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Dynamic Thermomechanical Behavior of Adhesively Bonded Composite Joints

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Abstract : Composite materials are increasingly being used as a substitute for metallic materials in many technological applications like aeronautics, aerospace, marine and civil engineering applications. For composite materials, the thermomechanical response evolves with the strain rate. The energy balance equation for anisotropic, elastic materials includes heat source terms that govern the conversion of some of the kinetic work into heat. The remainder contributes to the stored energy creating the damage process in the composite material. In this paper, we investigate the bulk thermomechanical behavior of adhesively-bonded composite assemblies to quantitatively asses the temperature rise which accompanies adiabatic deformations. In particular, adhesively bonded joints in glass/vinylester composite material are subjected to in-plane dynamic loads under a range of strain rates. Dynamic thermomechanical behavior of this material is investigated using compression Split Hopkinson Pressure Bars (SHPB) coupled with a high speed infrared camera and a high speed camera to measure in real time the dynamic behavior, the damage kinetic and the temperature variation in the material. The interest of using high speed IR camera is in order to view in real time the evolution of heat dissipation in the material when damage occurs. But, this technique does not produce thermal values in correlation with the stress-strain curves of composite material because of its high time response in comparison with the dynamic test time. For this reason, the authors revisit the application of specific thermocouples placed on the surface of the material to ensure the real thermal measurements under dynamic loading using small thermocouples. Experiments with dynamically loaded material show that the thermocouples record temperatures values with a short typical rise time as a result of the conversion of kinetic work into heat during compression test. This results show that small thermocouples can be used to provide an important complement to other noncontact techniques such as the high speed infrared camera. Significant temperature rise was observed in in-plane compression tests especially under high strain rates. During the tests, it has been noticed that sudden temperature rise occur when macroscopic damage occur. This rise in temperature is linked to the rate of damage. The more serve the damage is, a higher localized temperature is detected. This shows the strong relationship between the occurrence of damage and induced heat dissipation. For the case of the in plane tests, the damage takes place more abruptly as the strain rate is increased. The difference observed in the obtained thermomechanical response in plane compression is explained only by the difference in the damage process being active during the compression tests. In this study, we highlighted the dependence of the thermomechanical response on the strain rate of bonded specimens. The effect of heat dissipation of this material cannot hence be ignored and should be taken into account when defining damage models during impact loading.

Keywords : adhesively-bonded composite joints, damage, dynamic compression tests, energy balance, heat dissipation, SHPB, thermomechanical behavior
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