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Analytical models for functionally graded adhesive single lap joints: a comparative study

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Abstract

Functionally graded adhesives yielding a varying adhesive Young's modulus along the overlap are increasingly considered in order to allow for a more uniform stress distribution and to reduce the occuring stress concentrations in the adhesive layer of adhesively bonded single lap joints. The present work provides a comparative study of the existing analytical models for planar functionally graded adhesive single lap joints. The respective modelling assumptions as well as the conditions of applicability of the different approaches are examined in detail. In addition, a novel approach and possible extensions of the presented approaches are outlined and discussed. A thorough comparative study comprising various single lap joint configurations and adhesive Young's modulus distributions along the overlap is performed in order to assist the engineer to choose the adequate model for a particular single lap joint design. For an assessment of the accuracy, the calculated adhesive stress fields are compared to numerical results obtained with Finite Element Analyses. In addition, the effects of the adhesive Young's modulus range on the peak adhesive stresses are studied and discussed.

Keywords: Functionally graded adhesives, stress analysis, single lap joint, joint design

1. Introduction

Owing to its geometric simplicity and ease of manufacturing, the adhesively bonded single lap joint is the most common adhesive joint design in practice and most studied joint configuration in literature. Although using a single overlap with a homogeneous adhesive might initially lead to the conclusion that a uniform load transfer is present, the stress field in the adhesive shows a pronounced non-uniformity with local peak adhesive stresses at the ends of the overlap. In order to reduce the stress concentrations, several researchers have studied the effects of geometrical modifications of the joint such as tapering the adherends [1, 2], rounding the adherend corners [3–5] or including a spew fillet at the joint's end [6–9]. An extensive overview of expedient techniques can, for instance, be found in the textbook on adhesion technology by da Silva et al. [10]. Since a change in the joint's geometry is often unfeasible in industrial applications, alternative techniques that lead to a decrease of the occuring stress concentrations have been intensively investigated in recent years.

The use of mixed adhesives [11–16] as well as functionally graded adhesives [17–22] has proven to be successful regarding a reduction of peak adhesive stresses. Mixed adhesives, often referred to as bi-adhesives or dual adhesives,