Improvement of Mesh Fusion in LS-DYNA®

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Abstract

In this work, mesh fusion in MPP is successfully implemented in LS-DYNA. It has been demonstrated through benchmark examples that MPP mesh fusion can reduce the simulation time (25%) and make sure the accuracy (error within 2%) of the forming process. The result for the corresponding springback analysis is slightly large (error within 10%) and can serve as a rough and quick estimation.

Introduction

To improve simulation efficiency, mesh fusion has been implemented in LS-DYNA for a while. However, the implementation was only available in SMP, and its usage was very limited. Recently, mesh fusion has been successfully extended to MPP, and it can be activated with the existing keyword *CONTROL_ADAPTIVE through appropriate parameters NCFREQ, ADPCTL, CBIRTH and CDEATH.

The paper is organized as follows. The keyword to activate the MPP Fusion feature is first introduced. Numerical investigation with the NUMISHEET' 93 Benchmark is then conducted. Conclusion is drawn in the very end.

The Keyword *CONTROL_ADAPTIVE

Originally, adaptive fusion was implemented in SMP version. The MPP fusion feature was turned off with a warning message displayed at the beginning of any simulations that require fusion in MPP. As of Revision 113867, the MPP fusion is fully incorporated into the system.

The following keyword is the input to use the fusion feature.

```
*CONTROL_ADAPTIVE
$  ADPFREQ    ADPTOL    ADPOPT    MAXLVL    TBIRTH    TDEATH     LCADP    IOFLAG
    2.00      4.0         2         3         0.0        70.0       0         1
$  ADPSIZE    ADPASS    IREFLG    ADPENE    ADPTH     MEMORY     ORIENT   MAXEL
 0.0000000         1         0    5.000     0.0
$  IADPN90    IADPGH    NCFREQ    IADPCL    ADPCTL    CBIRTH     CDEATH   LCLVL
      -1         0         2         0        8.0      0.00       70.0
```

In the keyword, NCFREQ defines the fusion frequency, ADPCTL defines the fusion criterion, CBIRTH and CDEATH defines when the fusion starts and ends.

Numerical Investigation

To test the performance of the new feature, a number of simulations were carried out using the NUMISHEET'93 Benchmark, as shown in Figure 1. For each case, a forming process is first conducted, followed by the corresponding springback analysis. The simulations are first carried out in MPP with number of CPUs being 10. The performance comparison of the code with and without fusion is conducted. Specifically, we would like to check the differences in the simulation CPU time in the forming process, results in final springback angle, maximum effective plastic strain and minimum shell thickness in the workpiece with different number of CPUs running in MPP for cases with and without mesh fusion. As an illustration, the final mesh sizes and shapes of the springback angles running with 10 CPUs in MPP with and without mesh fusion are given in Figure 2. The differences of the two final springback angles are calculated to be 8.1%. In addition, the contours of the final shell thickness and effective plastic strains are provided in Figures 3 and 4, respectively. The difference in the minimum shell thickness is 1.4% and in the maximum effective plastic strain is 1.7%. The simulation time reduction is around 25% (not shown in the Figure).

To have a better view on the performances of the feature over different number of CPUs running in MPP, the forming process and springback analysis were carried out with the number of CPUs ranging from 1 to 35. Time costs of the cases with and without mesh fusion are shown in Figure 5(a), and the corresponding springback angles are given in Figure 5(b). Time reduction, differences in springback angle, minimum shell thickness and maximum effective plastic strain are shown in Figures 6(a), 6(b), 7(a) and 7(b), respectively. One can see that the overall time reductions in the forming processes are in general greater than or equal to 25%. The differences in springback angles are kept within 10%; the differences in the minimum shell thicknesses and maximum effective plastic strains are always kept within 2%, which means they are not affected significantly by the mesh fusion.

Conclusion

The mesh fusion feature is successfully implemented in MPP and available for use. The fusion feature reduces the computation time notably (around 25%) and has little effects on formability analysis, such as thinning and effective strain predictions. The difference in the corresponding springback results is also found to be smaller than10%. The performance and accuracy studies can guide users in applying this new technology in a production simulation environment. Generally speaking, we should feel comfortable to use the fusion feature extensively in all formability related simulation since the leading indicators (shell thickness and effective plastic strain) affecting formability is little affected but one can achieve a speed-up factor of 25% in simulation turnaround. In springback simulation, however, one should approach it with caution. One can apply the feature if the springback results are to be used for a quick and rough estimation. However, if the results are to be used for compensating dies and in deciding how much tools are going to be re-machined, then its application may not be appropriate. The factor that people have higher expectation for springback simulation accuracy, now in the sub-millimeter when compared with physical scanned panel, should be taken into consideration when applying the feature in different scenarios. In addition, one thing to be noted is that the 25% computation time reduction could be different for models of different sizes.

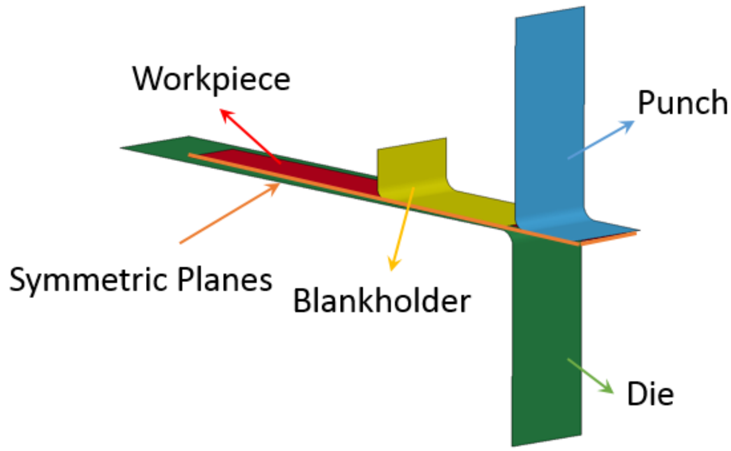
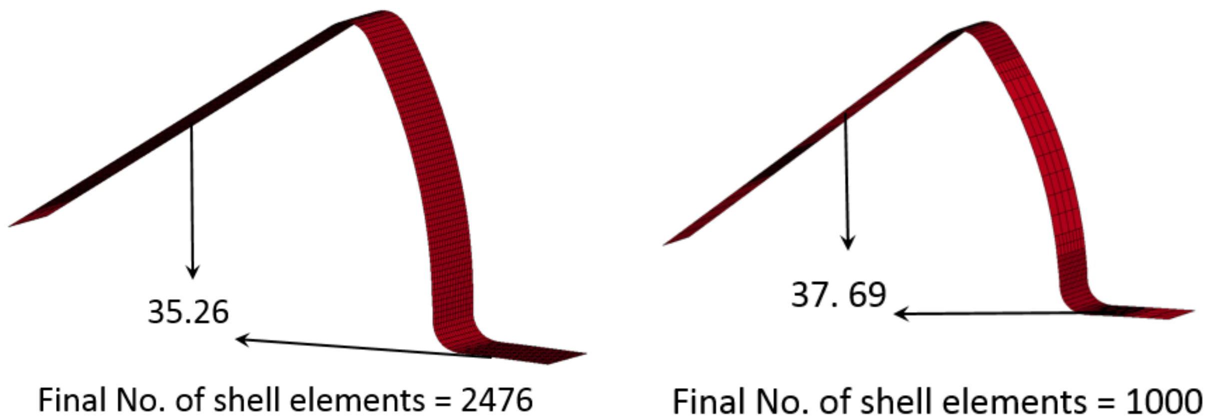
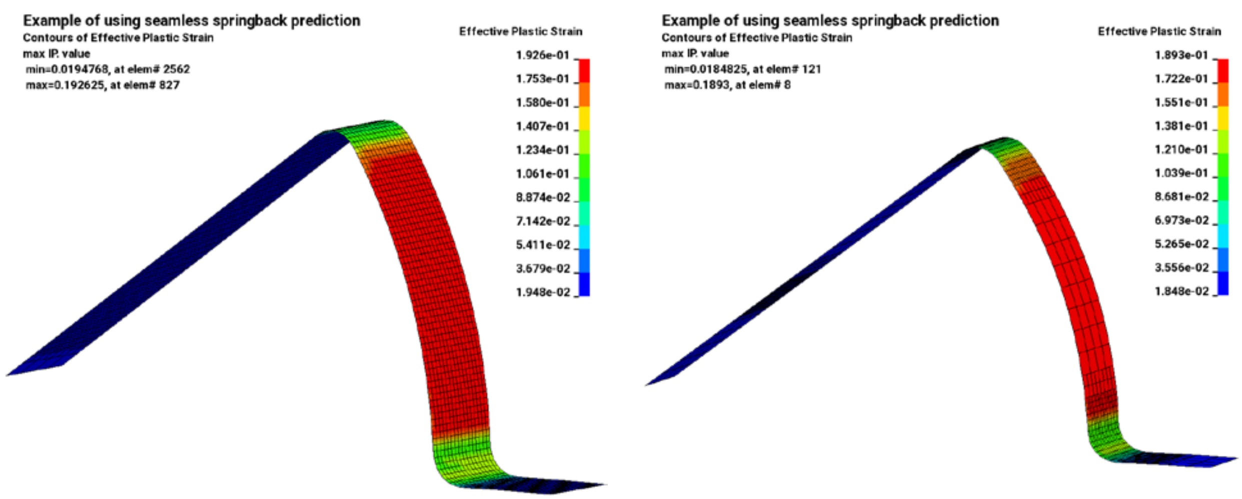


Fig. 1. NUMISHEET'93 Benchmark: The punch, die and blankholder are rigid; the workpiece is discretized into shell elements. A forming process is conducted, followed by a springback analysis.



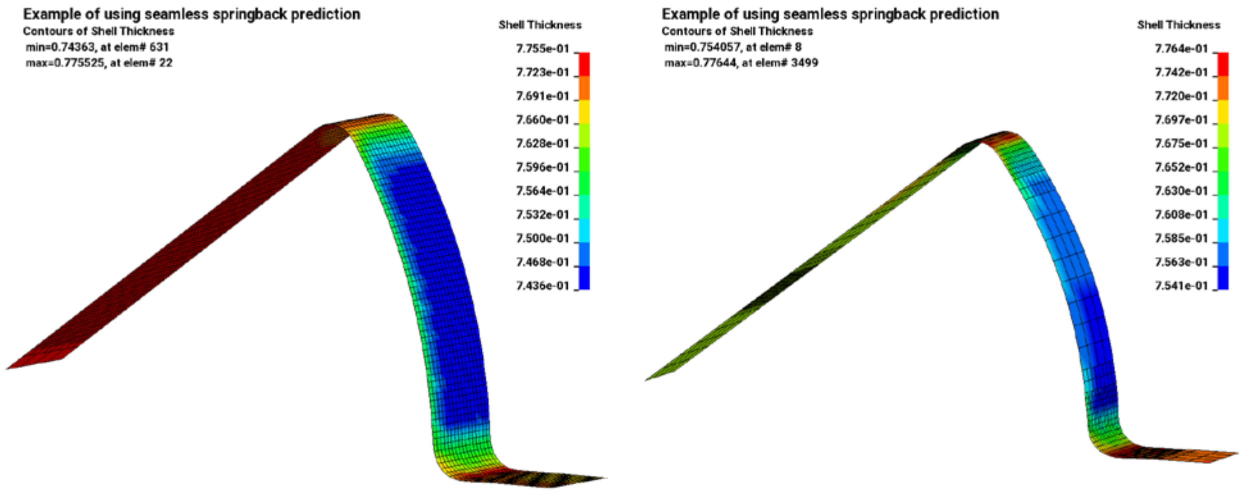
(a) No Fusion (b) With Fusion

Fig. 2. The final number of elements and springback angles of the workpiece running with 10 CPUs in MPP.



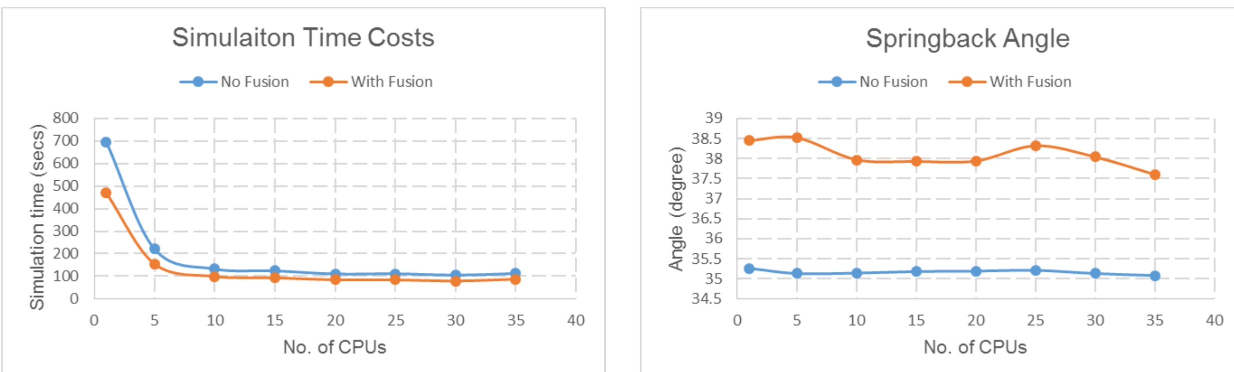
(a) No Fusion (b) With Fusion

Fig. 3. The final effective plastic strain contours of the workpiece running with 10 CPUs in MPP.



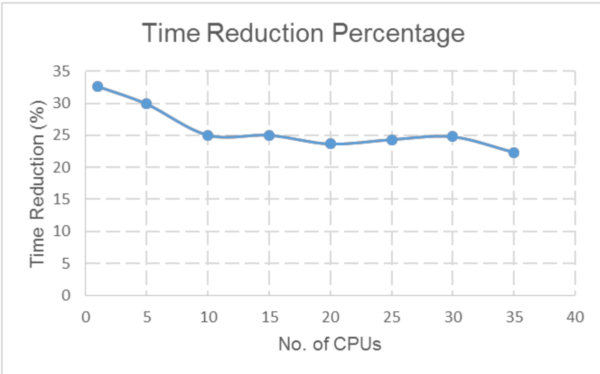
(a) No Fusion (b) With Fusion

Fig. 4. The final shell thickness contours of the workpiece running with 10 CPUs in MPP.

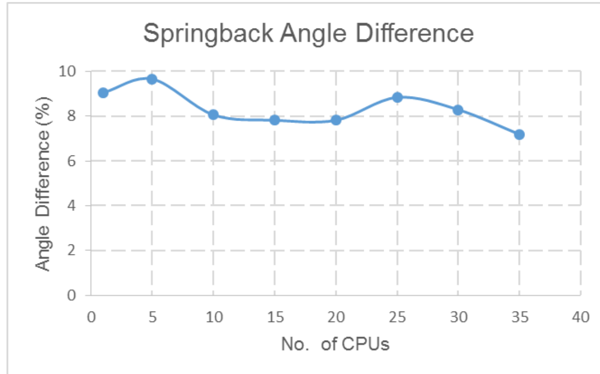


(a) Simulation time (b) Springback angle

Fig. 5. Comparisons of the simulation CPU time and springback angles in MPP with different number of CPUs, with and without mesh fusion.

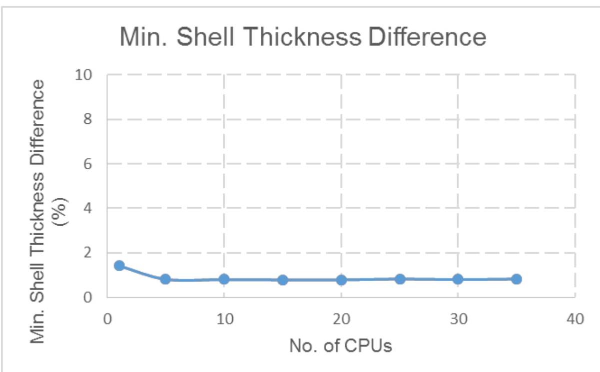


(a) Time Reduction

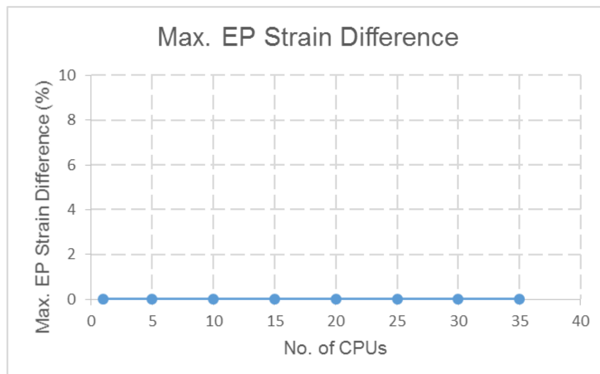


(b) Springback Angle Difference

Fig. 6. Time reduction and springback angle differences in MPP with different number of CPUs, with and without mesh fusion.



(a) Min. Shell Thickness Difference



(b) Max. EP Strain Difference

Fig. 7. Min. shell thickness and max. effective plastic strain differences in MPP with different number of CPUs, with and without mesh fusion.