Long-Term Reliability of Metal/Ceramic Structures

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A metal/ceramic component is joined at a high temperature (i.e., at the melting temperature of a Ag-Cu eutectic brazing joint which is less than that of stainless steel and alumina elements). This component is a part of an electromagnetic sensor whose long-term reliability has to be assessed. Because of the coefficient of thermal expansion mismatch, the temperature drop induces residual compressive and shear stresses in the brittle part of the component. These stresses may lead to failure induced by instantaneous or delayed crack propagation in alumina.

The fabrication process is simulated by a finite element computation [1]. Since the failure stresses of brittle materials are scattered, the initial and long-term lives are evaluated by using a probabilistic approach. By making the weakest link hypothesis and using the Weibull model, it is concluded that such a component cannot sustain the fabrication process. This conclusion is not realistic, however it shows that some cracks have propagated during this cycle and have been stopped by the compressive zones of the ceramic part. This result has been observed in real components.

To describe crack propagation and crack arrest, we have considered that the intersection between the crack path and the alumina microstructure consists of either grains of equal length and random toughness for transgranular failure, or grain boundaries of equal length and random orientation for intergranular failure. It can be noted that a Poisson mosaic could have been used [2]. The probability density function of the toughness is determined by micro-hardness experiments [3],[4]. By choosing the Griffith criterion, the propagation probability along a given path is computed. Consequently, the initial reliability of the component is assessed and it is shown that crack arrest is likely to occur.

Once the initial state of the alumina part is known, the increase of crack length is computed for in-service conditions. In particular, the fabrication stresses are considered as well as static fatigue. The sub-critical crack propagation is modeled and enables one to evaluate delayed propagation conditions. An upper bound to the propagation length is obtained by analyzing near-threshold conditions (i.e., for long-term lives).

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