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Optimising Test Sequences for Robust Material Identification in Composite Laminates

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Abstract

A wide range of data can be obtained using current measurement techniques (e.g. full field optical measurement). This richness can be beneficial for achieving more robust parameter identification, or identifying multiple parameters with a single test [1, 2]. Both of these aspects can be seen as improving the identifiability of the target parameters, which in turn can be seen as reducing the uncertainty of the identified parameters. More robust or multiple-parameters identification could reduce the number of characterisation tests required, and thus the cost of developing a new material. One approach to achieving this is to enrich the collected data, such as by generating a more comprehensive set of measurements. This strategy could involve modifying the geometry of the sample (e.g. adding holes or notches) or the loading path (e.g. imposing load cycles). However, it is important to consider the potential for noise in these measures [3]. While richer data may provide more information, it does not necessarily mean that the data is less noisy.

In this context, we would like to take another look at the identification of elastic parameters for composite laminates. Having at hand the classical ASTM Standard [4], we propose to restrict our study to the same amount of data as the standard. This method involves performing three tensile tests, each on a specifically stacked laminate, to determine the in-plane tensile properties of a given fibre-reinforced composite material. For each test, laminates with ply angles of $\pm 0^\circ$, $\pm 45^\circ$, and $\pm 90^\circ$ are fabricated. Strain gauges are used to instrument the tensile tests, providing the necessary information to determine the longitudinal and transverse moduli of the composite, as well as its Poisson's ratio and shear modulus. An important aspect considering this standard is the assumption of the independency of the tests, which facilitates data exploitation. We seek to enhance this sequence of tests, by seeking to minimise the uncertainty onto the identified parameters, while considering the co-dependency of the tests. In essence, the aim of this work is to decrease the uncertainty in the identified parameters by conducting at most three tensile tests.

Minimising uncertainty involves minimising the covariance matrix of the sought parameters [5, 6]. To achieve this, we suggest using the determinant and trace of the covariance matrix as metrics of interest. Additionally, we choose to act on the ply angles of the samples. In short, our framework consists of solving a bi-objective optimisation problem, by using the ply angles of the specimens as design variables. This study has several strengths, including the consideration of multiple constitutive parameters and tests. Modelling the problem is challenging due to the inverse nature of the problem. The results demonstrate that the proposed cost function successfully identifies a range of angle sequences, that better identify the elastic properties of a composite laminate.

Keywords

Identification · Inverse methods · Optimisation · Full-field measurement

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