Thermal ageing of electronic component solder joints for space applications: a combined finite element and deep learning approach

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Electronic assemblies used for space applications must fulfill high-end standards in terms of quality and reliability. These assemblies, made of components soldered on printed circuit boards (PCBs), are exposed to thermal cycling due to the satellite's orbit around the Earth and/or due to interrupted operating modes. Mismatches in the coefficients of thermal expansion of the assembly's materials, i.e. components, solder joints and PCBs, lead to cyclic deformation and fatigue damage within the joint [1,2]. This behavior is governed by the elasto-viscoplastic response [3] of the low melting temperature (tin-lead) solder alloys under typical satellite operation conditions, combined to the damage resistance of the material and interfaces.

The aim of the present study is to predict the fatigue behavior of these solder joints and more specifically the impact of the key material and geometrical parameters on crack propagation. The focus will be on chip resistor solders joints. Experiments have indeed shown that these assemblies are prone to premature crack initiation and propagation within the solder layer during thermal cycling.

A dataset of more than 170 micro sectioned joints has been compiled and is used to train a deep neural network. The model is divided into two sub models, the first being a classification between cracked and non-cracked solder joints (due to crack length data distribution centered in two regions) and the second, a regression to estimate crack lengths.

Alongside, finite element (FE) simulations making use of a temperature-dependent elasto-viscoplastic constitutive model for the solder material are performed with crack growth modelled through cohesive elements at the interface between the component and the joint, where failure is commonly observed experimentally. The deep learning processed experimental data and the FE simulations are compared, proving the ability of the numerical model to capture key failure trends.

Once validated, the FE model is used to run a parametric study by varying one by one the important material properties and geometric parameters, e.g., component length, thickness, termination length and solder joint thickness, providing new guidelines for electronic assembly designs.

References

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