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ON DESIGN OF ANISOTROPY DISTRIBUTIONS, APPLYING LAMINA FORMULAS FOR RESULT VISUALIZATION

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Summary: In rotational transformation of constitutive matrices, some practical quantities are often termed invariants, but the invariance relates to an unchanged reference direction. Rotating this reference direction, the practical quantities do change and this point is clarified with derived rotational transformation for the practical quantities. The results are applied in a 2D visualization of optimized constitutive matrices, that are distributed in a finite element (FE) model where each element has a specific reference direction. The visualized distributions of physical quantities are; stiffest material direction, material stiffest longitudinal constitutive component, level of anisotropy, relative shear stiffness and orthotropy test.
In free material optimization (FMO), the components of the constitutive matrices are optimized and they change in the space of a finite element (FE) model, i.e., they are distributed. The constraints for the non-dimensional description of these matrices are; symmetry, positive definite and normalized to unit trace. The optimized constitutive matrices should be visualized, but this is not an easy task and different techniques are applied in the literature. From the authors point-of-view the visualization should be related to the most important physical quantities. Analysis and optimization may be performed without rotational transformations in a common coordinate system with the x-direction as reference. However, the visualizations of the optimized results involve rotational transformation of material behavior, i.e., of the constitutive matrices. For each element in a FE model, the direction of stiffest material direction is taken as reference direction with stiffest direction defined as the direction of largest longitudinal components in an optimal constitutive matrix, here termed (a_1111)_t with t being the angle counter-clockwise from the common x-direction to the t-direction.
The traditional lamina formulas are well suited for localizing t for a specific element. With t , (a_1111)_t determined for all elements the available further physical information is calculated, applying the practical parameters (a_2, a_3, a_6, a_7)_t as evaluated for element e in the specific reference direction t_e. In the present note the non-dimensional, normalized practical quantities are given notation a , as alternative to the often preferred notation Q for corresponding dimensional quantities. The note shows that the name invariant is not a god choice. The practical parameters depend on the reference direction and the relations to the common x-direction are presented. The note ends with a suggested visualization for the optimal constitutive design obtained in recent research. Although written in relation to 2D constitutive matrices, the approach is also valid for; 2D structural stiffness matrices [S], 2D structural flexibility matrices [F], and 2D strength matrices in stress space [H] or in strain space [G]. Also laminate stiffness sub-matrices and laminate flexibility sub-matrices may be analyzed similarly.