Abstract

Modern engineered structures are currently developed with advanced materials for improving mechanical performances or to better meet the design requirements. For example, the capability to withstand multiple combinations of design loads or the in-service solicitations in a broad frequency spectrum. To do so, lightweight design approaches combining the simultaneous adoption of different materials are typically followed. In this regard, an efficient method for coupling different mechanical components is performed by using adhesive joints. These materials have the capability to save mass, connect different shapes and ensure a smoother stress distribution compared to conventional joining methods (e.g., welding, riveting, …).

An issue that often arises in designing adhesively bonded joints regards the presence of stress-singularities. These originate at the material interface as a consequence of discontinuities in the boundary conditions. Singular stress fields represent a concern during the design of mechanical connections as they could trigger cracks within the joint. Under severe loads plasticity can compensate the singualrity effects, nevertheless under low-amplitude loads this feature could weaken the joint integrity, reducing its service life and thus generating failures. Appropriate design plans should therefore be implemented to produce more reliable apparatus.

Moreover, structural design and analysis approaches assume mechanical properties in numerical codes as frequency, or load, independent for simplicity of calculation or due to the lack of experimental data. Such approach could lead to under/overestimate the structural responses, implying overdesign or failures in static, dynamic, thermal, or cyclic loading conditions.

The work proposed in this manuscript investigates both the effects of singular and non-singular stress fields on the Very High Cycle Fatigue (VHCF) performance of adhesively bonded butt-joints (Aluminum 7075 T6 - SikaPower®-1277 Epoxy resin) and loading-frequency effects under conventional excitations (i.e., 5, 25, 50 Hz) and the ultrasonic ones (i.e., 20 kHz) adopted in VHCF. To do so, analytical, numerical and experimental methods have been adopted. Analytical models were

used for both design the VHCF specimen and for achieve a stress singularity-free joint. Numerical techniques of Global-Local Finite Elements type studied the stress distributions in detail. Finally, fatigue experiments in both HCF and VHCF extracted S–N outcomes ad probability assessments were performed by using ad-hoc developed statistical models.

The suitability of the overall approach is numerically confirmed and a substantial increase of the joint life is experimentally observed if the singularity is removed. Nonetheless, a non-singular configuration leads to higher scatter data compared to the original specimen configuration.

Fatigue tests assessing the loading-frequency effects have shown an important impact of this phenomenon for the investigated adhesive. Indeed, test data present a clear separation, in the range of order of magnitudes of cycles, between low and high frequencies. The interpolation of fatigue strengths at $N=2\cdot10^6$ suggests a precise trend and such information is exploitable to extract values out of the experimental range. The experimental variability is present but has a minor impact on data.