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QUASI-STATIC AND DYNAMIC SIMULATION OF SHEET METAL FORMING PROCESSES USING LINEAR AND QUADRATIC SOLID–SHELL ELEMENTS

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ABSTRACT

A family of prismatic and hexahedral assumed-strain based solid–shell elements (SHB elements), with their linear and quadratic versions, are presented in this work to model thin structures. These SHB elements are based on a three-dimensional formulation with an arbitrary number of integration points along the thickness direction. Several special treatments are applied to the SHB elements to avoid all locking phenomena and guarantee the accuracy and efficiency of the simulations. These solid–shell elements have been implemented into ABAQUS using both static/implicit and dynamic/explicit versions. Several popular static and dynamic benchmark tests as well as sheet metal forming simulations are conducted to assess the performance of these SHB elements.

Keywords: finite elements, linear and quadratic solid–shell, assumed strain, quasi-static and dynamic, thin structures, sheet metal forming.

INTRODUCTION

In modern industry, the finite element analysis has become an essential approach in product design and manufacture processes. In order to obtain reliable simulation results for thin structures, much effort has been devoted to the development of locking-free solid–shell elements (Hauptmann, 1998; Abed-Meraim, 2002; Abed-Meraim, 2013). These elements combine the advantages of conventional shell and continuum finite elements. In this contribution, a family of solid–shell elements (SHB elements) are briefly introduced. They are based on a three-dimensional formulation with only displacements as degrees of freedom and an arbitrary number of integration points along the thickness direction. These SHB elements consist of linear prismatic (SHB6) and hexahedral (SHB8PS) elements, and their quadratic counterparts (SHB15) and (SHB20), respectively (Abed-Meraim, 2002; Trinh, 2011; Abed-Meraim, 2013). They have been implemented into ABAQUS software using both static/implicit and dynamic/explicit codes, which makes them capable of solving most three-dimensional thin structure problems. Several quasi-static and dynamic benchmark tests, which involve geometric and material nonlinearities, are first conducted to assess the performance of the SHB elements. Then, attention is focused on the simulation of complex sheet metal forming processes involving large strain, anisotropic plasticity and contact.

RESULTS AND CONCLUSIONS

The deep drawing of a cylindrical cup is analyzed here to study the earing profile of the cup in the case of anisotropic sheet metals. The sheet is made of an AA2090-T3 aluminum alloy. The Swift hardening law is considered to describe the isotropic hardening behavior, while the

Hill'48 yield criterion is adopted to model the anisotropic plasticity. All of the material parameters are summarized in Table 1 (Yoon, 2006).

$$\sigma_y = k(\varepsilon_0 + \varepsilon_{eq}^p)^n \tag{1}$$

Table 1 - Material parameters for AA2090-T3

	E [MPa]	ν	*k* [MPa]	ε_0	*n*	r_0	r_{45}	r_{90}
AA2090-T3	70500	0.34	646	0.025	0.227	0.2115	1.5769	0.6923

Both static/implicit and dynamic/explicit versions of the SHB elements are used in the simulations, and all results are compared with the experimental ones provided in (Yoon, 2006). Fig.1 shows the final height profiles of the cup obtained with the SHB elements for the quarter model using a single element through the thickness. One can see that the predicted height profiles are in good agreement with the experimental ones.

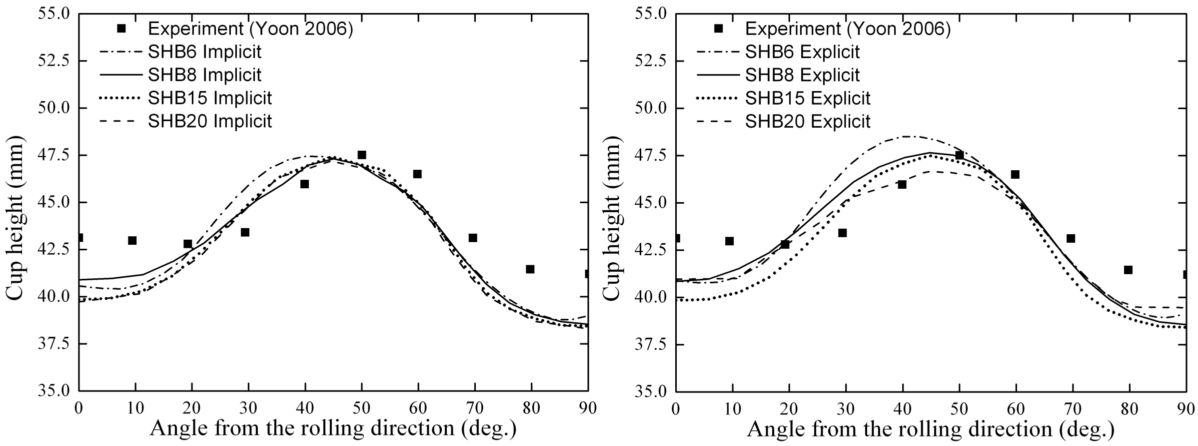

Fig.1. Predicted cup height profiles obtained by: (left) static/implicit and (right) dynamic/explicit analysis

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