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INFLUENCE OF TEMPERATURE ON COMPOSITE AERONAUTICAL STRUCTURAL BOLTED JOINTS

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Summary. *This work focuses on the analysis of temperature and bolt torque influence on aeronautical joint behaviour. A numerical model based on finite elements was developed. Results obtained from numerical simulations showed coupled influence of temperature combined with torque level on the joint.*

1 INTRODUCTION

Aeronautical structures are subjected to extreme changes in temperature, from 50 ºC and above to below -50º C. This problem becomes hardly when composite joints are considered, due to the different coefficients of thermal expansion of the metal and of the composite. The role of temperature in the behavior of these structural components has been poorly analyzed in the scientific literature. On the other hand, aeronautical joints are manufactured under standard values of fastener torque. The relationship is clear between the values of torque applied to the bolt and the resultant level of stress fields. The interaction of this preload and the geometrical change due to thermal load should also be analyzed. This paper focuses on the analysis of the influence of temperature in aeronautical joints. A numerical model based on a finite element approach has been developed reproducing a typical aeronautical bolted joint between composite laminate and titanium.

2 MODEL DESCRIPTION

A model based on finite elements was developed using Abaqus/standard. The geometry was defined reproducing a single bolted joint according to the ASTM 5961 standard [1], see figure 1a. Two composite plates were considered. Each composite plate, carbon/epoxy laminate (AS4/3501-6), was modelled as a quasi-isotropic stacking sequence $[\pm45/0/90]_{2S}$, with total thickness equal to 3.2 mm. Each ply (0.2mm thick), defined as an anisotropic material, consisted of a single layer of eight-node cubic elements, with reduced integration

(C3D8R in Abaqus/standard. The joint between both plates was based on a titanium alloy (Ti-6Al-6V-2Sn) bolt with a diameter equal to 5.94 mm. The bolt-hole clearance used in the joint was within current aerospace standard [2]. The influence of fastener torque was analyzed, defining four levels of torque: finger tight, the torque proposed in the standard ASTM 5961, and two values, below, and slightly above the normalized value. Friction between composite plates and metallic components of the joint was considered. Four levels of temperature were implemented, covering the temperature range from typical levels reached during flying operation (-50ºC) to high values in the zones close to heat sources, such as those reached in the areas surrounding the engine (90ºC). Two other intermediate values were considered: 20ºC and 50ºC.

4 RESULTS AND DISCUSSION

As was explained before, different combinations of fastener torque and temperature were modeled (up to 16 cases). The analysis was performed in three steps. In the first one, the preload simulating torque in the bolt was applied at room temperature. The second step consisted in the thermal load. In the third step a tensile load was applied to the plates, obtaining the load-displacement curve.

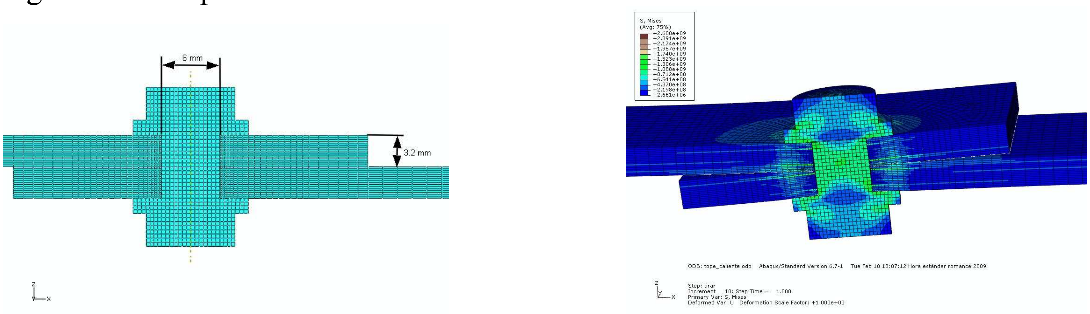

Figure1. a) Geometry of the undeformed model and b) Von Mises stress field obtained in third step.

5 CONCLUSIONS

Maximum levels of tensile and compressive stresses were obtained in both laminates and the bolt. Significant differences were found when extremely high and low temperatures were considered. On the other hand, the standard establishes the recommended fastener torque that should be applied in the bolt to ensure safety of the joint, it was found that critical levels of stress are associated with low torque at low temperature.

REFERENCES

[1] ASTM D5961, “standard test method for bearing response of polymer matrix composite laminates” (2005)

[2] CT. McCarty and MA. McCarthy, “Three-dimensional finite element analysis of single-lap composite bolted joint: Part II-effects of bolt-hole clearance”, Composite Structures, 71, 159-175 (2005)