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Finite element inversion method for interfacial stress analysis of composite single-lap adhesively bonded joint based on full-field deformation

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Abstract: A hybrid inversion method combining the finite element method and full-field displacement data was proposed to analyze the adhesive interface stress at a composite single-lap bonded joint. The displacement field distribution for the outer surface of the overlapped composite plate was measured through the two-dimensional digital image correlation method at different times by performing a tensile test. At the same time, the finite element analysis of the single-lap joint was carried out, which provided the data on structural deformation characteristics. Then, a polynomial interpolation method was used to establish the relation between the internal and external surface displacements. The displacements of the inner surface of the plate can be calculated from the measured displacement data of the outer surface of the plate by using the polynomial function. The displacements of the inner surface of the plate are regarded as the displacement load conditions for the outer and inner surfaces of the plate to establish the finite element model of the adhesive layer. The validity of the hybrid inversion method was proved by FEM analysis and experiments.

Keywords: Composites; Finite element stress analysis; Lap-shear; Mechanical properties of adhesives

1. Introduction

Fiber-reinforced composites are being widely used in aviation, aerospace, and other engineering fields because of their light weight, high performance, multifunctionality, and low cost. To reduce the weight of structures further, adhesive joint connections are widely adopted in composite structures. Compared to welding, riveting, and other traditional bonding methods, adhesive bonding ensures a more uniform stress distribution at the bonding interface so that the load transfer is continuous in plane. Therefore, it ensures the continuity of the reinforcing fiber and reduces plastic deformation caused by stress concentration at the edge of holes.

Many experiments showed that the composite bonding interface is prone to manufacturing defects, and adhesive joints can be easily damaged owing to local stress concentration. Chai [1] says that these defects, along with damage propagation at the bonded interface, are likely to cause the early failure of adhesive joints. Therefore, the reliability of the bonding interface influences the overall mechanical properties of a composite structure, and it must be ensured that the bonding interface is not damaged first. Understanding stress distribution in adhesive joints, particularly near the adhesive interface, is very helpful to design composite adhesive joints for increased load capacity with reasonable accuracy.

Many researches have been focus on the stress distribution of the adhesive joints in