A MULTI-MATERIAL OPTIMIZATION METHOD WITH MANUFACTURING CONSTRAINTS FOR TAILORED FORMING

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1. Introduction

New mechanical design approaches must be constantly developed to attend the specific requirements of new manufacturing technologies. Tailored Forming is a process chain with the objective of creating hybrid solid components by using semi-finished workpieces, theme of a collaborative research CRC 1153 [1]. With this technique, a new class of high performance parts can be constructed, aiming load-adjusted behaviour, lightweight or specific local properties. The objective of this paper is to find the optimal material distribution for its design, including the joining zone geometry, taking the specific manufacturing constraints of the process into consideration to bring the potential of Tailored Forming use to the maximum.
For that, Topology Optimization techniques were here reviewed, focusing on the progress made on the multi-material field, manufacturing constrained implementations and stress-based methods, since the forces at the joining zone are here a concern. Thereby, a new method was developed in [2], called Interfacial Zone Evolutionary Optimization (IZEO). This method is based on Evolutionary Algorithms methodology to solve optimization problems and has as objective function the minimization of weight, with stress constraints. The concept of it goes around an update process that happens only at the material interfacial zone, with predetermined steps of shape adjustment that gives a bi-directional ability to the algorithm (Figure 1).

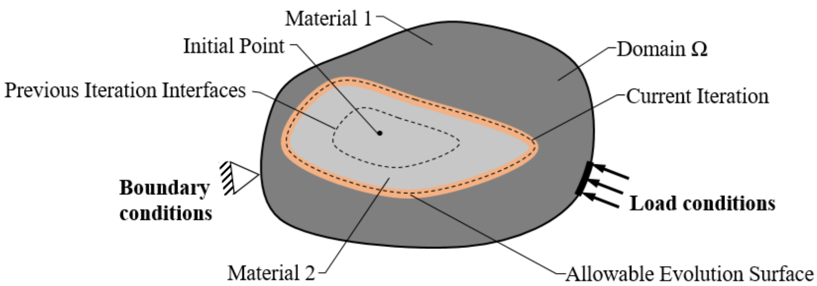

Figure 1: Representation model about the evolution process of IZEO.

The choice of such an approach was made based on advantages that evolutionary algorithms provide to follow-up the process and to make implementations through observations. It is shown that this interfacial limitation facilitates a gradual implementation of manufacturing constraints, which has been always a sensitive topic in the optimization field. Therefore, some of the geometric restrictions found in Tailored Forming were here applied through a flexible process, in order to generate useful results. Finally, an example is presented, where IZEO was able to generate a first dual-material high-performance design that can be manufactured today through the available technology.

2. Manufacturing Constraints

A key factor of the method is the possibility to implement a variety of manufacturing constraints. Following the same concept proposed in [3], the manufacturing constraints can be described as a combination of different geometric restrictions. The implementation of a set of different geometric restrictions allows the system to be flexible, which is an important characteristic when dealing with the process chain of Tailored Forming. The geometric constraints here implemented were the following: Symmetry; Minimum Member Size; Directional Placement; Continuous Phases limitation; and Outer Contour. These restrictions are implemented by allowing only certain elements to change in the evolutionary process. Therefore, the translation of manufacturing constraints into geometric restrictions is here an important step. Each restriction must be implemented in a very specific way and has a big influence in the final result.

3. Results

The algorithm for IZEO is implemented in MATLAB and here performed for 2D problems. As example of its implementation we take one of the demonstrators of the CRC 1153, which is a hybrid shaft made of steel and aluminium. This shaft is manufactured through the following process chain: laser or friction welding of the semi-finished workpieces, impact extrusion or cross wedge rolling, machining and heat treatment.

The description of these manufacturing restrictions is not simple, due to the different processes involved and its requirements. The shaft has to be designed with a serial configuration, having one side made of steel and the other of aluminium. Due to the properties of the materials, the process requires that at the joining zone, the aluminium must be in the outer side and the steel in the inner side (Figure 2).

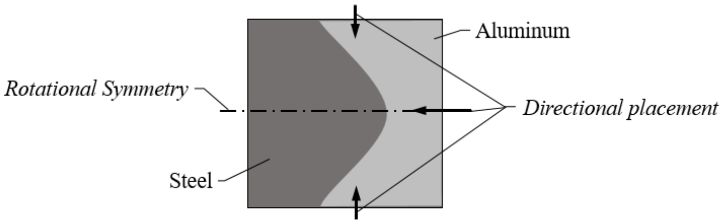

Figure 2: Representation of the geometric restrictions found in the manufacture of the hybrid shaft.

For the optimization process, the objective is to have a light component, meaning the most use of aluminium and a restricted safety factor. Since this shaft has a fixed geometry, this geometry is here our design domain and the initial point of the evolution for the aluminium is the extreme side where the aluminium is intended to be in the serial manufacture. The result of the optimization process is presented in Figure 3, where the load conditions of the simulation is also represented.

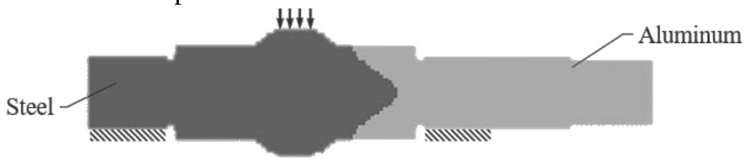

Figure 3: Optimized result for the hybrid shaft under bending with IZEO and manufacturing constraints.

4. Conclusions

The present study presented a method for generating optimized designs with the strong manufacturing constraints of Tailored Forming. The final result is highly dependent on the description of this restrictions, as expected. The 2D description is a current limitation, but it allows already a useful analysis of the method in this initial stage. Despite the method being heuristic, the results generated were realistic and simply to implement, showing that the method has a potential for further development and future applications.

Acknowledgments The authors thank the German Research Foundation (DFG) and the CRC 1153 for its support.

References

[1] SFB 1153, Prozesskette zur Herstellung hybrider Hochleistungsbauteile durch Tailored Forming. [online] Leibniz Universität Hannover. Available at: https://www.sfb1153.uni-hannover.de/sfb1153.html (accessed 09.04.2018).

[2] R. Siqueira, R. Lachmayer, I. Mozgova. Development of a Topology Optimization Method for Tailored Forming Multi-material Design, *COBEM Proceedings*, Curitiba, 2017

[3] S.L. Vatanabe, T.N. Lippi, C.R. de Lima, G.H. Paulino and E.C. Silva. Topology Optimization with Manufacturing Constraints: A unified Projection-based Approach, *Advances in Engineering Software*, Vol. 100, pp. 97–112. 2016