MODELING OXIDATION INDUCED CRACK HEALING IN NON-OXIDE CERAMICS AND METALLO-CERAMICS

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ABSTRACT

Recently it has been shown for non-oxide ceramics [1] and metallo-ceramics (in particular MAX phase ceramics [2,3]) that surface cracks can heal very effectively upon exposure to air at high temperatures, leading to a partial and sometimes an almost complete restoration of the (tensile) mechanical properties [4]. This high crack healing efficiency far exceeds that of diffusive healing of two fracture surfaces in contact [5,6] and is due to the formation of (a mixture of) oxides creating an almost dense deposit in the crack. For well-performing systems three requirements have been identified: (i) the oxide must adhere very well to the matrix material of the crack faces; (ii) oxidation must induce volume expansion, allowing the crack filling with oxides; (iii) the initial crack width must not exceed the thickness of the oxide layer formed. Therefore, the oxidation behavior of the crack surface plays a critical role on the crack healing and the subsequent strength recovery of the cracked ceramics.

In this work we present a model to describe and quantify the healing efficiency of oxidative crack healing of such high temperature ceramics as a function of the exposure conditions, the oxidation kinetics and the volume expansion upon oxidation. The model is based on geometrical consideration related to crack filling as well as stress transfer across an irregular crack with partial contact along the length of the crack. The model is applied to the most promising self healing high temperature materials such as SiC, Ti₃AlC₂, Ti₃AlC, and Cr₂AlC. Figure 1 shows a V-notch crack in a non-oxide ceramics. Figure 2 shows that the evolution of the crack length in Figure 1 with healing time at various temperatures.

The model calculations are supported by both 3-point bend test experiments on healed samples as well as by X-ray tomographic experiments on healed and partially healed samples.
REFERENCES


