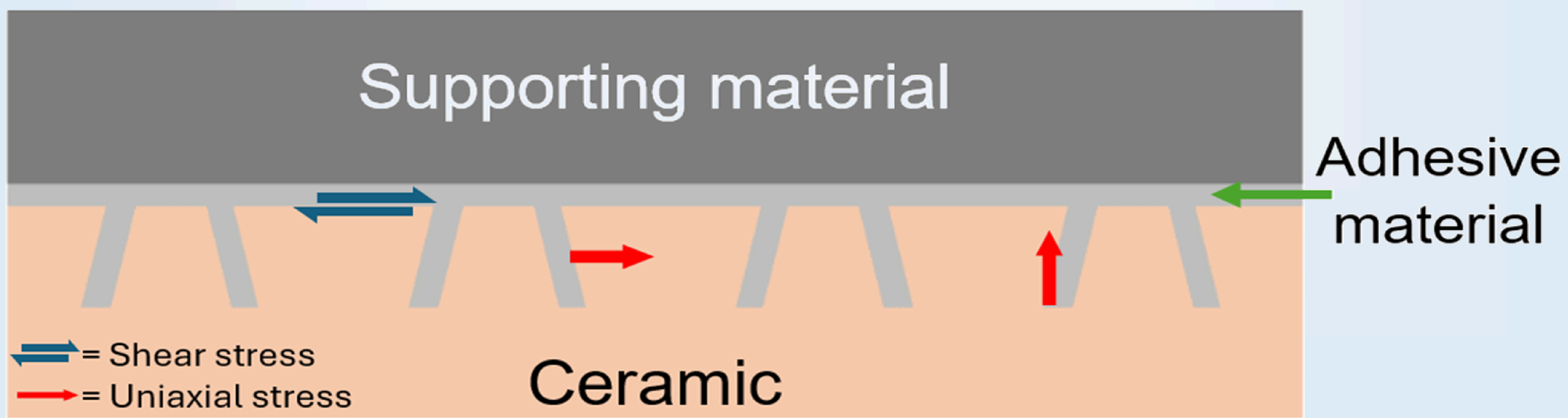
Many high-value industries (including medical, aerospace, nuclear, and defence) utilise **ceramics** for their favourable properties, such as high hardness, low thermal / electrical conductivity, and chemical resistance. The latter property results from chemical inertness, but this inertness also causes **weaker bond strengths when joining ceramics** with other materials, which is typically undesirable.

The brittleness of ceramics limits their machinability and restricts the use of mechanical fasteners (i.e. bolts, rivets etc.). Instead, polymeric adhesives are often used. Such adhesives **typically bond poorly with ceramics** and preferentially fail at the ceramic-adhesive interlayer, although this can be **overcome through altering the surface of the ceramic**[1,2].

2. Ceramic additive manufacturing

Additive manufacturing (AM) builds components layer-by-layer, each layer typically tens of microns thick. In recent years the fabrication of ceramics through AM has progressed to allow the production of far more complex geometries and components, even across **small dimensions of <500 µm**.

AM designs otherwise impossible to produce through conventional manufacturing techniques could improve the bond strength at ceramic surfaces through improved mechanical adhesion, known as **'mechanical interlocking'**, already seen to be successful at the nanoscale[2]. An example of this is shown below, capable of resisting both shear and uniaxial stresses that arise from loading of the bond.

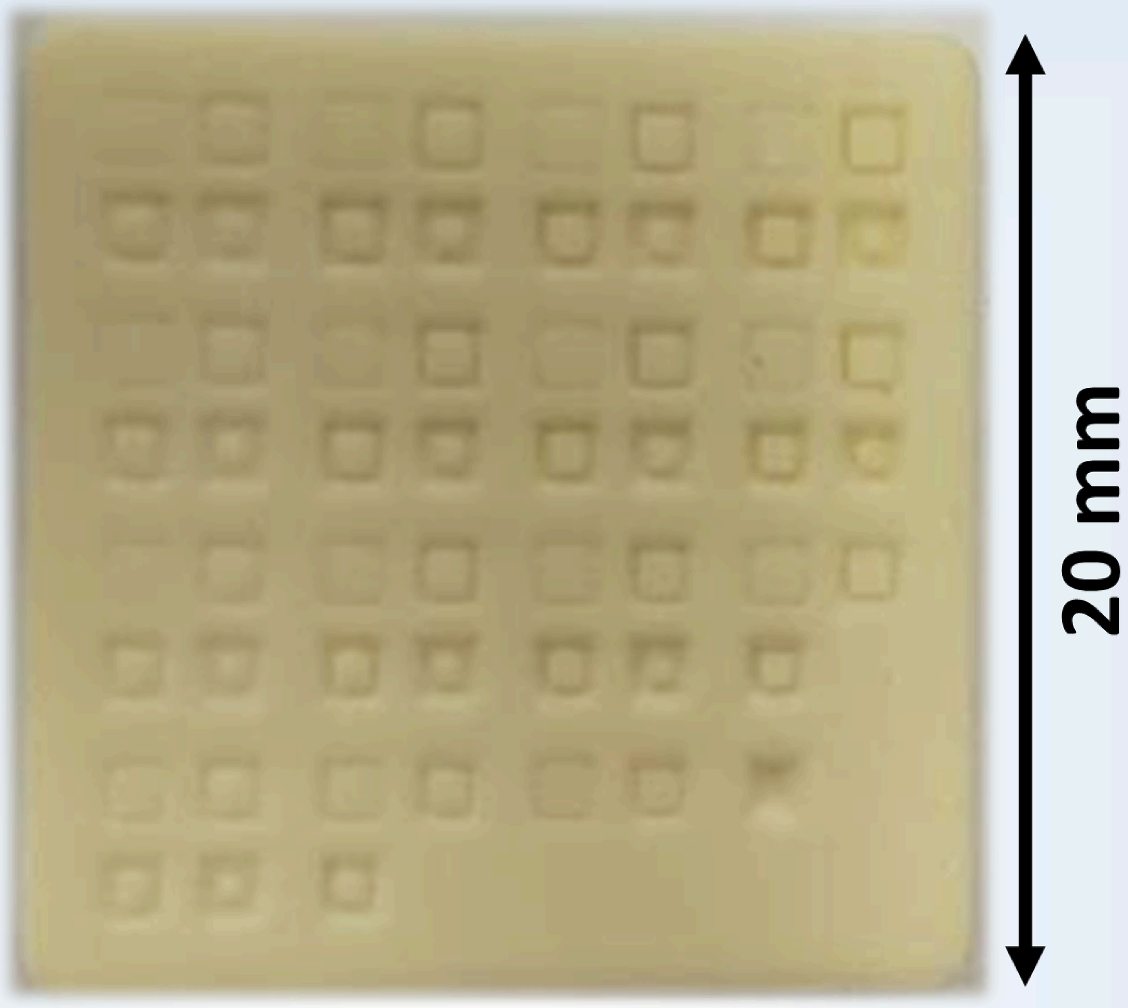


1. Harris, A. J., Vaughan, B., Yeomans, J. A., Smith, P. A., & Burnage, S. T. (2013). Surface preparation of silicon carbide for improved adhesive bond strength in armour applications. *Journal of the European Ceramic Society*, *33*(15–16), 2925–2934. https://doi.org/10.1016/J.JEURCERAMSOC.2013.05.026

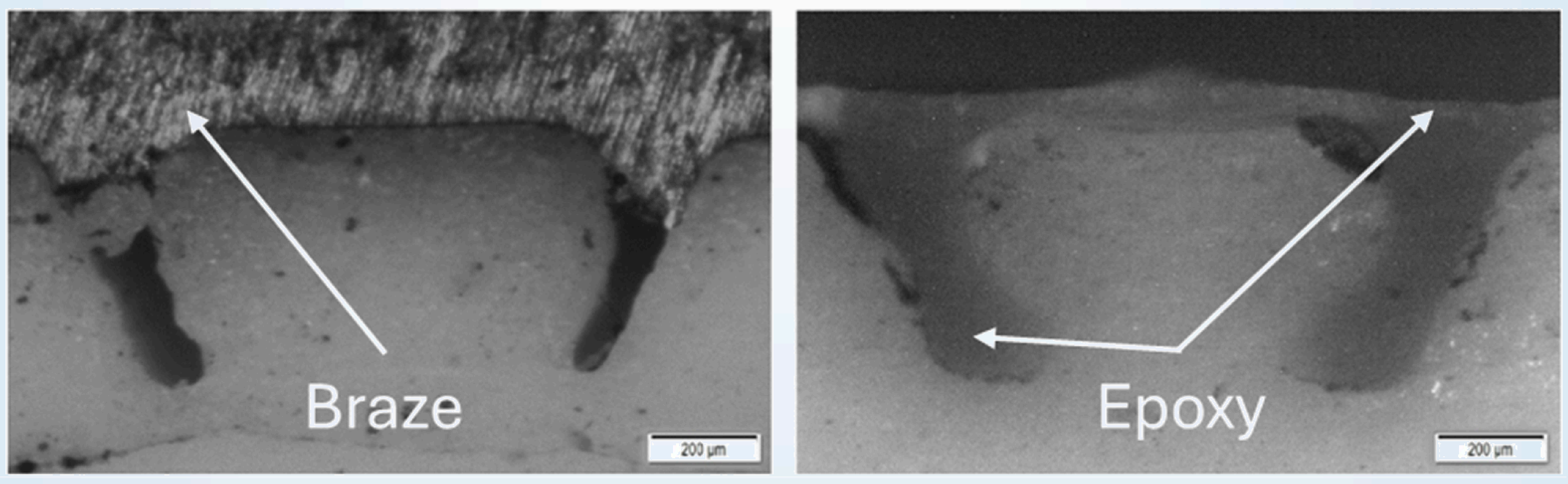
2. Abrahami, T., de Kok, M. M., Chakravarthy, V., Mol, M. C., Abrahami, S. T., M de Kok, J. M., Gudla, V. C., Ambat, R., Terryn, H., & C Mol, J. M. (2017). Interface strength and degradation of adhesively bonded porous aluminum oxides. *Npj Materials Degradation*, *1*. https://doi.org/10.1038/s41529-017-0007-0

3. Approach and results

AM alumina ceramic tiles were manufactured with **57 different surface geometries** through altering the channel depths, widths, and angles, as shown below:



These were then infilled with epoxy and an Incusil active braze alloy to assess the successful infiltration of each channel with these materials. The best formed channels are shown below:



The intended mechanical interlocking was not formed with the braze as it did not flow sufficiently to infiltrate the channel. However, the **epoxy entirely filled the channel** and cured, forming a well-formed jigsaw-shaped joint at the ceramic surface.

4. Conclusions

Whilst not tested mechanically due to the current cost and other challenges still faced by ceramic AM, the potential for increased bond strength through AM geometries on ceramic surfaces was demonstrated. These microscopic channels could be introduced to future AM components, regardless of complexity, **improving bonding with minimal disruption to the function of the macroscopic ceramic component**.

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Data beyond that presented here to support this study are not publicly available due to commercial sensitivity. Please contact d.powell@cranfield.ac.uk to discuss access.

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