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Quasi-trivial stacking sequences for the design of thick laminates

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Abstract

Quasi-trivial (QT) sequences have largely proven to be an extremely powerful tool in the design and optimisation of composites laminates. In this paper new interesting properties of this class of stacks are derived. These properties allow to obtain QT sequences by superposing (according to some prescribed rules) any number of QT elementary stacks. In this way, QT solutions with arbitrary large number of plies can be readily obtained, overcoming the computational issues arising in the search of QT solutions with huge number of layers. Moreover, a general version of the combinatorial algorithm to find QT stacks is proposed in this work. It is also proven that the previous estimation of the number of QT solutions, for a given number of plies and saturated groups, is not correct because a larger number of solutions has been found in this study.

Keywords: Composites, Laminates, Quasi-trivial solutions, Thick laminates, Anisotropy

1. Introduction

The utilisation of composite materials has undergone a boost in recent years. Indeed, composites allow for a great range of design, over multiple and very different applications. However, the design of a composite structure is a complicated task because of anisotropy and heterogeneity of these materials. Heterogeneity mainly affects the behaviour of the material at the microscopic scale (i.e. that of the constitutive phases), while anisotropy essentially appears at mesoscopic (ply-level) and macroscopic (laminate-level) scales. When dealing with the design problem of composite structures, laminates with *identical* plies (i.e, laminates composed of constitutive plies having same material properties and thickness) are often used (e.g. in aeronautical and automotive applications). In this case, the variables that can be used to tailor the properties of the structure are the total number of plies and their orientation angle. Therefore, the simultaneous design of both structure geometry and laminate stack is of paramount importance. In this background, engineers make a systematic use of some simplifying hypotheses/rules to get some desired properties (membrane/bending uncoupling, membrane orthotropy, etc.), which are difficult to be mathematically formalised and hard to be obtained otherwise. Unluckily, these design rules (e.g. symmetric stacks to get membrane/bending uncoupling, balanced ones to get membrane orthotropy, etc.) drastically reduces the design space and often lead to cut out

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