Optimal design of composite structures with curved fiber trajectories

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I. Introduction

IT is well known that using curvilinear fiber paths can significantly improve the structural performances of composite structures [1,2]. The fiber placement technology allows today to manufacture composite structures with such curvilinear fiber paths, should the component be flat or present a curvature. Several algorithms are available to simulate the fiber trajectories, see for example [3-5]. They are most of the time based on a reference fiber direction, which is translated, based on complex geometric equations, in order to provide tows as parallel as possible to each other. Most of these algorithms fail to provide such parallel courses, and in practice overlaps and gaps appear between adjacent tows, leading to over-thickness or small voids, where delamination is prone to occur and where the material allowables are difficult to estimate. Some other algorithms are demonstrated only for simple almost flat structures [3] or for specific geometries [4].

In this paper, the fiber trajectories are computed over a 3D surface using the fast marching based method [6] presented in [7]. This method assumes that the parallel courses of the fiber placement machine are the positions of a propagating wave front over the surface. The wave front is assumed to be infinitely long in order to define courses which cover the whole surface. The general 3D surface is defined by a 3D mesh. A reference fiber is defined over the mesh. It represents the general shape of the fiber over the surface and it is the initial position of the wave front. The Eikonal equation is solved over the 3D mesh, with the reference fiber as an initial condition, to compute the travel time of the wave front at the nodes of the mesh. A modified fast marching method is proposed in the paper [7] for the case of an infinite wave front. The position of the wave front, which is the fiber course, is obtained from iso-values of the computed travel times (Figure 1).

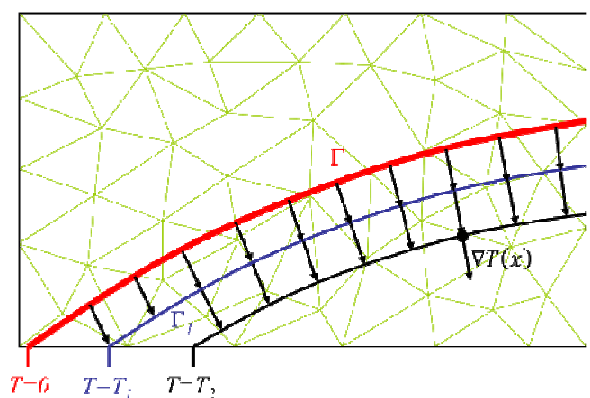

Figure 1. Reference fiber and solution of the Eikonal equation on the mesh

This new approach is then used to solve optimization problems, in which the stiffness of the structure is maximized. The design variables are the parameters defining the position and the shape of the reference curve.

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The shape of the design domain is discussed, regarding local and global optimal solutions. Different optimization methods are compared on several applications. A discussion on the sensitivity analysis for gradient-based methods is proposed. The benefit in using such a parameterization is discussed based on a comparison to a solution relying on local optimal orientations in the structure. A first solution [8] is presented in Figure 2.

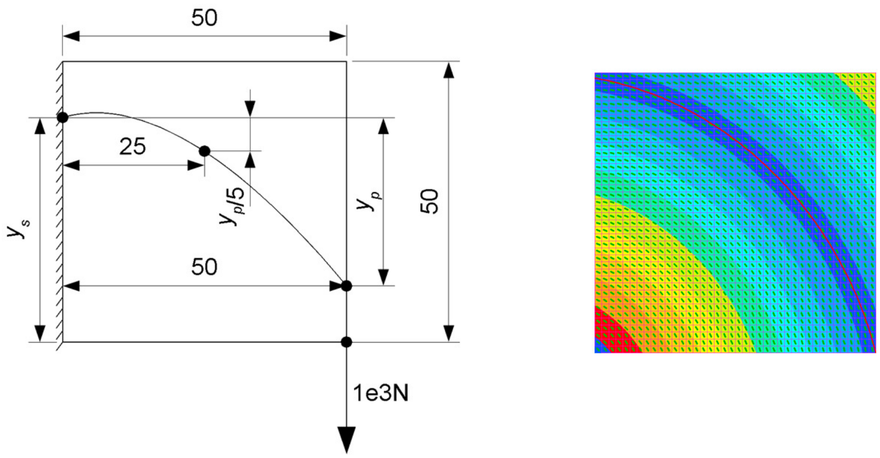

Figure 2. Parameterization and solution

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