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ORIGINAL RESEARCH

Substructuring in the implicit simulation of single point incremental sheet forming

The incrementally updated approach

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Abstract This paper presents a direct substructuring method to reduce the computing time of implicit simulations of single point incremental forming (SPIF). Substructuring is used to divide the finite element (FE) mesh into several non-overlapping parts. Based on the hypothesis that plastic deformation is localized, the substructures are categorized into two groups: the plastic—nonlinear—substructures and the elastic—pseudo-linear—substructures. The plastic substructures assemble a part of the FE mesh that is in contact with the forming tool; they are iteratively updated respecting all nonlinearities. The elastic substructures model the elastic deformation of the rest of the FE mesh. For these substructures, the geometrical and the material behaviour are assumed linear within the increment. The stiffness matrices and the internal force vectors are calculated at the beginning of each increment then they are statically condensed to eliminate the internal degrees of freedom (DOF). In the iteration process the condensed stiffness matrices for the elastic substructures are kept constant. The condensed internal force vectors are updated by the multiplication of the condensed stiffness matrices and the displacement increments. After convergence, any geometrical and material nonlinearity for the elastic substructures are nonlinearly updated. The categorization of substructures in plastic and elastic domains is adapted during the simulation to capture the tool motion. The resulting, plastic and condensed elastic, set of equations is solved on a single processor. In an example with 1600 shell elements, the presented substructuring of the SPIF implicit simulation is 2.4 times faster than the classical implicit simulation.

Keywords Substructuring · Incremental forming · Finite elements

Introduction

Single Point Incremental Forming (SPIF) is a displacement controlled process performed on a CNC machine. A clamped blank is deformed by the movement of the tool that follows a prescribed toolpath [1, 2], a sketch of SPIF is presented in Fig. 1. Because SPIF is a dieless process, it is perfectly suited for prototyping and small volume production. The simulation of SPIF results in enormous computing times for two reasons. First of all, the blank is deformed by a sequence of small increments that requires thousands of numerical increments to be performed. Secondly, the small contact area between the forming tool and the blank requires a very fine FE mesh to capture the introduced deformation. The extreme computing times currently limit the applicability of FE simulations to very simple academic samples.

The implicit simulation of SPIF provides a very good agreement with experimental data [3]. For nonlinear

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