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RELAXATION OF RESIDUAL STRESSES DURING MULTI-PASS MACHINING: SIMULATION WITH THE LEVEL-SET METHOD AND PROCESS OPTIMIZATION

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ABSTRACT

One of the major difficulties of the machining process is to control the final shape which can deviate from the nominal one. Two major sources are relaxation of residual stresses and cutting forces [3]. This contribution focuses on the first one even if a coupling between the two is available. For almost all applications, residual stresses are generated during previous operations such as forging and heat treatments. However, during cutting operations, these are relaxed and lead to undesired distortions which can be out of tolerance bounds. Numerical prediction of this effect is thus very important so that a better approach can be proposed (e.g.: the numerical command of the machine does not match anymore the nominal shape).

Modeling the machining process through classical finite element simulations using conforming meshes faces a major limitation: its flexibility. Indeed, modeling the numerous tool paths on one side of the workpiece requires numerous complex mesh adaptation operations as the mesh needs to match the final boundary. Moreover, cutting paths cannot be defined within the workpiece mesh once before the simulation. In order to circumvent these limitations, an innovative approach based on the level-set method has been developed within our in-house software Morfeo (for Manufacturing ORiented Finite Element tOol). The level-set is a signed distance function defined at the nodes of the finite element mesh. It is used to represent material interfaces, holes, cracks, etc (see [1] and [2]). In this contribution, a machining path is defined by way of level-sets and a proper integration algorithm is used at the elements containing the newly created free boundary during a machining operation. This approach enables the required flexibility to simulate such process by avoiding expensive remeshing. Furthermore, cutting paths do not deform with the mesh but defined once for all before the simulation so that distortions between

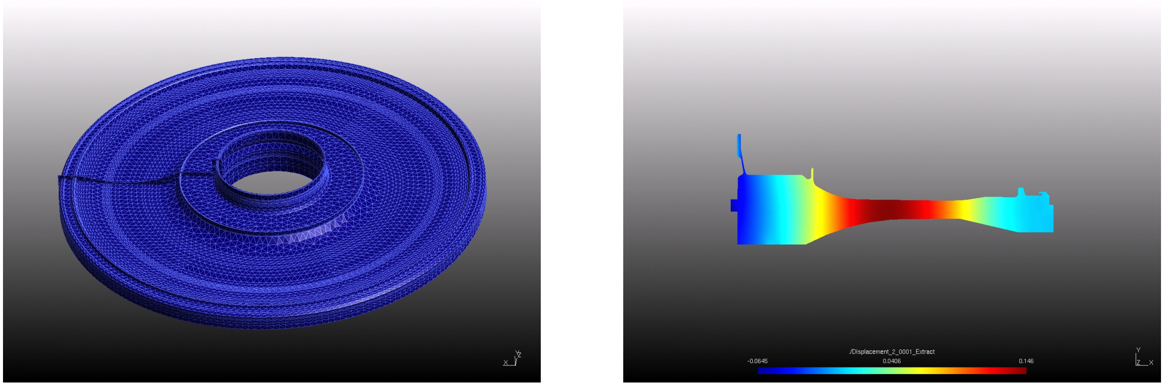

Figure 1: Left: Final machined workpiece containing a section before any operation. Right: Axial distorsions over a cross-section induced by relaxation of residual stresses after one machining pass (before removal of clamping system)

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the process stages are correctly taken into account; only the level-set being recomputed between two operations.

This approach has been initially developed for two-dimensional axisymmetric industrial workpieces as illustrated on Figure 1 (left). It has recently been extended to fully three-dimensional problems. The validation of the method has been conducted in close collaboration with industrial partners, based on experimental measures of distortions (see Figure 1 (right)).

An automated optimization loop has been tested in order to improve the final shape. Among the numerous design parameters, following ones are considered: final workpiece position within the raw material, geometrical position of tool paths and the number of passes.

In addition to this, influence of cutting forces is currently studied. The cutting forces are obtained using a semi-analytical procedure: numerical simulations are performed at the local scale for a nominal tool shape while an analytical model is used to account for the shape variation and orientation of the tool.

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