Shape Optimization with Casting Manufacturability Constraints

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ABSTRACT

We present a method to incorporate casting manufacturability constraints in shape optimization to eliminate defects that can lead to premature fatigue failure, such as porosity and shrinkage. Structural optimization typically accounts for responses that guarantee the structural integrity under service conditions. However, such methods may render designs that complicate the manufacturing process. Moreover, lack of consideration for the effects of the manufacturing process in the optimization may lead to designs that exhibit manufacturing defects that may lead to mechanical failure. This is the case with castings, where porosity in regions that are stressed during service may lead to crack initiation and consequently fatigue failure.

In the proposed method, we consider simple thermal models to predict shrinkage defects, such as those based on Chvorinov's rule, whereby the solidification time is a function of the casting modulus (cf. [1]); locations with the longest solidification times are deemed as potential shrinkage defects in the casting. The optimization aims to stay below a porosity-weighted maximum stress level (e.g. the maximum stress level will be greater in regions with little porosity and less in regions with more porosity) throughout the casting with minimal geometry changes, while satisfying structural criteria (such as deflection and stress) under service loads. To demonstrate our method, we study the design of the outer profile of a wheel spindle. The profile is represented by splines, and an axisymmetric model is employed to perform the thermal and mechanical analyses.

[1] Stefanescu, D. M. (2005). Computer simulation of shrinkage related defects in metal castings–a review. International Journal of Cast Metals Research, 18(3), 129-143.