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NUMERICAL MODELLING AND EXPERIMENTAL BEHAVIOUR OF ADHESIVE JOINTS UNDER DYNAMIC LOADING

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ABSTRACT

Adhesive joints play an essential role in the aeronautical industry, but the methods to dynamically characterize these joints are not standardized. In addition, there is a lack of research regarding the use of composite specimens. The Butt Joint (BJ) and Single Lap Shear (SLS) tests are intended to obtain the traction and shear strengths of adhesive joints. However, these tests are not particularly designed to extract the input properties needed to feed a cohesive model in a Finite Element (FE) framework. The main reason is the material strength under prediction caused by a non-uniform stress field on the adhesive region. The objective of the present study is to define suitable specimens for the characterization of the tensile and shear strengths of the FM-300M structural adhesive under Quasi Static (QS) and Dynamic (DYN) conditions.

A bonded specimen, in particular a SLS configuration, has been selected for the adhesive shear strength characterization. The Double Lap Shear (DLS) configuration was discarded due to the impossibility to control a perfect symmetric crack front in both bonded areas. Carbon-Fiber-Reinforced Polymer (CFRP) adherents are used to obtain a strength value representative of a composite bonded structure. This specimen does not require complex mechanization as for example collar type or split cylinder lap joints. Therefore, it is more suitable for composite adherents [1]. The slotted configuration is used to ensure the line of force to be coincident with the adhesive. Besides, the bending deformation is reduced with this configuration because the cross-section inertia of the arms is higher than with the unslotted configuration.

The QS geometry recommended by the AITM1-0019 standard has been modified to reduce bending and achieve a pure shear deformation mode. In addition, the specimen dimensions have been adapted for the DYN characterization to account for a possible magnification of the adhesive strength due to the strain rate sensitivity of the adhesive and to improve the dynamic equilibrium. The Split Hopkinson Pressure Bar (SHPB) device in compression configuration (Figure 1) has been used for the DYN characterization. The tensile configuration has been discarded because requires the use of complex adherent-bar fixing systems. We analysed two impact velocities of the striker: 6.5 m/s and 12 m/s. This way, with these two strain rates plus the QS reference, we will have enough data to clarify the strain rate dependency of the adhesive. The classical SHPB analysis method is applied to compute the shear stress at the adhesive and Digital Image Correlation (DIC) for the shear strain. The QS and DYN specimen dimensions have been defined through parametric studies based on numerical simulations. The adhesive material model used in these simulations does not include the strain rate

dependence of any property. For this reason, different inputs for the shear strength have been considered. The mode II fracture toughness (G_{IIc}) has been demonstrated to modify the strength prediction. The reason is that the region of degraded material (fracture process zone) is concentrated in a smaller area when G_{IIc} is reduced [2].

SLS simulations exhibit a pure adhesive fracture while delamination appeared at the BJ specimen. Therefore, steel adherents were selected for the BJ test. A novel bonne shaped BJ specimen has been proposed to characterize the traction adhesive strength (Figure 2). The SHPB device in tensile configuration has been used for the DYN characterization. The proposed bonne configuration allows to apply pretension torque between the specimen and the bar in order to reduce noise on the strain gauge signals. The dimensions of the specimen have been selected to have a homogeneous stress field at the adhesive and a proper dynamic equilibrium, reducing as much as possible the inertial effects. An auxiliary adherent-bar mounting system has been designed to isolate the adhesive joint during the application of the pretension torque. In addition, a manufacturing tooling system, based on calibrated shafts, has been designed in order to ensure a perfect alignment of the two adherents with the two tester bars (Figure 2).

This research contributes to the definition of standard methods to characterize adhesive joints, boosting the design of aeronautical components. This work has received funding from the Clean Sky 2 Joint Undertaking (JU) under grant agreement No. 886519. The JU receives support from the European Union’s Horizon 2020 research and innovation programme and the Clean Sky 2 JU members other than the Union.

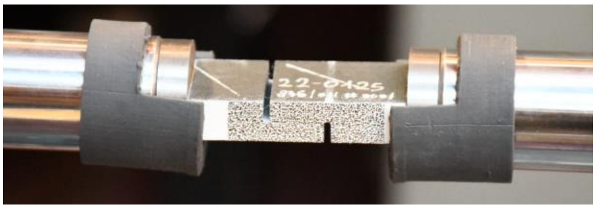

Figure 1: SHPB assembly of the DYN SLS test. 3D printed flexible savers are used to ensure a correct placement of the specimen on the bar ends.

Figure 2: Left: Isometric real view of the BJ bonne specimen. Middle: render of the adherent-bar mounting system. Right: Render of the BJ manufacturing tooling system.

REFERENCES

[1] M. Adamvalli y V. Parameswaran, «Dynamic strength of adhesive single lap joints at high temperature», *International Journal of Adhesion and Adhesives*, vol. 28, n.º 6, pp. 321-327, 2008.

[2] A. Soto, E. González, P. Maimí, A. Turon, J. S. de Aja, y F. M. de la Escalera, «Cohesive zone length of orthotropic materials undergoing delamination», *Engineering Fracture Mechanics*, vol. 159, pp. 174-188, 2016.