

## **Simplified Stress Analysis of Multilayered Adhesively Bonded Metallic Structures**

K. Sekmen<sup>1</sup>, E. Paroissien<sup>1</sup>, F. Lachaud<sup>1</sup>

<sup>1</sup>Institut Clément Ader (ICA), Université de Toulouse, ISAE-SUPAERO, INSA, IMT MINES ALBI, UTIII, CNRS, 3 Rue Caroline Aigle, 31400 Toulouse, France.

Aircraft structures are designed by the assembly of beams with concentrated caps and of thin plates. Bolting technologies have been commonly used to assemble these structural members in order to carry loads. However, the main drawback of these joints is the local reduction of the strength-to-stress ratio. Compared to the bolted joints, adhesive bonding technology allows for the increase of static and fatigue strength while reducing the weight [1]. The finite element (FE) method is able to address the stress analysis of bonded joints. Nevertheless, analyses based on FE models are computationally expensive. Therefore, it is profitable to develop new simplified approaches enabling extensive parametric studies. A semi-analytical technique was developed to model the joints based on the formulation of 4-node special elements, termed macro-elements, which is able to simulate an entire bonded overlap at low computational costs [2,3]. In this paper, a multilayered bonded-bar and a multilayered bonded-beam macro-elements are derived from bonded-bar and bonded-beam macro-elements [3]. 1D-bar and 1D-beam simplified stress analyses of such multilayered joints are presented in order to predict the adhesive stress distributions along the overlap. For validation purpose, the results obtained by the simplified 1D-bar and 1D-beam model are compared with the results predicted by 1D-FE models. Good agreements are shown. Finally, the parametric studies are performed in order to understand the mechanical behavior of multilayered adhesively bonded metallic structures. This presented simplified stress analysis can be used to deduce the sizing guidelines as a consequence of these parametric studies.

[1] A. Higgins, *Int. J. Adhes. Adhes.*, 20, 367 (2000).

[2] E. Paroissien, M. Sartor, and J. Huet, in *Advances in Integrated Design and Manufacturing in Mechanical Engineering II*, p.95, S. Tichkiewitch, M. Tollenaere, and P. Ray, Eds. (Springer, Dordrecht, 2007).

[3] E. Paroissien, M. Sartor, J. Huet and F. Lachaud, *J. Aircraft*, 44, 573 (2007).