EFFECT OF FRICTION ON CONTACT STRESS DISTRIBUTION IN PIN LOADED ORTHOTROPIC PLATES

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Abstract

The increasing use of composite materials in the development of structural components has caused engineers to increase their efforts to study the stress field and failure modes associated with these materials under varying engineering applications. One such application that has received much attention is the stresses associated with the mechanical joining of composites. Mechanical joining includes bolted, riveted and pinned joints which are relatively easy to assemble and disassemble. Since these joints are the only form of joining that permit disassembly, they have received much attention from researchers [1-10]. These joints are however prone to high stress concentrations which occurs in the vicinity of the hole which is undesirable and is often the source of premature failure of composite joints.

A large number of the published works on the stresses in pin-loaded composite plates are based on the complex stress functions of Lekhnitskii [2] and assume that the composite plate is a two dimensional homogenous sheet with anisotropic elastic properties. Oplinger and Ghandi [3] were the first to present a solution to the frictionless pin-loaded orthotropic plate using a least square boundary collocation technique. In their work they evaluated plates with finite and infinite geometry and multiple hole configuration with rigid pins. Ogonowski [4] later applied the least square boundary collocation method to finite geometry plates and determined the stresses in isotropic lugs with rounded and square ends.

Klang[1] and Hyer and Klang [5-7] evaluated the stresses in an infinite, pin-loaded orthotropic plate. They considered the effects of pin elasticity, friction and clearance on the stresses near the hole. They concluded that pin elasticity is not as important as clearance, friction or the elastic properties of the plate in determining the contact stresses. In a later work, de Jong [8] presented a generalized approach to the problem of a row of pin loaded holes in a composite plate where the centerline of the holes and the direction of the pin loads are not necessarily coincident with one of the material symmetry axes. He concluded that a numerical solution to this general problem is not possible because of the problems in formulating the boundary conditions at the contour of the hole and at the outer contour of the domain under consideration. Kradinov, et. al. [9] later presented work which evaluated the contact stresses around bolt holes and bolt load distribution in single and double lap joints of composite plates under general loading conditions and uniform temperature change. They used the complex potential theory and the variational formulation to account for bolt stiffness, bolt-hole clearance, and finite geometry of the composite laminates. Zang and Ueng [10]
employed a compact, analytic method to obtain solutions for the stresses in a rigid pin-loaded orthotropic plate. They expressed certain displacement conditions at the contour of the hole which satisfy the physical displacement requirements of the loaded plate. They did not consider the effect of pin-hole clearance but assumed that the contact zone spanned the diametric line of the hole.

In this work an analytical solution for determining the stresses in a pin loaded orthotropic plate is presented employing complex stress functions which satisfies the displacement boundary conditions along the contact region. The method is established on the notion that the contact boundary at the pin-plate interface of the loaded plate is unknown a priori and must be determined as part of the solution process. It is further assumed that the pin is rigid, clearance exists between pin and plate, and that under the action of the pin load, the boundary of the hole deforms as an ellipse. Additionally, the coefficient of friction remains constant throughout the contact zone. Numerical solutions are obtained for [90°/±45]s carbon fiber reinforced laminates with varying clearance and friction coefficient.

References