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# Efficient implicit simulation of incremental sheet forming

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## SUMMARY

In single point incremental forming (SPIF), the sheet is incrementally deformed by a small spherical tool following a lengthy tool path. The simulation by the finite element method of SPIF requires extremely long computing times that limit the application to simple academic cases. The main challenge is to perform thousands of load increments modelling the lengthy tool path with elements that are small enough to model the small contact area. Because of the localised deformation in the process, a strong nonlinearity is observed in the vicinity of the tool. The rest of the sheet experiences an elastic deformation that introduces only a weak nonlinearity because of the change of shape. The standard use of the implicit time integration scheme is inefficient because it applies an iterative update (Newton–Raphson) strategy for the entire system of equations. The iterative update is recommended for the strong nonlinearity that is active in a small domain but is not required for the large part with only weak nonlinearities. It is proposed in this paper to split the finite element mesh into two domains. The first domain models the plastically deforming zone that experiences the strong nonlinearity. It applies a full nonlinear update for the internal force vector and the stiffness matrix every iteration. The second domain models the large elastically deforming zone of the sheet. It applies a pseudolinear update strategy based on a linearization at the beginning of each increment. Within the increment, it reuses the stiffness matrix and linearly updates the internal force vector. The partly linearized update strategy is cheaper than the full nonlinear update strategy, resulting in a reduction of the overall computing. Furthermore, in this paper, adaptive refinement is combined with the two domain method. It results in accelerating the standard SPIF implicit simulation of 3200 shell elements by a factor of 3.6. 

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KEY WORDS: efficient implicit solver; incremental forming; refinement

## 1. INTRODUCTION

A common aspect in incremental forming processes, such as rolling or incremental sheet forming (ISF), is the small contact area between the forming tool and the workpiece. In such processes, the deformation is introduced by small load increments. The forming tool needs to travel all over the workpiece several times to reach the final geometry. A sketch of single point incremental forming (SPIF) is presented in Figure 1. SPIF is a displacement-controlled process performed on a computer numerical control machine. A clamped blank is deformed by the movement of the tool that follows a prescribed tool path [1]. An extensive overview of the process has been given in [2–4]. Simulating incremental forming processes is highly expensive in terms of computing time regardless of the used time integration scheme: explicit or implicit. This is a result, mainly, of the incremental aspect of the forming, introduced by a small contact area. The small contact area requires a fine mesh to capture

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