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Shell element with thickness stretch

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INTRODUCTION

The finite element method is commonly used to simulate the behavior of sheet forming processes, in order to efficiently realize high-precision machining. There are two types of elements used in numerical simulation based on the finite element method. One of them is a continuum element, the other is a structural element. In numerical simulation of thick sheet by using a continuum element, bending behaviors can be considered accurately [1]. A continuum element is widely used in practical simulations to model the complex behaviors, however. These simulations suffer from huge computational cost. On the other hand, in the case of using a structural element, which is derived from the plate theory [1], bending behaviors cannot be treated accurately. For example, a structural element gives good results for simple bending problems. However, for a sheet forming process, structural elements are not sufficient to simulate the complex behaviors, such as, the deformations of the sheet and the contact forces at the sheet-die interface. As for structural element, in order to evaluate a deformation and a surface traction in the transverse direction at the bending correctly, it is necessary to account for changes of stress distribution in the transverse direction.

In recent years, the development of structural element not relying on the plate theory assumption has attracted increased attention. The shell element considering thickness change by assuming strain in the transverse direction is proposed by Büchter and Ramm [2]. The method of introducing a strain field [2] must assume the stress distribution. Thus, the effect of the surface traction has to be assumed. Other methods are introducing additional degrees of freedom at each node [3, 4].

In this article, a novel shell element that accounts for the change in thickness is proposed. Toward this end, we introduce a displacement field in the transverse direction and propose a new shell element, in which the thickness change is considered, without assuming plane stress in the transverse direction.

PROCEDURE

We introduce a displacement variation along the transverse direction, and propose the structural element which is considered the stress distribution included the effect of the surface traction and thickness change.

NUMERICAL EXAMPLE

We illustrate some important results of our shell element through a numerical example (as depicted in Fig. 1).

The stress distribution resulting from our analysis is compared to that obtained using a commercial code employing a solid element in Fig. 2. Similarly, the displacement in the transverse direction (td) at the center of the middle cross-section of the proposed element is verified by comparison with that obtained by the conventional element, in Fig. 3. This result shows that the proposed approach can capture the effect of the surface tractions (i.e., the normal forces applied on the surfaces).

CONCLUSION

The proposed shell element can account for the change in thickness. Further study of this article is to extend nonlinear numerical analysis, such as, large deformation.

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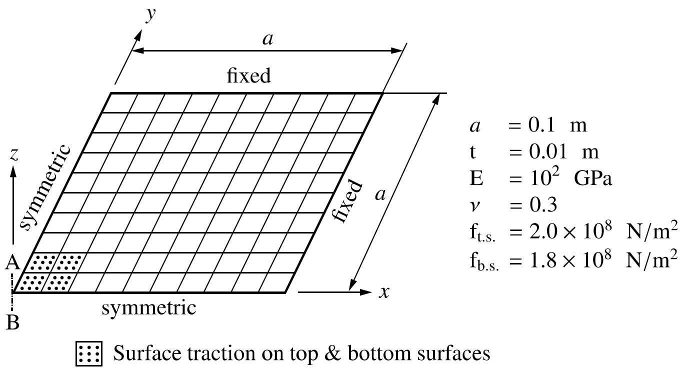

Fig. 1 Simulation model and model parameter

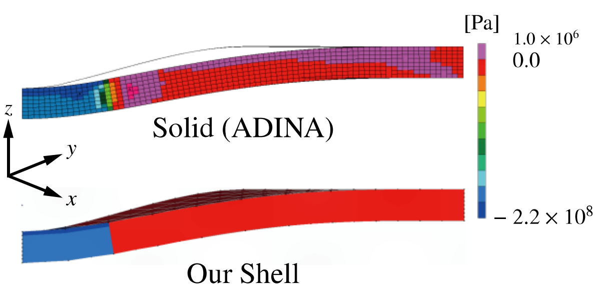

Fig. 2 Stress distribution in z direction

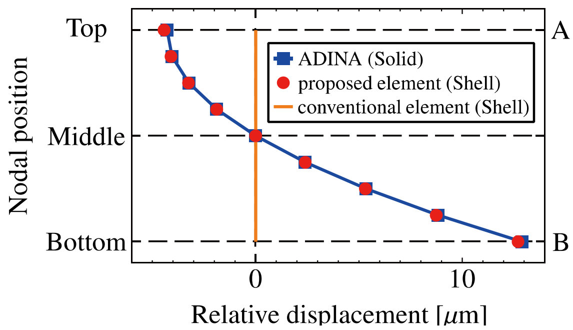

Fig. 3 Displacement through the thickness