Recent advances in topological shape optimization by the Level Set Method

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1. Introduction

In the recent years the level set method has proven its ability to tackle, numerically, difficult problems of structural shape optimization. The basic principle of the method lies in the use of two ingredients: the shape representation by the zero level set of a scalar function over a fixed mesh and the shape evolution through a gradient method based on the computation of the shape derivative.

The shape derivative characterizes the variations of the objective function with respect to small changes of the shape. It is, in most of the cases, quite easy to compute analytically even for real problems, weird objective functions and nonlinear state equations.

The level set representation, and its implicit character that avoids describing geometrically the boundary of the structure, allows to handle smoothly topology changes. It acts also as a regularizing tool that prevents the algorithm from oscillations and instabilities. In addition, the use of a fixed mesh is a big advantage over the classical boundary variation methods, especially in 3D.

Since its introduction in the early 2000's, the level set method has been studied by many authors over the world and successfully tested on various academic cases. However this method has not been applied on many industrial cases. Most of the real applications of shape and topology optimization so far have been computed using commercial codes that use variations of the homogenization method, like the popular SIMP method.

A few months ago, we have started a collaboration with ESI-Group – editor of the Systus software – and the French car manufacturer Renault, in order to implement the existing knowledge on the level set method in a commercial code. This work includes the development of various additional formulations and constraints to fulfill the needs of the industry for a versatile topology optimization tool able to treat real problems. It includes nonlinear mechanics, multiphysics models, complex geometrical constraints (like the ones induced by the molding process) and an automated workflow.

As a first (still academic and very classical) example, we show below a MBB beam optimized for the compliance (see Fig. 1) and another one with an additional constraint over the maximum thickness of the shape (see Fig. 2), in order to allow the molded structure to be cooled in an acceptable time after metal injection.

Figure 1: MBB beam optimized for the compliance without any additional constraints

Figure 2: MBB beam optimized for the compliance with an additional constraint over the maximum thickness of the shape

References

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