Formulation of failure criteria for anisotropic parts into the NURBS-based-SIMP algorithm

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ABSTRACT

In the last two decades, Topology Optimization (TO) has gained an increasing attention in both scientific and industrial communities: today, it constitutes an important field of research and it is applied in many industrial applications. TO methods and new additive layer manufacturing (ALM) technologies constitute the perfect pair to manufacture optimised components of complex shape. Moreover, in the last five years suitable ALM technologies have been emerged which allow for printing composites. This implies the development of pertinent numerical methods and design criteria to conceive parts of intricate shape which must integrate the influence of the anisotropy of the material. Nowadays, the well-known Solid Isotropic Material with Penalization (SIMP) [1] TO algorithm (which is among the most used TO in industrial and scientific communities) is often employed to optimise the topology of anisotropic materials, although it was originally conceived for isotropic ones. In particular, when dealing with anisotropic media, the integration of suitable failure criteria in the problem formulation is of paramount importance. The main issue when dealing with the formulation of such failure criteria in the TO problem is the proper handling of the local information related to the stress field of each element. In particular two tricky aspects must be faced. Firstly, what is a suitable penalisation scheme for a generic anisotropic material? Secondly, how should the failure criterion be integrated into the problem formulation? Although stress-based TO is a well-known problem, a significant amount of studies [1] focuses just on isotropic materials by using the Huber-Henky-Von Mises criterion. Indeed, to the best of the authors' knowledge, only few works dealing with failure criteria of anisotropic materials in TO can be found in literature [2]. Nevertheless, the main issue is the significant discrepancy between the optimized results provided by the classical SIMP algorithm and the actual stress field evaluated on the reassembled geometry.

In this work, the classical criteria of Tsai-Wu, Tsai-Hill and Hoffman have been integrated into the NURBS-based-SIMP method, developed at the I2M laboratory [3, 4]. Each criterion is reformulated in the context of the NURBS hypersurfaces formalism and considered as a constraint function into the problem formulation. The proposed approach fully exploits the advantages of the NURBS-based-SIMP approach: (1) a small number of design variables; (2) topology described through purely geometric entity unrelated to the mesh of the finite element model; (3) the implicitly defined filter zone provided by the NURBS hypersurface local support and (4) a fully CAD-compatible optimized topology.

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