Size effect in advanced materials for aero engines

Arun Raina

German Aerospace Center (DLR e.V.)
Am Technologiezentrum 5, 86159 Augsburg, Germany
E-mail: arun.raina@dlr.de – Web: www.dlr.de/sg

ABSTRACT

Intermetallics such as γ-Titanium Aluminide (TiAl) alloys and composites such as Ceramic Matrix Composite (CMC) materials are attractive replacements of currently used Nickel based super alloys in the low pressure and low temperature sections of a jet engine. TiAl and CMC materials have better specific strength and excellent oxidation resistance compared to Nickel based super alloys [1, 2]. However, due to their complex microstructure sensitive macroscale mechanical response these advanced materials have not found wide acceptance in the aerospace industry until now.

In this work, an investigation of the sensitivity of the fracture strength of TiAl and CMC materials to the specimen size is performed. The observed size effect is not predicted by the classical weakest link Weibull model. Therefore, a physically motivated modification to the Weibull theory is proposed.

The simulations of failure in TiAl are performed with the method of phase field fracture [3]. The length scale parameter introduced to regularize the sharp crack topology is conventionally understood as a numerical parameter which is related to the finite element size. We investigate the nature of this length scale parameter and its relation to the specimen volume in the light of new data available for the given TiAl alloy with full 3D simulations of compact tension test and three-point bending test.

Finally, simulation results are shown for a statistically representative unit cell of a TiAl alloy microstructure. A failure map within the parametric space of non-dimensional groups w_c/w_p versus ℓ/a_T presents interesting features of the microstructure sensitive TiAl alloys. Here, w_c and w_p represent the threshold energies for fracture and plastic flow, respectively; ℓ is the average grain size and a_T is the transitional flaw size.

REFERENCES

[1] F. Appel and R. Wagner, Microstructure and deformation of two-phase γ-titanium aluminides, Materials Science and Engineering, **R22**, 187-268 (1998).

[2] J. A. DiCarlo, Advances in SiC/SiC Composites for Aero-Propulsion, N. P. Bansal and J. Lamon, eds. Ceramic Matrix Composites: Materials Modeling, and Technology. Chapter 7. Hoboken, NJ: John Wiley & Sons, 217-235 (2015).

[3] C. Miehe, F. Aldakheel and A. Raina, Phase field modeling of ductile fracture at finite strains: A variational gradient-extended plasticity-damage theory, International Journal of Plasticity **84**, 1-32, (2016).