Design for Additive Manufacturing: Innovative topology optimisation algorithms to thrive additive manufacturing application

Summery

The dissertation concerns the investigation and development of design methodologies carried out to thrive the additive manufacturing application. The purpose of the research is to address several problems and opportunities related to the conceptual design phase of components to be produced by means of additive technologies. The focus has been on the development of the *Top* Suite, a collection of three innovative topology optimisation algorithms named *TopTM*, *TopComp* and *TopFat.*

The first topology optimisation algorithm *TopTM* finds the optimal final topology concurrently optimising the structural stiffness and the heat exchange in a coupled thermo-mechanical system. This algorithm is suitable for the optimisation and lightening of several real components such as heat exchangers, engines, and turbine blades. The problem is density-based formulated and solved using an optimality criterium in limited code lines in the commercially available software Ansys Mechanical.

The second algorithm, named *TopComp*, is suitable for the optimisation of fibre reinforced composites. The final output is the optimal combination of the matrix material distribution together with the optimal embedded fibre orientation. Fully optimised fibre reinforced composites are appropriate for substituting metal components in several applications, leading to outstanding weight reductions. The problem is density-based formulated and solved using an optimality criterion using Ansys Mechanical.

The third topology optimisation algorithm is named *TopFat.* This algorithm provides the final optimal topology considering the presence of defects due to the additive manufacturing process. Consequently, the final topology is guaranteed to be structurally safe considering the process-induced defect presence, both in the quasi-static and fatigue regime. The problem is density-based formulated and solved using a first-order method. The *TopFat* algorithm includes two different stress constraints that represent a critical challenge in the topology optimisation procedure. Therefore, the *TopFat* algorithm is firstly implemented in solved in the Matlab environment as a quite complex code. As a complement of this research, the *TopFat* procedure is extended to the commercially available software *HyperWorks*.

The whole *Top* Suite is thought to be integrated and implemented in commercially available software with a double purpose. Firstly, commercially available software like *Ansys Mechanical* and *HyperWorks* already have an easy-to-use user interface, tools for the geometrical and finite elements manipulation, and output visualisation which increases enormously the *Top* Suite applications for real and complex components. Secondly, the absence of complex coding and dedicated platforms permits the additive manufacturing community to access the *Top* Suite straightforwardly and take advantage of these design methodologies.

Overall, this dissertation is thought to foster the additive manufacturing application in terms of applicability, effectiveness and reliability.