On Mesh Fusion Scheme in LS-DYNA®

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Abstract

In this paper, the limitation of the original mesh fusion method in LS-DYNA® is discussed. A new mesh fusion scheme is proposed and implemented in LS-DYNA. It is shown through a numerical example that the original method could sometimes fail in predicting the shell thickness distribution, while the proposed scheme is able to do so.

Introduction

Mesh adaptivity has been implemented in LS-DYNA for over 20 years. There are adaptive mesh refinement (fission) and mesh coarsening (fusion), both in SMP and MPP. As shown in Fig. 1, in one single adaptive time step, when the predefined mesh fission condition is satisfied, a 3/4-node shell element (parent element) can be split into four 3/4-node shell elements (child elements). On the contrary, when mesh fusion is invoked, four 3/4-node shell elements (child elements) could be merged into one 3/4-node shell element (parent element). The topology related to the existing mesh fission/fusion algorithm is quite mature, but the story might be different when considering the property inheritance between the parent and child elements. As a matter of fact, when mesh fission happens, the properties of the parent element are all copied to all of its child elements. There is no information loss during this process. However, when mesh fusion happens, one single parent element can never carry all the properties belonging to the four child elements.

This paper is organized as follows. The mesh fusion schemes, both the original algorithm and the proposed one, are first discussed. A numerical example is presented to demonstrate the capability of the new scheme. The paper ends with a short conclusion.

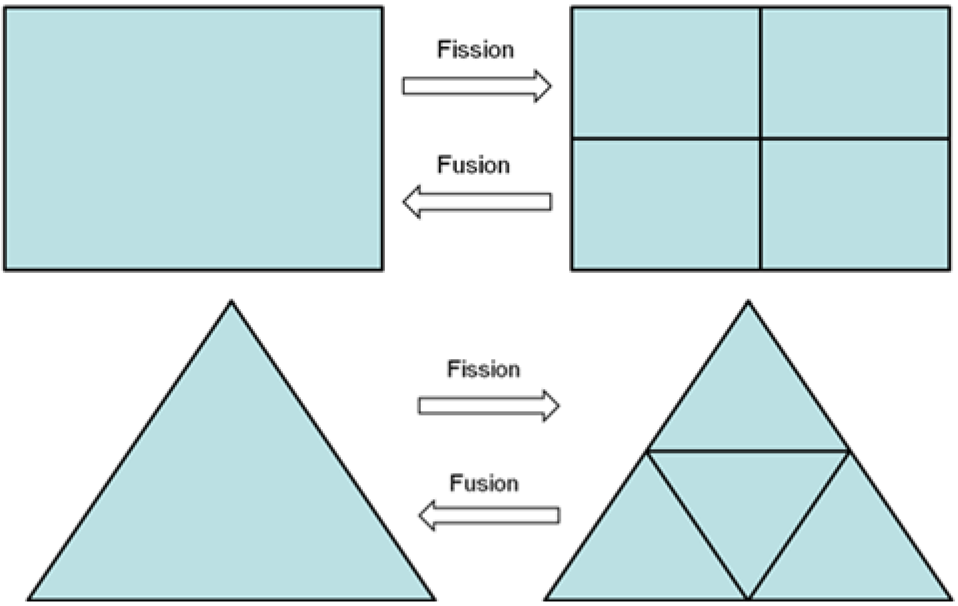


Fig 1: Fission/Fusion Topology in LS-DYNA

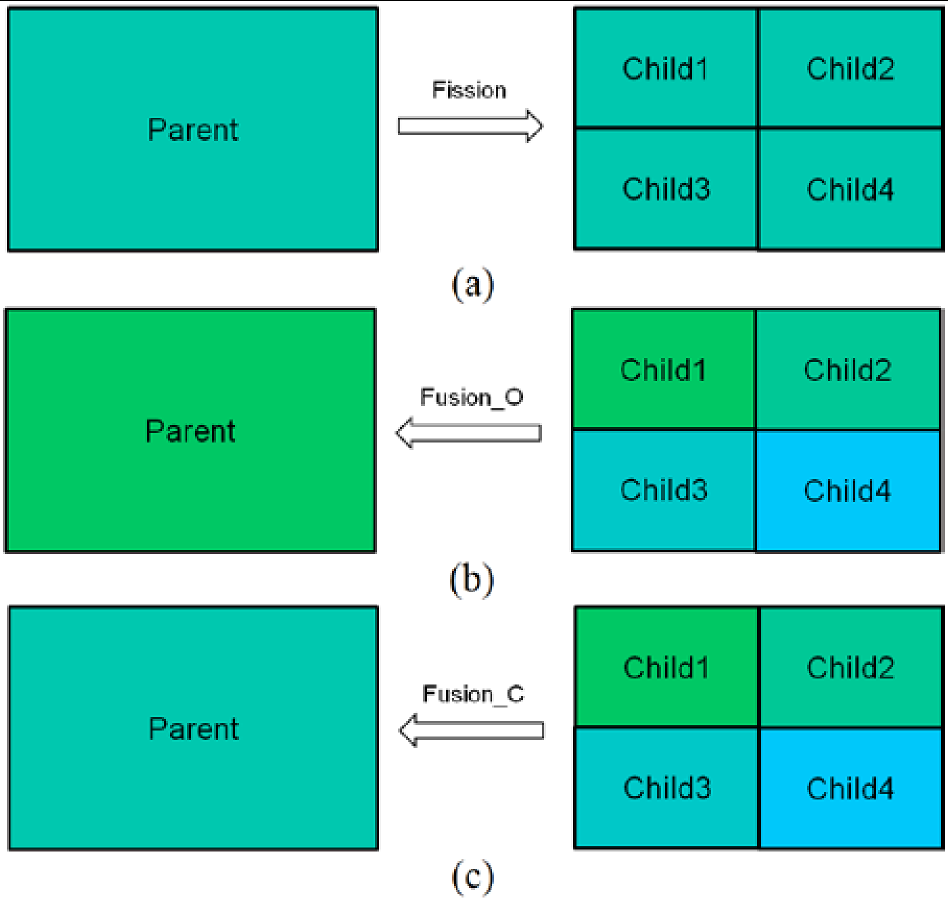


Fig 2: Property Inheritance in the Mesh Fission/Fusion Scheme: (a) Fission---All four child elements gets a complete copy of parent element's property; (b) Original Fusion Scheme---The parent element directly takes the property of child1, discarding the properties of the rest child elements; (c) Current Fusion Scheme---The parent element's property is treated as the average of those from the four child elements.

Property Inheritance in Mesh Fission/Fusion Scheme

As shown in Fig. 2 (a), when a parent element is split into four child elements, its properties, such as thickness, stresses, strains and other history variables are directly copied to the four child elements. One may notice that, during this process, there is no information loss.

However, when four child elements are merged into one single parent element, it would be almost impossible to keep the integrity of all the information. Originally, LS-DYNA directly takes the properties of the first child element as those for the parent element, which directly throws away the properties of the other three child elements in one adaptive step. Recently it is found that this approximation could lead to accumulated errors in the shell thickness and possibly other properties in a forming process. In fact, it might be more straightforward that the properties of the parent element being treated as the average from those of the four child elements. But one needs to be careful on averaging the related properties. For instance, the average of stresses can easily alter the principal directions at each integration points, possibly causing instabilities in the upcoming solution process. In addition, whether a history variable can be averaged or not really depends on its physical meaning.
To conservatively resolve the issue, in our current implementation in LS-DYNA, a few variables, such as shell thickness, elastic strains of the parent element are taken as

the average of the four child elements, the rest variables of the parent shell are kept the same as the original treatment.

Numerical Example

We are considering a example of sheet metal forming, simulated by the moving mesh refining and coarsening method[1]. As schematically shown in Fig. 3(only 1/4 of the model is provided due to symmetry), a rectangular plate is formed by a cylinder forming tool, both of which were modeled by quadrilateral shell element. An automatic contact between the blank and the tool is enforced. The tool travels parallel to the edges of the plate. Details on size of the model, material properties and simulation approaches are not provided. Here two things need to be emphasized: 1) the simulations are carried out in LS-DYNA; 2) theoretically, along the edge of the plate, the shell thickness should be uniform.

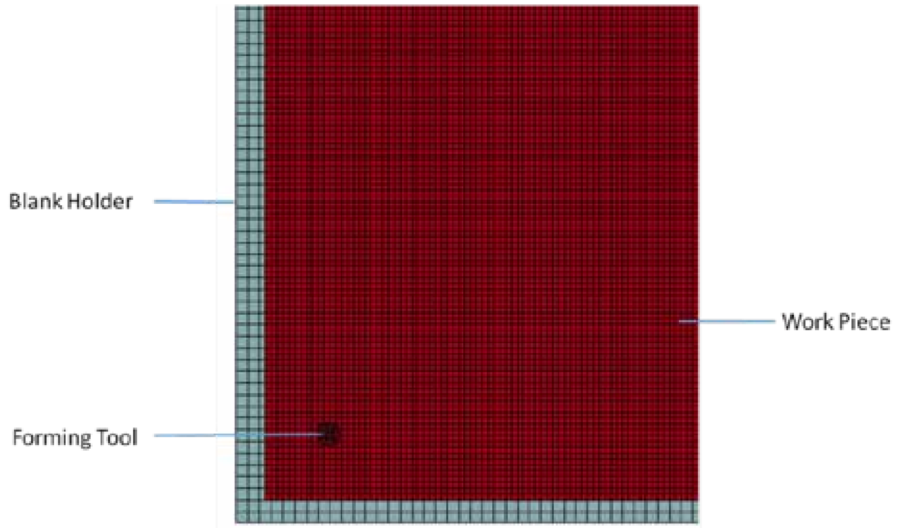
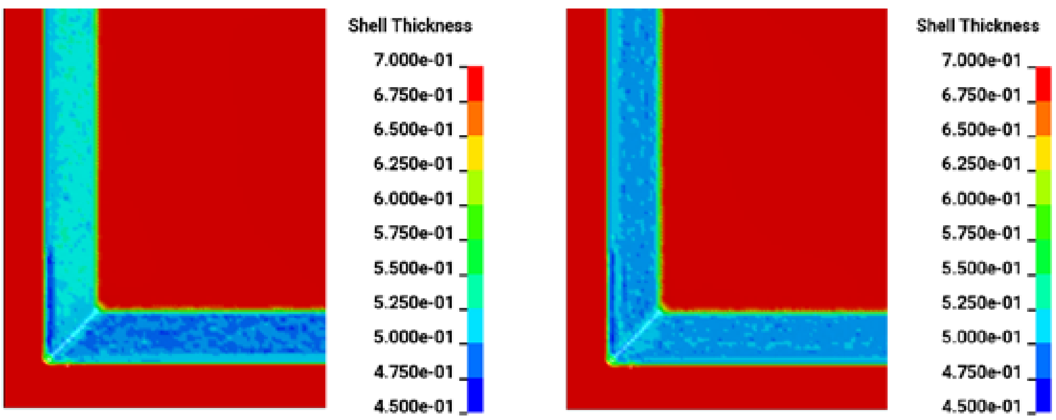


Fig. 3 The incremental sheet forming model (1/4 of the model): a sheet blank resting on a blank holder is gradually formed by a cylinder forming tool.

The contours of the shell thickness obtained from simulation with the original and current schemes are shown in Fig. 4 (a) and (b), respectively. One can see that the shell thickness contour obtained from the original method is not uniform along the edges of the blank (Fig. 4 (a)), which is not correct. After the averaging scheme is imposed, the contours becomes homogeneous, as predicted (see Fig. 4 (b)).



(a) No Averaging (Original) (b) With Averaging (Current)

Fig. 4 Shell thickness contours at the end of a forming simulation

Conclusion:

In this work, a new mesh fusion scheme is proposed and implemented in LS-DYNA. It is shown through numerical examples that the original method in LS-DYNA could sometimes fail in predicting the shell thickness distribution, while the proposed scheme is able to do so.

Revision Information:

Revision 125927: the new feature is available, both in SMP and MPP.

Reference:

[1] Ninshu Ma, Kenji Miyamoto, Yahia Abdel Nasser, Houfu Fan, Xinhai Zhu, Moving mesh refining and coarsening for increment sheet forming simulation, Proc. JSTP2018 spring conference, May 31-June 2nd, 2018, Tokyo.