Introduction of a New Function, (CONTROL_FORMING_SCRAP_FALL), in LS-DYNA & Its Applications in Scrap Fall Simulation

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Abstract

In stamping plants, one of the most common defects is scrap fall failure, in which some of the trimmed scraps do not fall according to the designed chutes or intended path. The scrap fall failure can damage dies or/and panels and cause stamping production line shutdown, which could easily result in millions of dollars lost. This paper is focused on developing effective analytical tools to detect potential scrap fall failures in tool/die design stages.

Scrap cutting/separation from its parent sheet metal is an important step in properly simulating the scrap falling sequence. There are several critical characteristics which need to be properly captured by an analytical method in order to "detect" scrap fall errors. First, many broken-off scraps carry the initial kinematics and dynamics from the upper moving trim steel through contact during the trim process. Second, the trimming action is not simultaneous along the trim curve even in most simple direct trims. In complex cases such as multiple direct trim processes or mixture of direct trim and cam trim, the sequence of the scrap separation is very different from one design to another. In addition to the scrap separation sequence and the initial kinematics and dynamics of the scrap, contact between scrap and low trim steel and post is another very critical factor to the trajectory of the scrap fall.

Some efforts ([1], [2], and [3]) have been made to understand and detect the root causes of scrap fall issues. To our best knowledge, there are no methods available today which could consider all three above factors accurately. Therefore, simulation results from those methods might not yield the results observed in the stamping plants (refering to some cases presented in the paper).

To capture above mentioned three characteristics in simulation of scrap fall, a new function, called ***CONTROL_FORMING_SCRAP_FALL*** *in LS-DYNA, has been jointly developed by Ford and LSTC.*

In this paper, we will first reveal the basic parameters employed in the new function, and illustrate how they are used to simulate the scrap separation & falling with a few simple cases. Then, several complex examples will be shown to illustrate how the new function along w/ LS-DYNA existing capabilities to be able to simulate real trimming processes accurately (to capture above mentioned three key characteristics) and detect scrap fall failures.

Introduction

Three examples will be given in this paper. The first one will be used to explain how the new function works and what are the parameters & modeling techniques involved. The second example is to illustrate why the new function is needed in order to accurately understand and simulate the scrap fall from a trimming process on a real die design. The third example is also from a real die design case and is used to reveal that the new function can be applied to simulate a complicated multiple trimming process successfully.

From the demonstration of the three cases, we would like to conclude that this new function, "CONTROL_FORMING_SCRAP_FALL", can help improve the accuracy of the scrap fall simulation and is robust to be applied to complicated die design cases.

Section 1 – How does the "CONTROL_FORMING_SCRAP_FALL" work?

The detail description is given in LS-DYNA User's manual (Version 971, revision 1127). see attachment-1. It involves the following parameters, i.e. PID (part ID), VECTID (vector ID), NDSET (node set), LCID (Load curve ID), DEPTH, and DIST.

VECTID is the Vector ID used to define a trim steel movement (directions).
LCID is the curve ID which is used to define the steel trim kinematics
NDSET is "A Node Set" which consists of all the nodes along the cutting edge of the trim steel.
PID is used to define all the parts (ID) of the scrap pieces which will be trimmed away.
DEPTH is a parameter to define a threshed value of allowed small penetrating distance between the cutting edge of the trim steel and the scrap pieces. Nodes along the scrap edge are released from automatically-added constraints, based on the parts included in the PID card, and free to move after the threshed value is reached.
DIST is a distance tolerance measured in the plane normal to the trim steel moving direction, between nodes along the cutting edge of the steel trim defined by the NDSET and nodes along edge of the scrap.

The following is an example to illustrate how the new function works. Figure 1-1 is the model which consists of three parts. Many details are given in LS-DYNA User's manual.

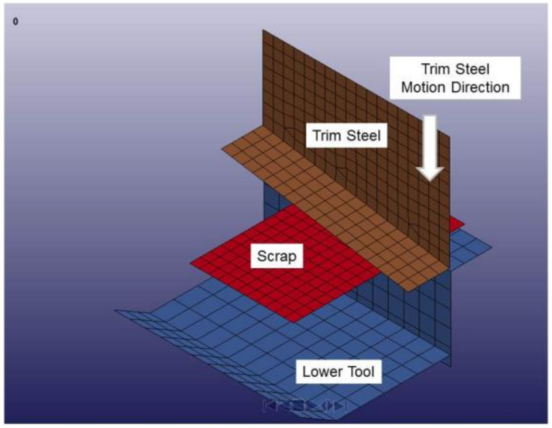


Figure 1-1 Simulation model

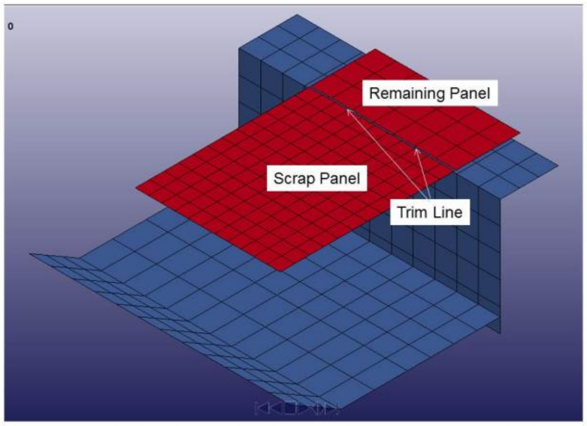


Figure 1-2 Scrap/parent piece

The sheet panel, which will be trimmed, is modeled as two pieces. One is called "scrap" and the other is "parent piece" as shown in Figure 1-2. The "parent" is not necessarily to be included in the simulation. Therefore, they are not included in other examples shown below.

The trim line is defined along the edge of the scrap which is determined automatically by the Control_Forming_Scrap_Fall with the information from the NDSET and DIST.

A simple trim process, in which the trim steel will move down with a constant speed, is simulated. When the steel trim cuts into the panel, detected by the penetration of the nodes along the trim steel cutting edge into the scrap piece, the constraints imposed on the nodes on the scrap piece will be released. The scrap will, first, be pushed down along with the trim steel through the contact and fall after it is completely separated (or trimmed). The following Figures are used to illustrate the simulated trimming process.

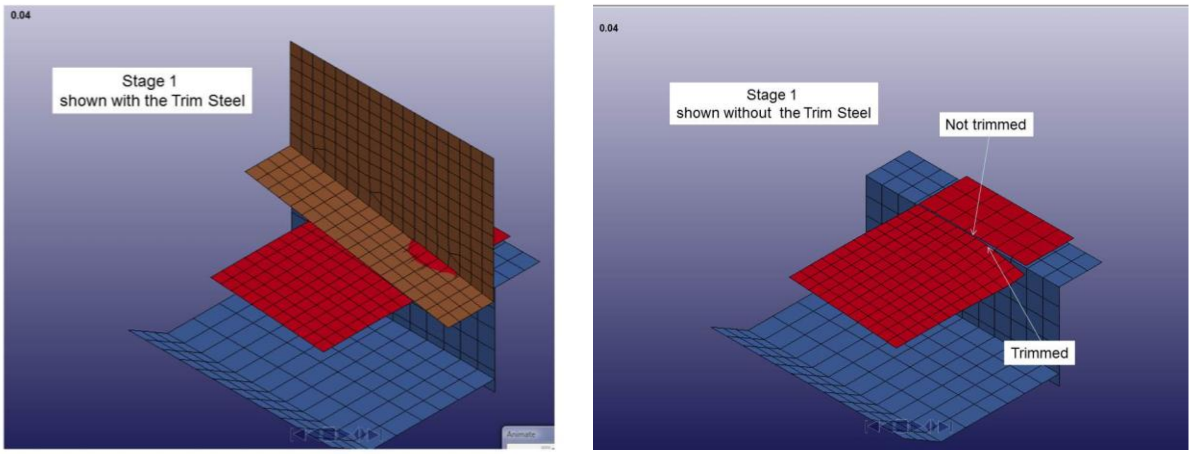


Figure 1-3. Early stage of trimming (right - trim steel not shown)

The same trimming process, simulated by the approaches used in [2] & [3], results are shown in the following two Figures.

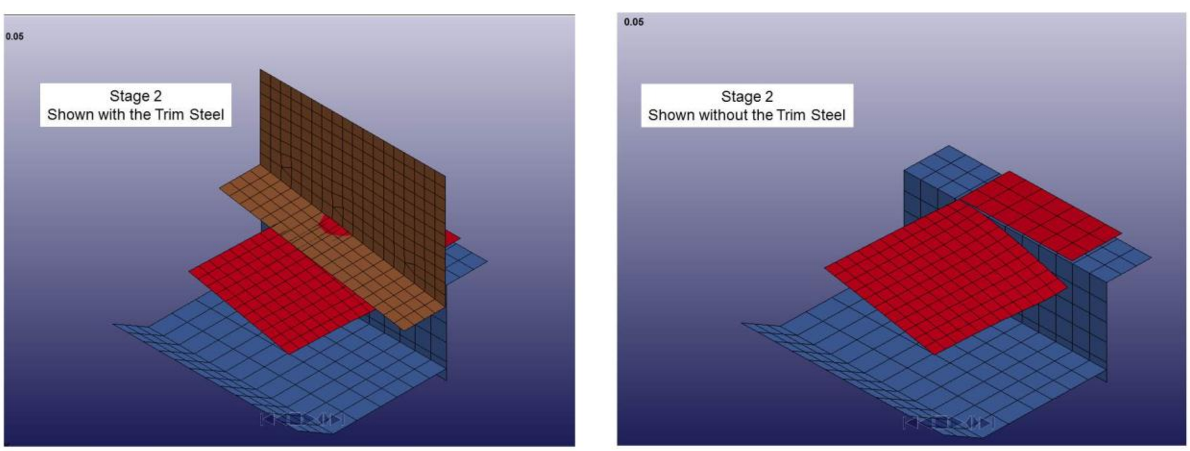


Figure 1-4. Final stage of the trimming (right – trim steel not shown)

The same trimming process, simulated by the approaches used in [2] & [3], results are shown in the following two Figures.

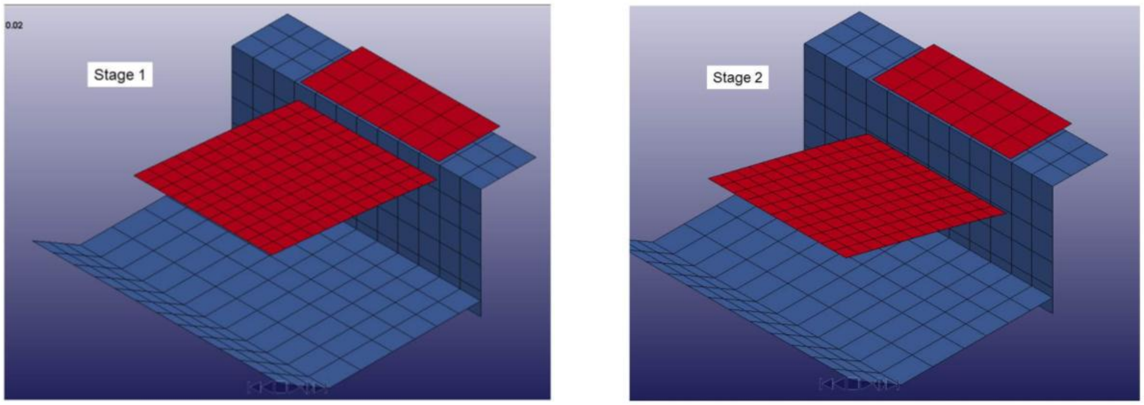


Figure 1-5. Trimming results with other approaches ([2], [3]).

From Figures 1-3 to 1-5, the results of the scrap fall from the two different simulations are quite different. We believe that the results from the process with the new function of CONTROL_FORMING_SCRAP_FALL are more close to the reality because (1) it includes the effect (contact) from the Trim Steel to the scrap and (2) it simulates the sequence of the scrap separation.

Section 2 – Application of the New Function in Direct Trim

Direct Trim is a terminology used at Ford for a trimming process that all the trim steels, applied to the interested scrap, are moving in vertical direction. Since the trimming direction is aligned with the direction of the gravity force, it is considered as the most simple trimming process and, usually, has the least concerns for the scrap fall failures. However, from the following example, one can see that the new function developed in LS-DANA is really needed in order to accurately simulate a simple direct trim process.

Figure 2-1 is the die design for a hood outer panel. The interested scrap (circled out in the Figure) is through a direct trim.

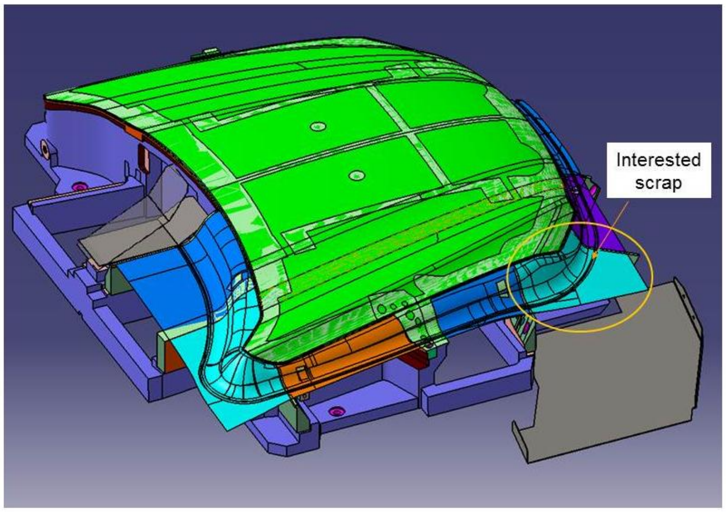


Figure 2-1. Overview of a die design for a hood outer panel

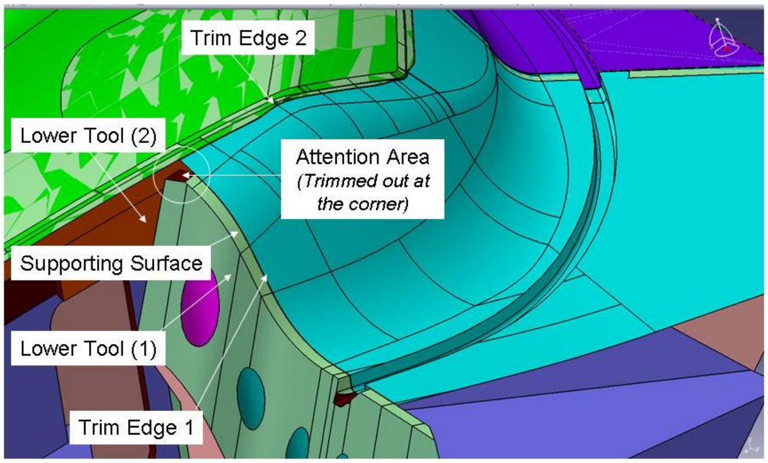
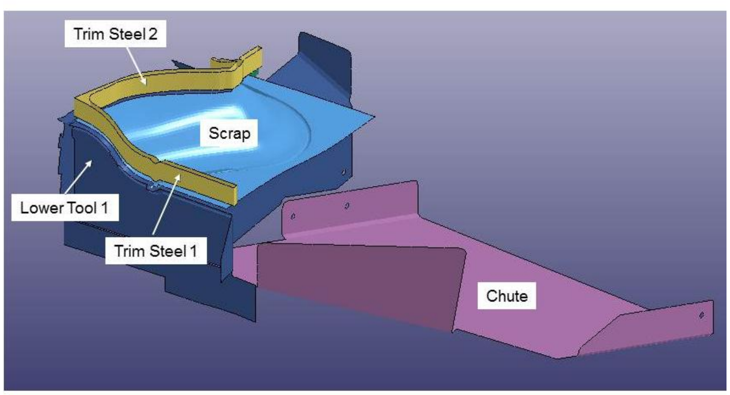


Figure 2-2. Details of the tools/panel near a corner of two trim edges

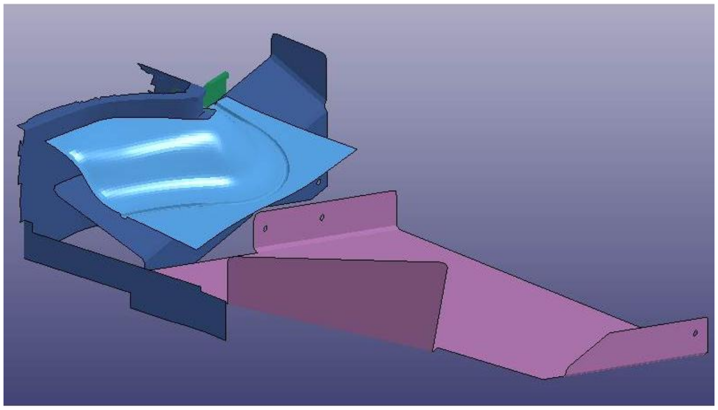
There are two trim edges. At the intersection of the two trim edges, i.e. "Attention Area" circled out in the Figure 2-2, the trim steel, which cuts along the "Trim Edge 2", would have interference with the "Lower Tool 1" if it had not had the offset on the “Lower Tool supporting surface” at the corner. This design feature, i.e. the offset on the "Lower Tool supporting surface", is necessary to ensure no interference between the trim steel and the tooling. Also, this area is usually the last one to be cut by the trim steel. Consequently, motion of the scrap (fall) can be affected by the sequence of the scrap separation. Improper design of those features may result in concerns on scrap fall.

The design feature and its importance to the scrap fall are one of the reasons which motivated us to develop the new function. Figure 2-3 shows the CAE model and simulation results from LS-DYNA applied to the interested scrap.

LS-DYNA Simulation w/
CONTROL_SCRAP_FALL

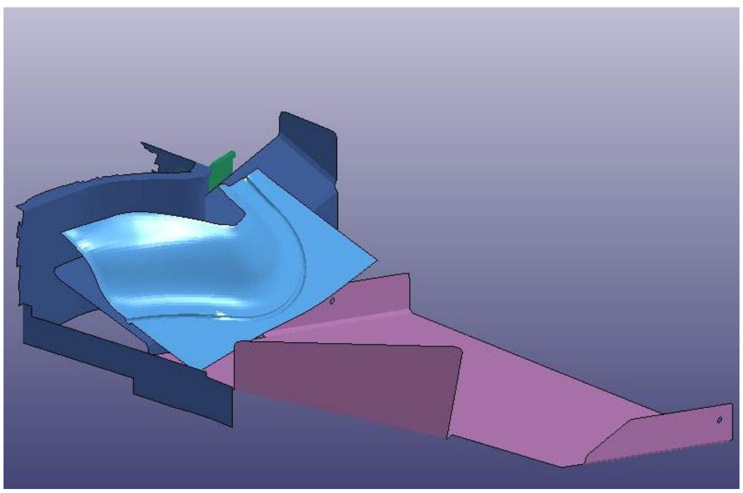


LS-DYNA Simulation
@ 0.025 (s) after the scrap is trimmed



Trim Steel and Lower Tool (1) are not shown in the picture

LS-DYNA Simulation
@ 0.07 (s) after the scrap is trimmed



LS-DYNA Simulation
@ 0.45 (s) after the scrap is trimmed

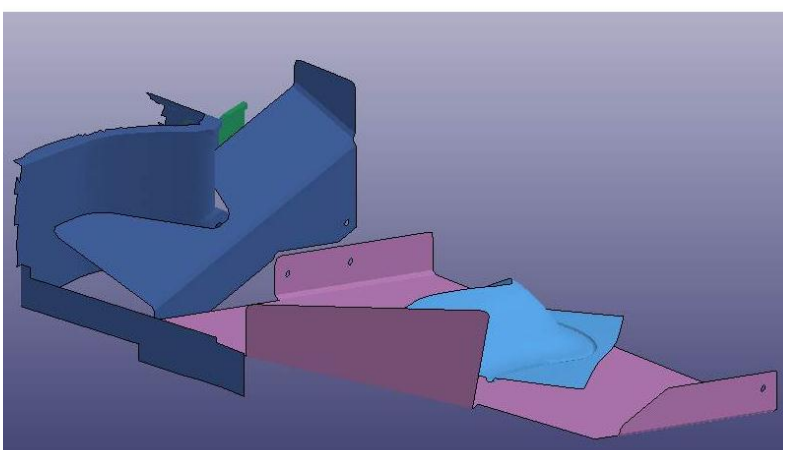


Figure 2-3. The direct trim model at a hood corner and simulation results

Section 3 – Application of the New Function in bypass Trim Process

In addition to the direct trim, a process to have all trim steels move align the same direction other than the vertical is called Angle Trim at Ford. A trim process, which consists of at least one direct trim and one angle trim, is called bypass trim. In the following example, an example of a bypass trim process (Figure 1) is simulation and explained.

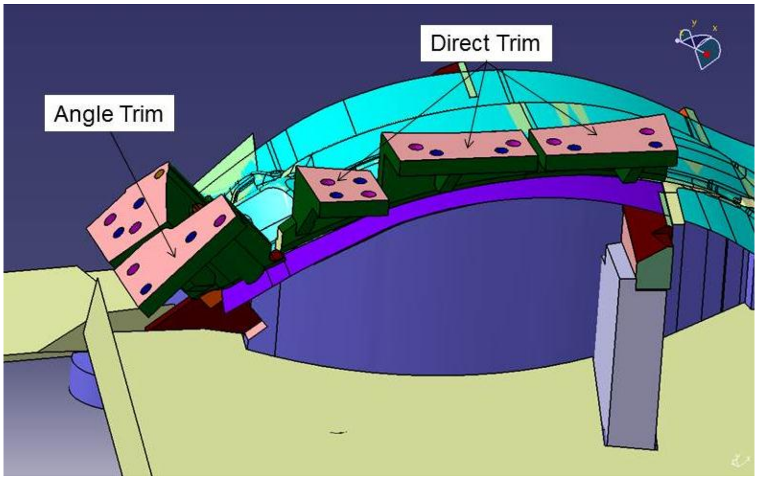


Figure 3-1. An example of a bypass trim

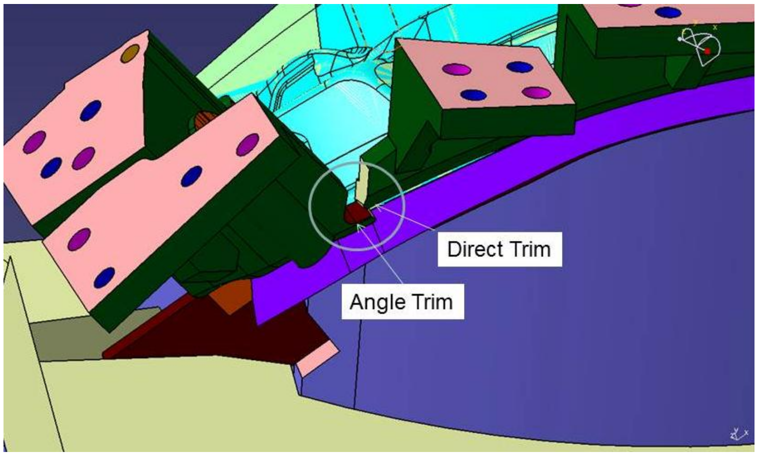


Figure 3-2. Intersection area of two trim steels

In the circled area of the Figure 3-2, the angle trim and the direct trim need to cut on the same trim line with some overlap in order to ensure the scrap is trimmed. The sequence is that the angle trim cuts first, followed by the direct trim. After the scrap is trimmed, the direct trim moves away first and followed by the angle trim. Since the entire trim process completes within a few seconds, it is not trivial to design the required overlapped trim line (area) and sequence of the trim steels moving in and out to ensure the trimmings are done properly while the scrap falls according to designed chutes or intended path. In reality, scrap fall concerns are often surfaced in early tool try-out for this kind of bypass trims. Then, a costly and time consuming re-work process is needed to fix the issues (usually by trial and error approach). With the help of upfront engineering with the help of CAE simulation, the scrap fall concerns can be reduced. In addition, the CAE simulation can also help the re-work process to quickly identify what may be the most effective fix after the model is correlated.

Following are the Figures of the simulation used LS-DYNA with the new function of CONTROL_FORMING_SCRAP_FALL.

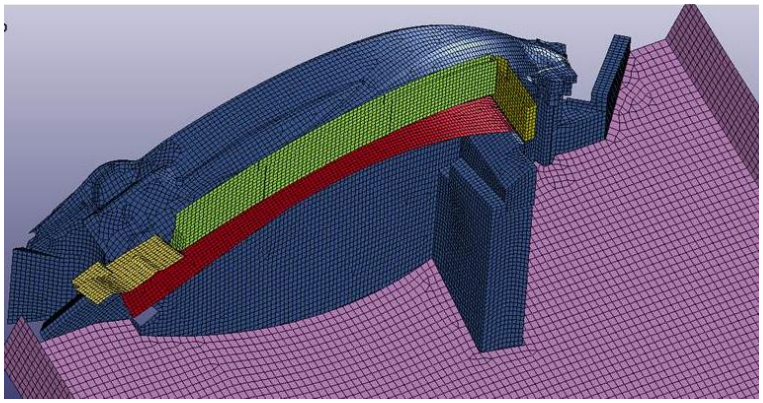


Figure 3-3. LS-DYNA model

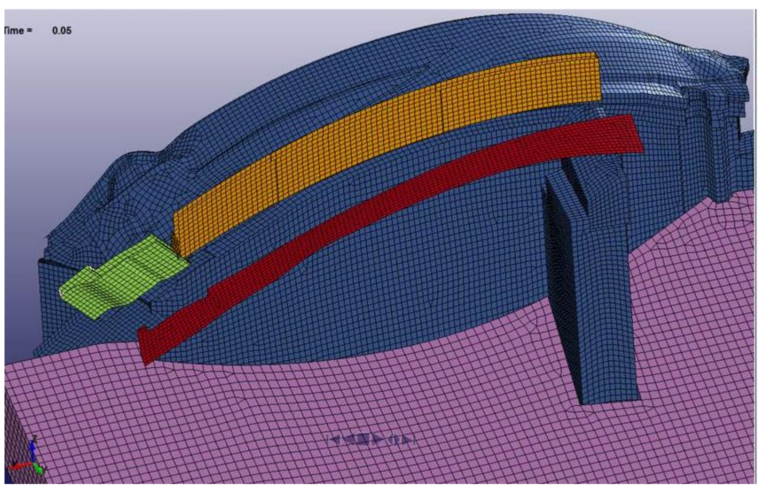


Figure 3-4. Results of the LS-DYNA Simulation

Conclusion

A new function and process, which can accurately simulate scrap trim and fall, has been successfully developed and implemented into LS-DYNA. The new function, CONTROL_FORMING_SCRAP_FALL, can be used in various trimming processes and should result in more accurate results, comparing with previous process used in [2] & [3], in scrap fall simulation.

References:

1. Beril Gumus & Bulent Ekici " A New Sheet Die Design Methodology to Eliminate Scrap Shedding Problems During Mass Production", ASME 2010 10th Biennial Conference on Engineering Systems Design and Analysis.
2. Diane Xu & Jim Kosek "Application of Scrap Shedding Simulation in Stamping Manufacturing", 10th International LS-DYNA User Conference.
3. eta/DYNAFORM 5.6, " Die System Simulation", www.eta.com