Script for Automated One Step Forming Analysis using LS-DYNA® and LS-Prepost®

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Abstract

Mapping of metal forming data on metal parts for Crash Simulations helps to simulate the widely known effect of stiffer physical properties due to manufacturing processes. LS-Dyna® has enhanced the previously available capability to simulate one step analysis on metal parts and can use the existing finite element geometry taken from a full vehicle model. This method is quicker than running an incremental analysis for hundreds of parts which would take a considerable amount of time. This analysis is done manually one part at a time along with some necessary preprocessing. For this process to be useful in a full vehicle crash analysis, where multiple parts have metal forming data mapped, an automated process with minimal user interaction in model set up is required. A script was written to facilitate this method. This paper discusses the algorithm used to automate the set up process.

Introduction

One step forming or inverse forming methods have been available for a considerable period now. The method performs an inverse analysis without the need for the die and binder geometry. Added complication of contact is avoided while running this analysis. LS-Dyna® Implicit method is used along with a specific set of control cards to run the deck. The method for one step analysis is explained in August 2011 edition of FEA Information Engineering Journal. The mesh used for the simulation can be taken directly from a full vehicle model thereby avoiding use of a refined mesh typically used in incremental metal forming simulations. The results from this simulation can be directly used to replace the existing parts in the full vehicle model. This can be done as the one step analysis does not renumber the nodes and elements. Replacing the part with the one step results will help in reducing time required for the initialization process in LS-Dyna® for a crash simulation. This process if done manually will require a significant time in both pre and post processing each part. Alternately the results can be mapped to the existing mesh. With the second method, time is only spent in pre-processing and the only post processing required is adding a *INCLUDE_STAMPED_PART card in the main deck for crash simulation.

The above method is easy when running one single part. In large models hundreds of parts might need to be mapped. To run parts individually can be a time consuming affair as it involves part set up and post analysis result check. Existing techniques use a GUI based system to run multiple parts. Again this requires specific preprocessing of parts and takes time to make sure the setup is correct. Special care has to be taken to handle one step simulation of Tailor Welded parts. This led to developing a script for automating this entire process with minimal user interaction.

Automation of One Step analysis for multiple parts

Automation of a procedure means to have zero to minimum user interaction during the process. In full vehicle crash simulations most of the load carrying members are identified as candidates for mapping metal forming data. These set of parts can be a mix of Tailor Welded Parts (TWP), Press hardened steel parts and stand alone parts that are neither.

The following steps are followed for *Pre Processing* of all the parts.

- Identify all the parts from the full model that needs to use metal forming data. A Preprocessor like LS-Prepost[®] can be used to read the full vehicle model. After Identifying all the required parts only these are written out using "write active parts" feature
- Create a list of parts that are Tailor Welded and those that are Press Hardened Steel. These are identified in text files twbparts.txt and phsparts.txt. Each TWP part set is a single line in the twbparts.txt file. The phsparts.txt file contains one part per line.
- Fill all the holes in the part. LS-Prepost[®] is used in a no-graphics mode to do all the preprocessing. Filling holes in parts is done using a auto fill feature in LSPP.
- Make sure normals of all the elements within each part are pointing in the same direction. For tailor welded parts all the parts in a single TWP should have their normals pointing in the same direction
- Currently only material models MAT_24 and MAT_36 are supported in the LS-Dyna[®] One step method. So if some parts are using any other material models they need to be converted to MAT_24. Strain rate data existing in the material definition is ignored during the one step analysis. A standard set of control cards are used for the analysis set up.
- Keywords used for one step simulation
    CONTROL_FORMING_ONESTEP
    CONTROL_FORMING_ONESTEP_AUTO_CONSTRAINT
    CONTROL_IMPLICIT_GENERAL
    CONTROL_IMPLICIT_SOLUTION
    CONTROL_IMPLICIT_TERMINATION
- An *autolock* feature is used to constrain the boundary of the part to simulate drawbeads. The force used to lock the parts is calculated based on the material properties like thickness and strength.
- Convert under-integrated element formulation type 2 to type 16 shell formulation
- Write a keyword deck that combines the control cards and part data and submit the run.

Post Processing steps

- Check if the job terminated normally or abnormally.
- Elements that were created to fill the holes are removed from the final result file.

- Find the max and min thickness and Plastic strains for each part. In case the plastic strains are high then take an image of the part.
- Create a *INCLUDE_STAMPED_PART card and move the result of the analysis into a separate sub folder.
- For all parts both thickness and plastic strain data is mapped. For press hardened steel parts only thickness data is mapped.
- A report is generated and appended after each part/TWP is completed. This functions as the run log that can be seen to check progress of the run.

The above steps have to be followed for every part in the list chosen by the user. Tailor welded parts are run first followed by the individual parts

PERL is chosen as the language to write the code as it is platform independent. With very minor modifications to the code it can be very easily adapted to windows, Linux and UNIX operating systems. The flow chart that was used for the automation algorithm is shown in Figure 1. For the windows version a batch file is written and the user drops the keyword file with all parts chosen into the batch file. For Linux and UNIX a shell script is started with the LS-Dyna® keyword file as the input. Proper PATH and licensing environment variables are appropriately set for the executables in the script and needs to be modified to suit individual sites.
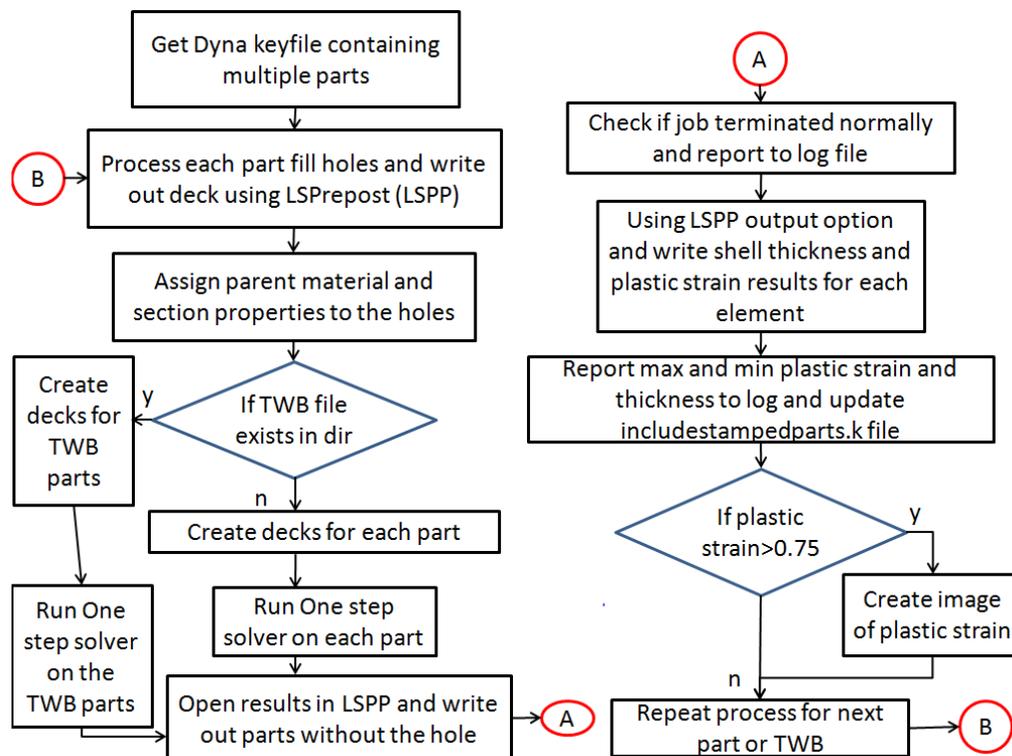

Figure 1: Flowchart

Results and Discussion

The script was tested using hundreds of parts. The results are for all the parts are reported in to a log file. The log file consists of the information if the part was a TW part or an individual part. In case of TW parts all the parts for a particular TW are listed out and maximum and minimum thickness along with plastic strains are reported. If the strains are above 75% then it is highlighted as HIGH STRAIN in the report. Figure 2 shows a sample of the log.

Figure 2: RUNLOG.txt

A keyword file with *INCLUDE_STAMPED_PART information is written to a file and the results of each run are moved to a folder STAMPED_PARTS. The file can be included in the main deck of a full crash analysis file and the mapping of all the chosen parts is then done at initialization of the run. Figure 3 shows an example of the include-stamped-part file.

Figure 3: Include stamped part file

One step solution is sensitive to some types of mesh and parts. This sensitivity can lead to parts showing very high strains or could result in abnormal termination. Some of the reasons for this are listed below.

- A part that is tubular shaped cannot be formed
- Parts that have regions folded over after a forming process or parts with very sharp corners will either terminate abnormally or show very high plastic strains. An example is shown in Figure 4 below. The geometry shown below is a simplified mesh and not the exact mesh from a manufactured process or the actual geometry of the part. Such a sharp corner cannot be formed without it cracking.
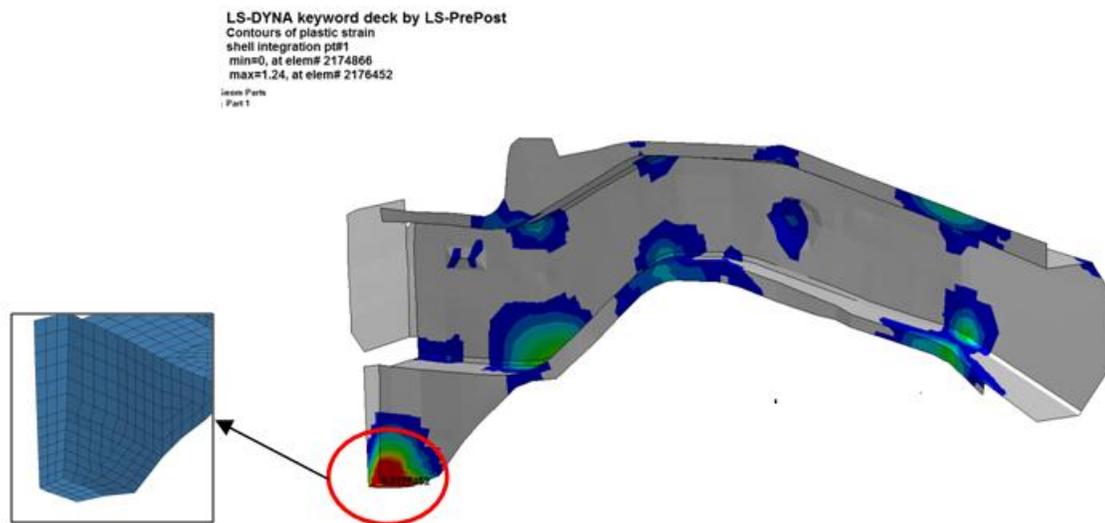

Figure 4: Folded with Sharp Corners

- Parts with bad mesh will terminate. This can be collapsed quads or elements with very high aspect ratios.
- If LS-Prepost® is unable to fill the hole in the part then the analysis will terminate abnormally. The LS-Dyna® Onestep algorithm has checks that look for parts that cannot be unfolded or have internal holes.
- Very large parts can abnormally terminate if memory is insufficient in the machine. Auto memory is not sufficient for one step implicit forming. Memory can be accessed using *KEYWORD *memory* option.
- There should not be any free edges or T edges within the parts. Figure 5 shows an example of free edges within parts. Here the elements were created by mistake and were not deleted. Automated element quality check would have failed to detect these elements.
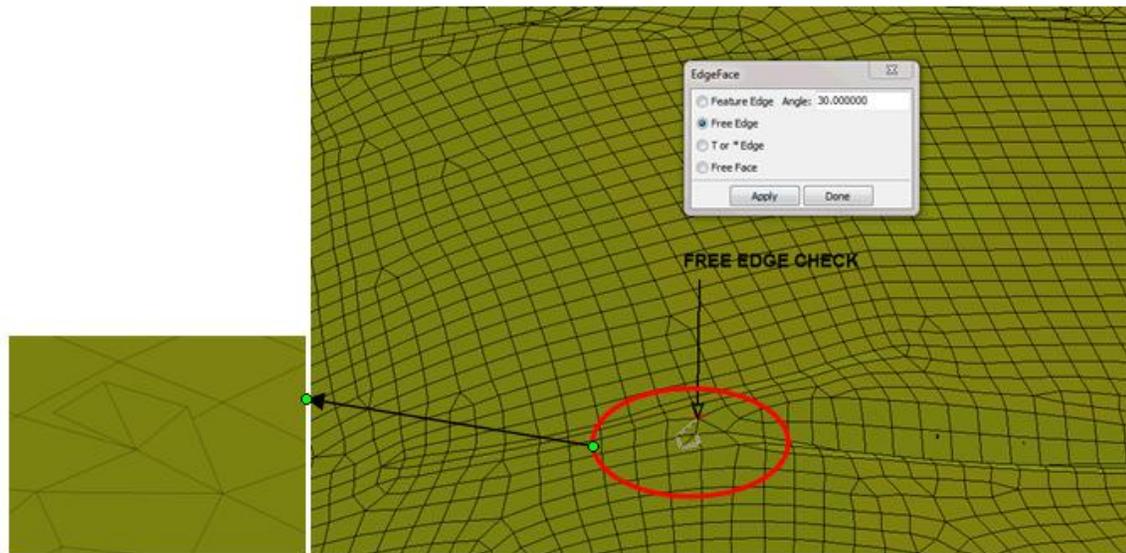
Figure 5: Example of part with free edge

- In case of TW parts the user has to make sure that the nodes are merged at the interface of multiple parts that make up the TW part. The script automatically performs a merge node operation just in case the user forgets to merge nodes at interface of the parts.
- TW parts with holes at interfaces of parts leads to the hole not being filled up by LS-Prepost®. The script has been modified to address this issue. TW parts will be joined together and then holes filled to run the one step solution.
- Parts with internal tabs can cause problems for filling holes and cannot be formed in a single step. The actual manufacturing process for the geometry shown in Figure 6 would involve multiple steps to punch out the tab after the stamping process.
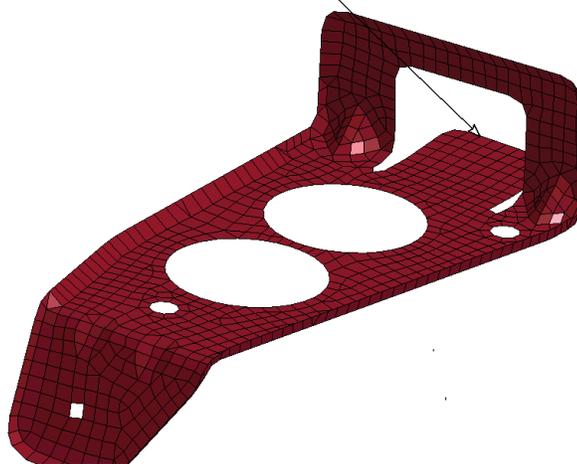

Figure 6: Part with internal tab

After fixing the parts that terminated abnormally the job can be submitted again. The script checks if a part already has existing results in the STAMPED_PARTS folder and then skips those parts. It will then update the include-stamped file and the run log.

Conclusion

The automated PERL script can solve hundreds of parts within a very short duration. This will save considerable amount of time for engineers since the script is very easy to use and has minimal user interaction. An added benefit to the methodology is the ability to detect a badly meshed part that could potentially lead to instability in a full vehicle crash analysis.

Future work would be needed to update the code when the hole-filling within parts will be built into LS-Dyna® One step algorithm. The script will be made available to users through *ftp.lstc.com* site.

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References

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