Improvement of Sandwich Structure Part Adaptivity in LS-DYNA

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INTRODUCTION

Mesh adaptivity on sandwich structure part has been implemented in LS-DYNA® for a while. However, the original implementation can only handle sandwich structure part with one layer of solid element, and its usage has been very limited. In this work, the original implementation is successfully extended to multilayer solids, and this feature can be activated with a newly added parameter IFSAND in the keyword *CONTROL_ADAPTIVE.

It is demonstrated through a benchmark example that mesh adaptivity on sandwich structure part works very well, and it can provide more detailed fringe contour resolution, for example, at rounded punch corners, while keeping the computational cost at an acceptable level.

Adaptive Mesh Fission for Sandwich Structure Part

A sandwich structure part consists of two layers of shells each at top and bottom and a core of solid elements in between. As adaptive mesh fission for shells are quite mature in LS-DYNA, the key for the adaptivity of sandwich structure part is the mesh fission scheme for the solid, which is accomplished by making use of the corresponding adaptive mesh of the shells. For instance, if the two shells are discretized into quadrilateral elements and the solid into hexahedral ones, the solid can be adaptively refined by sweeping the corresponding top and bottom adaptive shell through the thickness direction, as shown in Figure 1. If the shells are discretized into triangular elements and the solids are discretized into wedge elements, then the shells can be adaptively refined as more triangular elements and solids refined as more wedge elements (not shown in the Figure).

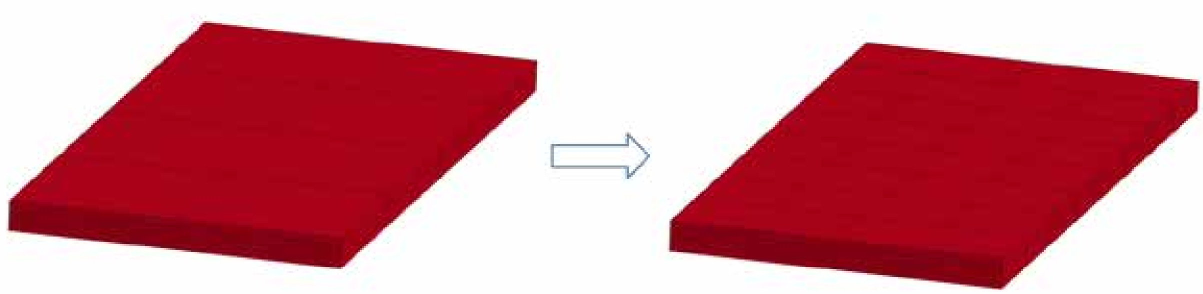


Figure 1. Mesh Fission for Sandwich Structure Part: 32 hexahedral elements are refined to 128 of the same type, as a sweeping of the top and bottom adaptive shell elements through the thickness. The number of layers of the solids always remains the same.

Activating the New Feature

The mesh adaptivity for multilayer solid core of sandwich structure part can be activated by using a new option in the existing keyword *CONTROL_ADAPTIVE, as shown in the following keyword:

```
*CONTROL_ADAPTIVE
$  ADPFREQ    ADPTOL    ADPOPT    MAXLVL    TBIRTH    TDEATH     LCADP    IOFLAG
    0.50      4.0       1         4         0.0        .0006       0        1
$  ADPSIZE    ADPASS    IREFLG    ADPENE    ADPTH     MEMORY     ORIENT   MAXEL
    1.5       1         0         8.000     0.0
$  IADPN90    IADPGH    NCFREQ    IADPCL    ADPCTL    CBIRTH     CDEATH   LCLVL
      -1
$  CNLA                                                                   IFSAND
                                                                            1
```

In the keyword, the common adaptive parameters directly apply to the adaptivity of the sandwich structure part. For instance, ADPFREQ defines adaptive fission frequency, ADPTOL defines the fission tolerance and ADPOPT defines the fission option. When the option **IFSAND** is set to be 1, the feature is invoked. Adaptive fusion feature is not yet available for the sandwich structure part.

Numerical Example and Discussion

To test the new feature, a number of simulations were carried out using the NUMISHEET '96 S-rail Benchmark, as shown in Figure 2. For each case, a forming process is first conducted without adaptive mesh refinement, followed by a corresponding one with adaptive mesh fission.

In the first case, the solid is discretized into one layer of hexahedral elements and the shells are discretized into quadrilateral elements, respectively. The contours of the effective plastic strains at the end of the forming processes with and without adaptive mesh fission are shown in Figure 3. Although the difference of the maximum effective plastic strains in the solid are very small (0.5330 without mesh fission and 0.5469 with fission), the contours with adaptive fission is clearly more localized around the corner areas. This is as expected, given that the newly generated small elements around the comer areas shall provide higher resolutions to the local fringe contours.

In the second case, we would like to consider the solid discretized into multiple (in this case, three) layers of hexahedral elements. The contours of the effective plastic strains at the end of the forming processes with and without adaptive mesh fission are shown in Figure 4. The maximum effective plastic strains are 0.8348 without mesh fission and 0.9159 with fission. Again the one with adaptive mesh fission is more localized at the corner area. Compared to the result obtained from the first case, the current one provides a more detailed gradient in the thickness direction. In fact, the maximum plastic strains are much higher for the 3 layer cases than those for the one layer cases. It is believed that the multiple layer models provide better result in that the nodes of the solid are not completely restricted by the nodes of the shells on the sandwich, as opposed to the one layer solid model that inevitably imposes extra constrains to the solid nodes, which is less realistic.

In the third case, the shells are discretized into triangle elements and the solid is discretized into wedge elements, so as to show that the hexahedron is not the only option for the solid in sandwich structure part. The resulting effective plastic strains for the case with and without adaptive mesh fission are shown in Figure 5. The contour results present similar localization trend as those in the previous two cases.

To have a better comparison on the maximum effective plastic strains in the solid obtained from the three different cases, the maximum values are summarized in Table 1. One can see that the maximum effective plastic strain neither relies much on the type of the element, nor does it depend much on whether the adaptivity is on or off. In fact, it seems that the number of layers in the thickness direction mainly determines the maximum magnitude of the effective plastic strain. Specifically in the current examples, the maximum values for one layer of element (Hexahedral or Wedge) are around 0.55, while those for three layers of element are higher than 0.83. However, this does not necessarily mean adaptivity is not important in the simulation. The local distribution patterns of the contours are very different, especially in the corner areas, which is usually the locations of great importance. In all respect, the multi-layer core of solid elements feature, as well as the mesh adaptivity option, are both of great significance in the forming simulation of the sandwich structure part.

To uncover the underlying reason why the effective plastic strain resulting from three layers of solid elements is larger, the two cross sections of the solids from the corresponding sandwich structure parts are plotted in Figure 6. Assume that the two sandwich structure parts are subjected to the same pure bending force, which yields a linear distribution of the effective plastic strain along the thickness direction. As can be seen from Figure 6, the Gauss integration point (red dot) corresponding the maximum effective plastic strain of the three layer model is in general closer to the surface, leading to a higher value even though the deformations of the two models are exactly the same.

CONCLUSION:

A new feature of mesh adaptivity for sandwich structure part is successfully implemented and available for use. The new feature supports the adaptive fission of the solid with multiple layers, as compared to the original restriction that allows only one layer of solid elements. This improvement not only provides more detailed information through more layer of elements in the thickness direction, it also provides more freedom to the material within the solid, i.e., nodes of the solid are no longer solely attached to the shells. On the other hand, the adaptive mesh refinement feature serves to provide better resolution of the simulation results in local area of interest while keeping the computational cost to an acceptable level.

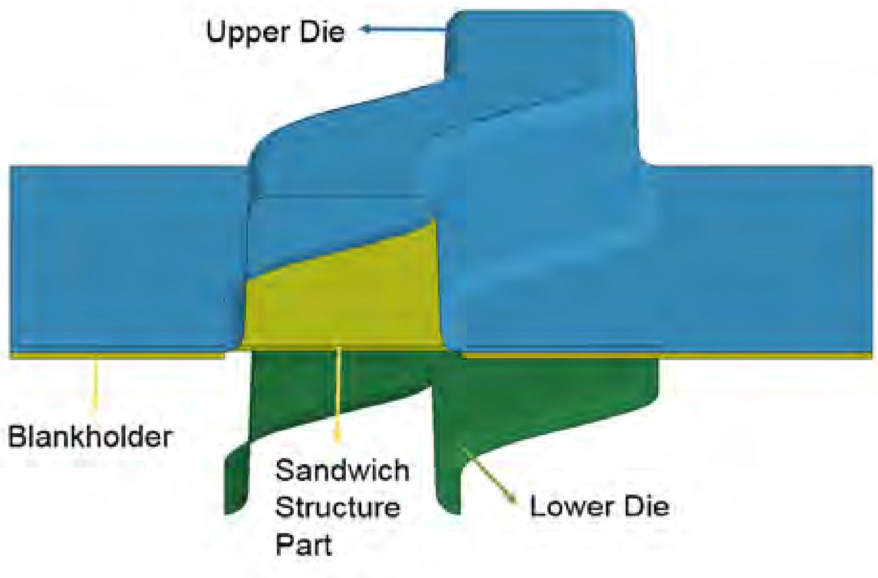
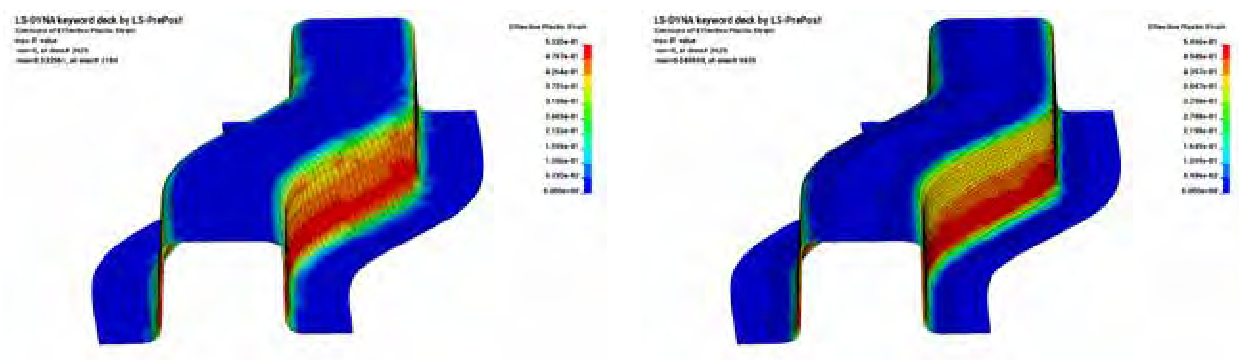
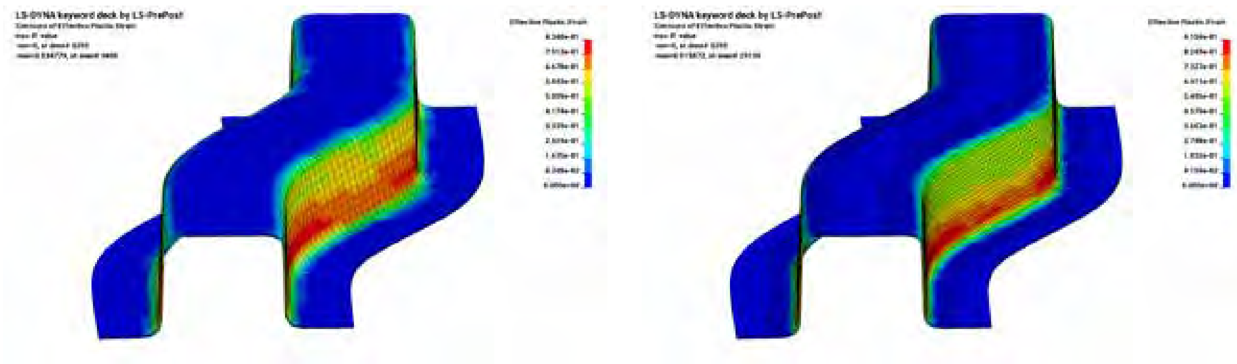


Figure 2. NUMISHEET '96 Benchmark: The upper/lower die and blankholder are rigid; the sandwich structure part consists of one upper, one lower shell and the solid in between. Several forming processes are performed, with different discretization schemes.



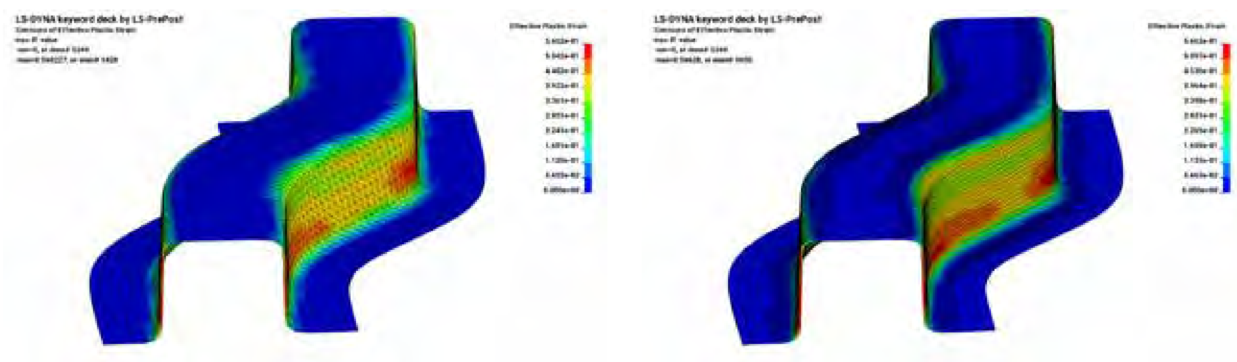
(a) No Fission (b) With Fission

Figure 3. Effective plastic strains of the solid at the end of the forming processes, with and without adaptive fission. The solid is discretized into one layer of hexahedral elements.



(a) No Fission (b) With Fission

Figure 4. Effective plastic strains of the solid at the end of the forming processes, with and without adaptive fission. The solid is discretized into three layers of hexahedral elements.



(a) No Fission (b) With Fission

Figure 5. Effective plastic strains of the solid at the end of the forming processes, with and without adaptive fission. The solid is discretized into one layer of wedge elements.

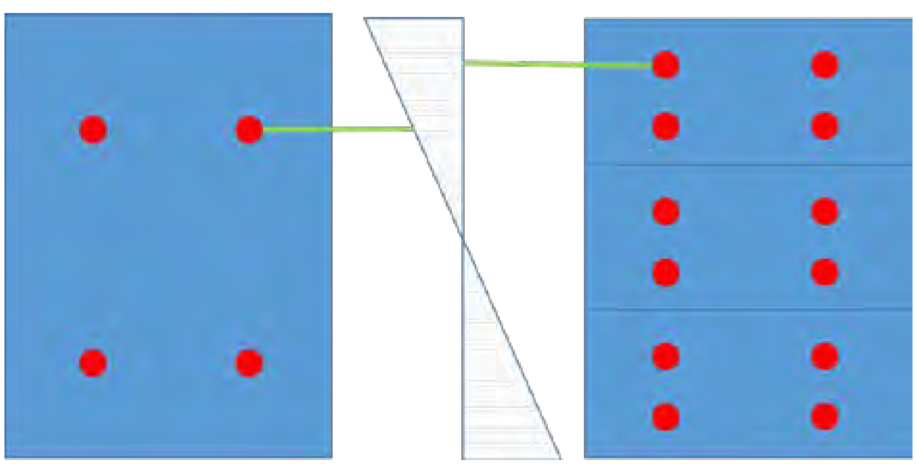


Figure 6. Schematic of the solid cross sections with one and three layers of elements, the dots (red online) denote the locations of Gauss integration points. The two sandwich structure parts are subjected to the same pure bending force. One can easily tell that the one with three layers of elements shall present higher effective plastic strain, simply because the corresponding Gauss integration point is closer to the surface.

	Hex, 1Layer	Hex, 3Layers	Wedge, 1Layer
No Fission	0.5330	0.8348	0.5602
With Fission	0.5496	0.9159	0.5663

Table 1. Comparisons of the final maxinum effective plastic strains for the solid meshes of different cases, with and without mesh fission.

ACKNOWLEDGEMENT:

The feature in this article was requested by BMW. Their valuable feedback during the development is highly appreciated.

REVISION INFORMATION:

Sandwich Structure Part Adaptivity feature is available starting in Revision 116282.