Abstract thesis:

DEVELOPMENT OF SOLID-SHELL ELEMENTS FOR LARGE DEFORMATION SIMULATION AND SPRINGBACK PREDICTION

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Objective of the thesis is to develop a finite element that is effective for simulation of thin-walled behavior, such as in metal forming processes. The thesis includes six chapters and is structured as follows. The first chapter presents the objects for the research. The second chapter introduces background methods which will be incorporated in the solid-shell elements. The third chapter develops an alternative ANS technique and applies it to the solid-shell elements. As a result, in that chapter a new solid-shell element based on the alternative ANS technique is proposed. Elastic applications of the just developed solid-shell element are illustrated in Chapter 4. In Chapter 5, plasticity theory and numerical problems in plasticity deformation are presented. The thesis specially concentrates on treating a current industrial problem: spring back prediction. Results in Chapter 4 and Chapter 5 demonstrate the capabilities of the proposed solid-shell element. Chapter 6 withdraws conclusions and then makes some remarkable future developments.

Chapter 1. INTRODUCTION

The solid-shell elements are attractive ones. They possess performance of the EAS elements while they are insensitive to distorted mesh. Furthermore, they are stable and time saving elements. Obviously, because of having the solid's configuration, the solid-shell elements are suitable for handling contact in metal forming simulation, particularly for simulation of sheet metal products whose ratio between length and thickness is large. They can be easily combined with the standard solid elements in problems dealing with complex structures meanwhile they can also work as shell elements. For transverse shear locking removal, the elements employ the ANS techniques because the ANS method is cheaper than the EAS method in removing transverse shear locking. To get rid of volumetric locking and membrane locking, the elements adopt techniques of the EAS method. The solid-shell elements are able to simulate thin and moderately thick-walled structures.

Chapter 2. BACKGROUND ON THE DEVELOPMENT OF SOLID-SHELL ELEMENTS

This chapter discusses the difficulties when using the low-order standard solid element and the well-known degenerated shell elements. Apart from that, all the methods that concern the solid-shell elements: the EAS (formulated in Green-Lagrange strain) and the classical ANS methods (applied for finite deformation solid elements) are introduced.

In this chapter, separated performances of the ANS and EAS elements are investigated. The ANS, EAS elements used in the thesis have been implemented in a MATLAB code, according to the theories presented. Through the numerical tests we see that the transverse shear locking treatment is ideally suited by the ANS method. In the case the Poisson's ratio is different from zero, the ANS method gives less accuracy. The EAS method is also useful to shear locking removal but computational cost of the EAS method is more expensive than the ANS. The volumetric locking is effectively removed by the EAS method. The SRI is completely suitable for volumetric locking removal but this method cannot pass the patch test.

Chapter 3. SOLID-SHELL ELEMENTS FOR FINITE DEFORMATION

In this chapter, an alternative ANS technique, called ANSn technique, is proposed. This one is applied for transverse shear locking removal. Afterward, in order to generate an original solid-shell element (named SS7n), a combination of the alternative ANS technique with the EAS method is described. In the thesis, the solid-shell element, which adopts the classical ANS element, is named SS7. Both the SS7 element and the original SS7n element satisfy the patch tests. By analysing eigenvalues we see that both the elements are free from volumetric locking and transverse shear locking.

Chapter 4. ELASTIC APPLICATIONS

In this chapter, numerical tests, both linear and nonlinear applications, are presented to demonstrate the capabilities of the proposed solid-shell element, SS7n. Various tests, which include shear, membrane and volumetric locking benchmarks, are taken into considered to demonstrate performance for the SS7n solid-shell element. The SS7n shows good performances, even with distorted mesh, for incompressible behavior and for bending behavior of thin and thick-walled structures.

Chapter 5. PLASTIC APPLICATIONS

In this chapter we investigate plastic behavior of the SS7n element. First of all, available plastic theory in FEAP is briefly presented. Then, numerical tests are investigated to look for differences in plastic behavior between the ANS and ANSn techniques. The SS7n element, in general, gives similar results as the SS7, except the cases where large aspect ratio and large deformation occur simultaneously.

Chapter 6. GENERAL CONCLUSIONS AND FUTURE WORKS

CONCLUSIONS

An alternative ANS technique has been presented in Chapter 3. This alternative ANS technique can incorporate with the EAS method to result in a new solid-shell element, named SS7n. This alternative ANS technique assumes that the transverse shear strains are linear in the thickness direction and in an in-plane direction. Meanwhile, following the classical ANS technique, the assumed transverse shear strains are only linear in one in-plane direction. The classical and the alternative ANS techniques were systematically compared together. Both of them can assist the solid-shell elements, SS7 and SS7n, pass the membrane and bending patch tests. Performances of the SS7 and SS7n elements have been investigated for both bulk problems and shell-like structures, ranging from thin to moderately thick structures. Theory in Chapter 3 and the plasticity test with pinched cylinder in Chapter 5 proved that the new solid-shell element, SS7n, leads to a better approximation of strains and stresses in the thickness direction than the SS7 element (with the classical ANS technique). Also, the SS7n element is less sensitive to distorted mesh than the SS7 element.

FUTURE WORKS

In the thesis, only some basic aspects belong to metal forming field have been investigated. The following works should be pursued:

- Investigating capabilities of the classical ANS technique and the alternative ANS technique in approximating transverse stresses and strains.
- Apart from the springback prediction, there are also several interesting topics in metal forming field, such as tearing, wrinkling, limit forming curve, etc. Performances of the solid-shell elements with these topics may be perspective.
- The SS7n element is well applicable to structural problems. For some specific applications, such as collapse of shells, structural stability, etc. peformances of the SS7n would be useful.

The solid-shell theory in this thesis will be useful for researchers who want to apply 3D solid elements to simulate thin-walled structures.