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Multiple concurrent optimization paths in evolutionary topology optimization considering maximum member sizes

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Abstract
The constant increase in productivity and manufacturing efficiency drives the industry to incorporate optimization techniques beyond the capabilities of manual optimization and numerous iterative loops within the product design phase. As a result, topology optimization is becoming an integral part of the design process. Nevertheless, design proposals obtained from topology optimization do not always meet all manufacturing constraints, and can be difficult to interpret. Usually, these proposals have to be modified more or less extensively by experienced engineers to be viable for prototyping and production. Oftentimes, these manual modifications and redesigns adversely affect the optimality of the design proposal.

This problem is particularly evident for cast parts. One of the reasons for poor castability is the occurrence of substructures with large cross-sectional areas connected to thin struts, large pockets of material, and other discontinuities in wall thicknesses within the part, all of them increasing the risk of casting defect formation. Some commercial topology optimization tools already allow for the consideration of maximum member sizes. This restriction aims to decrease the possible range of wall thicknesses that can occur within the design proposal. The implementation in mathematical optimization methods is fairly unproblematic. For evolutionary optimization methods, which might start with a full design space and huge member sizes, the matter becomes rather difficult.

Using a new evolutionary optimization method developed at the Volkswagen AG as a starting point, a mechanism was designed to enforce maximum member sizes via repetitive discrete events within the optimization process. These act as a penalization of substructures with maximum member sizes exceeding a specified limit, but allow for the structure to be repaired by the optimizer between these events. The modified optimization method was successfully tested for robustness and convergence on two- and three-dimensional academic test problems and industrial parts. In direct comparison to a commercial product using a mathematical approach and SIMP material model, the obtained results were promising. To increase the coverage of the possible solution space, a mechanism for optimization branching was developed. The possibility to simultaneously pursue both an unaltered and modified version of the structure at each discrete penalization event generates a binary tree of variations which have been shown to converge in several different local optima with a high degree of optimality, considering the additional member size restriction. This work was done to provide a framework for further development of both maximum member size restrictions and branching optimizations.

Currently, the optimization method is being used successfully to optimize automotive parts to gain further insight into the behavior of the member size restriction.

The goal is to refine the optimization branching process and to develop advanced branching and penalization event strategies. Furthermore, the possibility to apply this method to sheet metal structural optimization will be investigated.