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FAST SIMULATION - ASSISTED SHAPE CORRECTION AFTER MACHINING

Résumé

Distortions after machining of large aluminium forgings are a recurrent problem for the aeronautical industry. These deviations from design geometry are caused by the presence of residual stresses, which are developed along the manufacturing chain, especially after the heat treatment of quenching. To restore the nominal geometry, a series of highly manual and time-consuming reshaping operations need to be carried out.

This work is concerned with the development of efficient computer simulation tools to assist operators in bending straightening, which is one of the most common reshaping operations.

To this end, we develop a Finite Element simulation model which is representative of the manufacturing chain, including quenching, machining, and reshaping, which allows to predict residual stresses and distortions in thick-walled aluminium forgings. The model is validated against experimental data found in the literature. Then, we introduce the concept of reshaping diagrams, a tool that allows selecting a nearly optimal bending load to minimize distortion. We show that the reshaping diagram needs not to account for the residual stress field, as its only effect is to shift the reshaping diagram by some offset. Therefore, the overall behaviour including a realistic 3D residual stress field in a forged part can be retrieved by shifting the residual stress-free reshaping diagram by the appropriate offset. Finally, we propose a strategy to identify the offset on-the-fly during the reshaping operation using simple force-displacement measures.

Then we explore the use of novel numerical techniques, especially Model Order Reduction (MOR), with a two-fold purpose: i) to speed-up the computation of reshaping diagrams; and ii) to account for various process parameters, such as initial distortion or the reshaping setup. To this end, we rely on the Sparse Subspace Learning method (SSL), a non-intrusive MOR method that allows reconstructing the solution space directly from the outputs of the Finite Element model. With the parametric solution at hand, the optimum reshaping configuration can be found in real-time, to minimize distortion before launching the actual reshaping operation.

Finally, we propose the first steps towards the extension of the above methodology, which combines reshaping diagrams and MOR methods, to a multi-stage setting in which several shape correction operations take place sequentially.

Mots-clés : Residual Stresses, Distortion, Reshaping, Model Order Reduction