Studies on the Efficiency of LS-DYNA® in Sheet Metal Stamping for Feasibility and Formability Analyses

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Abstract

Feasibility and formability analyses serve different purposes in automotive panel designing. The turnaround cycle of forming simulation is essential, since the designs change very frequently in early stage of vehicle development. The goal of this study is to evaluate the feasibility by using LS-DYNA® as an alternative to Autoform for both early product evaluations, as well as more detailed formability analysis in GM's production developments. Targeting the requirements of feasibility and formability analyses, the key techniques of using LS-DYNA® in sheet metal forming simulations are systematically studied, such as element formulation, material model, adaptive meshing, and mass scaling, etc. The study shows that the simulation time is able to be significantly reduced by choosing proper combination of the numerical parameters, while the accuracy of the results remains satisfying.

In this study, 21 production developments by Autoform were translated to LS-DYNA so that they could be run using the LS-DYNA solver on GM's HPC server. These 21 parts encapsulate all three engineering modules and contain a wide variety of parts. Given the computational resources available in GM, the simulation time and results by LS-DYNA are competitively comparable to Autoform.

Introduction

Stamping simulations have become widely used to assess the formability of automotive sheet metal panels throughout the industry. They can be used early in a product development cycle to ensure a formable product is achievable as well as prove out a process by which it can be achieved. They can also be employed as the product matures to validate the final forming process. As time goes on, the accuracy and turnaround time of the simulations will become even more critical as the product development cycle time is being compressed. This analysis must also take into account the new materials that are being introduced as well as the additional operations being evaluated.

There are several different finite element codes that can be used to assess sheet metal formability in a production intent environment. There are also different degrees of accuracy that may be utilized for different stages of product development. A more coarse, quicker running model may be more suitable early in a product development timeframe where a quick turnaround time for feedback to the product engineer is critical as the product is in a fluid state. This feedback loop will be greatly dependant on the speed with which product geometry can be incorporated into a stamping model and run through a forming process. This also includes the CPU run time associated with the file. There are also times in a product cycle where a more refined, more accurate formability model is needed as the product becomes more mature. During this time frame, accuracy is more important whereas CPU run time is not as critical.

The goal of this study was to evaluate the feasibility of using LS-DYNA as an alternative to Autoform in both the early product feasibility stage as well as a more detailed production intent analysis. This includes a comparison between the CPU run time between the two different software packages, as well as the formability results themselves. For the early up-front analysis, we employed the LS-DYNA feasibility setting. The LS-DYNA Baseline setting was used for the more refined formability analysis. The optional LS-DYNA settings would allow the user the flexibility to choose which level of detail is optimal for a particular time in the product development.

To evaluate the feasibility of using LS-DYNA, 21 Autoform models were translated to LS-DYNA so that they could be run to compare the formability results, as well as the CPU run time with the original Autoform file. The 21 parts reviewed represent a cross section of parts that would typically be evaluated and encapsulate all three of the engineering modules inside GM. Furthermore, both of the LS-DYNA settings were evaluated in this study.

Materials and Methods

The input and material files were exported out of the 21 Autoform developments. These files contain the process set-up, the material information, and the corresponding tool geometry. The resulting files were then used to translate the Autoform developments into LS-DYNA input files. These translated files were then run using LS-DYNA with two different settings, Baseline and Feasibility.

First of all, a systematic study was done to investigate the influence of the various numerical parameters setup on the interested simulation results by balancing the efficiency and accuracy. The optimal combinations of key parameters were then come up for the full spectrum of the selected production developments. The parameters adopted for the Baseline and Feasibility settings are summarized below in Table 1.

Table 1. Parameters used for the LS-DYNA Baseline and Feasibility Settings

	Baseline	**Feasibility**
Element Type	16	2
Integration point number	5	3
Max adapt level	4	3
Velocity (mm/s)	5000	5000
Time step (s)	1.2E-6	6.0E-6
Mass scaling	Regular	Selective

Results Review

The first metric that was evaluated was the CPU run time for the respective draw simulations. The respective run times for 7 of the 21 parts analyzed can be seen below in Table 2. The LS-DYNA Feasibility and Baseline Runs were performed on the GM HPC using 8 CPU's. The Autoform iterations were performed using the GM HPC using 4 CPU's. The run times shown below in Table 2 are the respective CPU run times and do not include queue time.

Table 2. CPU Run time Comparison Between Autoform, The LS-DYNA Baseline Setting, and The LS-DYNA Feasibility Setting for Seven Selected Parts Evaluated using GM HPC

Part Name	Autoform Run Time (Mins)	LS-DYNA Feasibility Run Time (Mins)	LS-DYNA Baseline Run Time (Mins)
Panel-Roof	13	3	15
Panel-R/Cmpt Floor	12	10	69
Door Frame	206	32	172
Fender	6	8	37
Front Door Outer	8	2	10
Hood Inner	28	16	57
Body Side Otr	97	48	243

The next items for comparison are the analytical results themselves. In this study, only the draw operation was considered. Further studies might be required for line die simulations and panel springback. There are many result parameters that could be compared. In this study, the main things considered were the thinning and the FLC failures. Furthermore, the overall results were viewed on a more macroscopic basis to compare the two software packages.

As seen in Figure 1, the results are very similar between the LS-DYNA Baseline setting and the Autoform simulation for this structure panel. The locations of the predicted failures are similar, as are their relative locations on their corresponding FLCs.

There are also similarities seen in Figure 2 for this Body Side Outer panel. In the three locations where Autoform predicts failure, the thinning levels predicted by LS-DYNA, both the Feasibility and Baseline settings, are relatively close to those predicted by Autoform.

As seen in Figure 3, there is a discrepancy between the draw simulation for the Autoform run and the LS-DYNA Baseline setting. The LS-DYNA Baseline run predicts a FLC failure, whereas the Autoform simulation passes. Upon further inspection, there is a sharp edge in the tool mesh that causes a failure in the LS-DYNA Baseline run. There is also a discrepancy in the results for the Deck Lid seen in Figure 4. The Dyna-Baseline shows a failure that Autoform doesn't. There appears to be a very small issue in the tool mesh that may be causing this split.

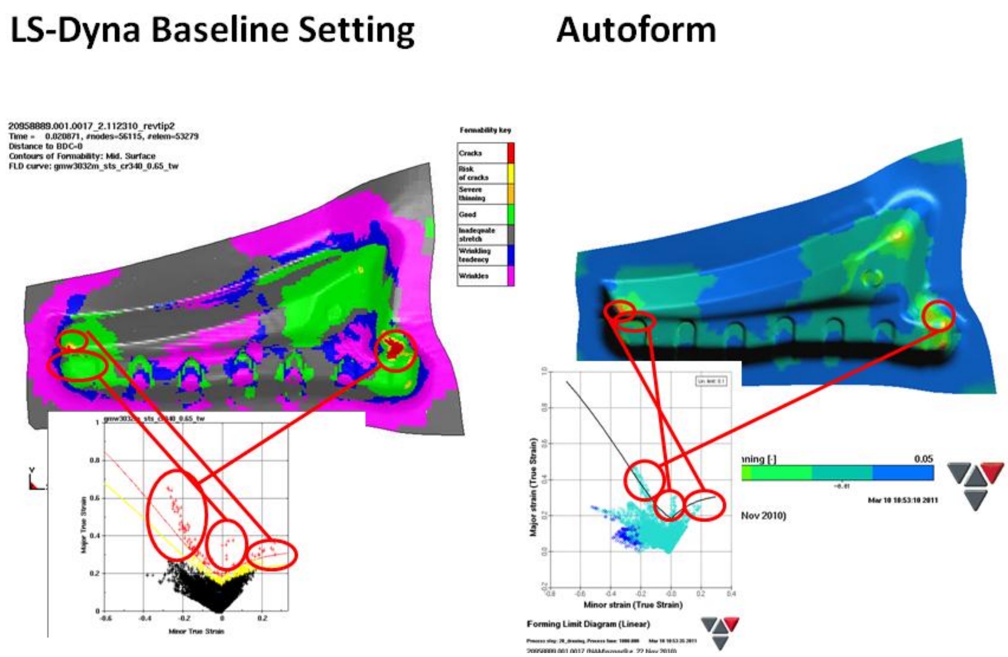

Figure 1. Draw Result Comparison Using Autoform and The LS-DYNA Baseline Setting for a Structure Part

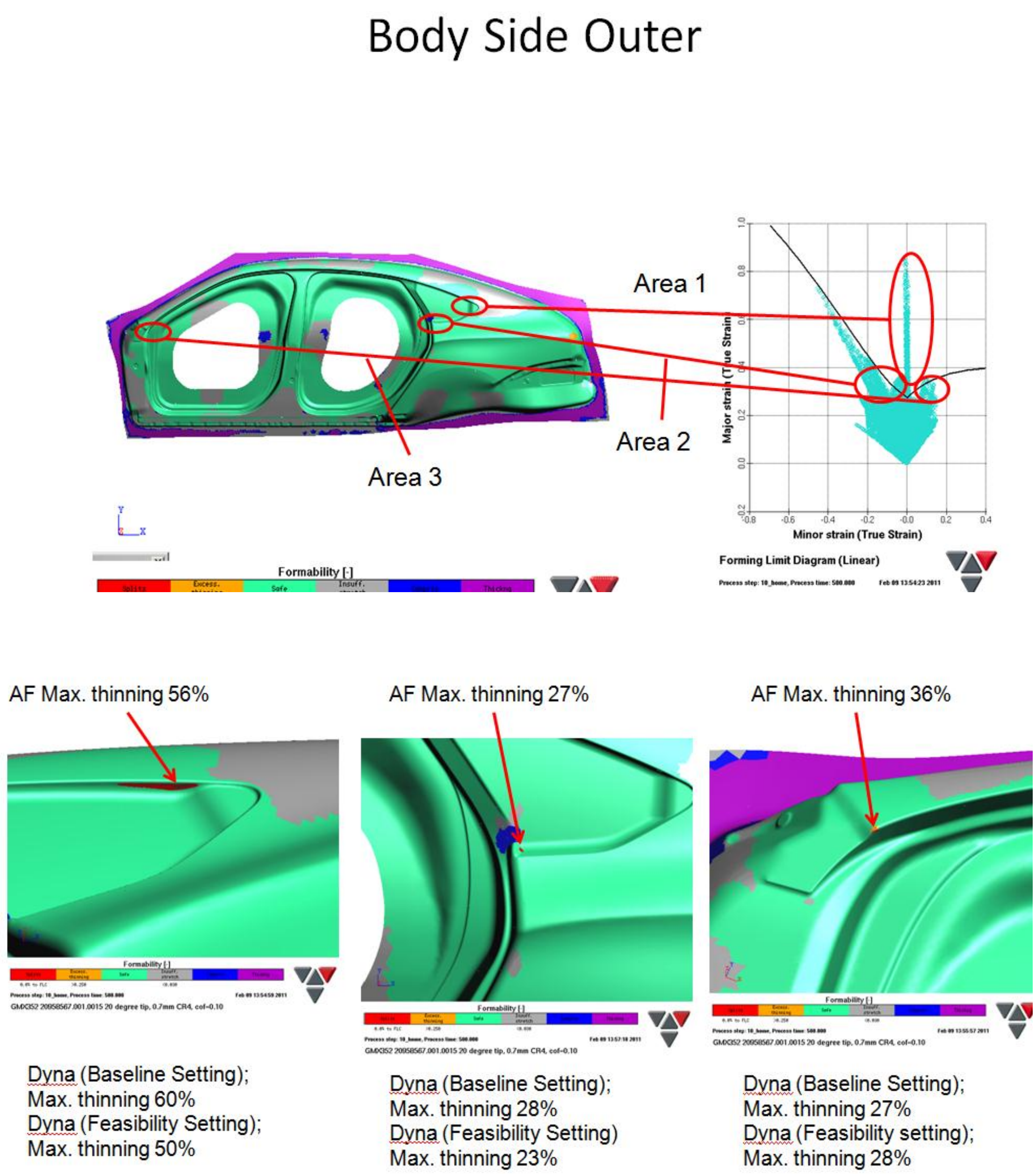

Figure 2. Thinning Comparison Using Autoform, LS-DYNA Baseline, and LS-DYNA Feasibility Settings for a Body Side Outer Panel

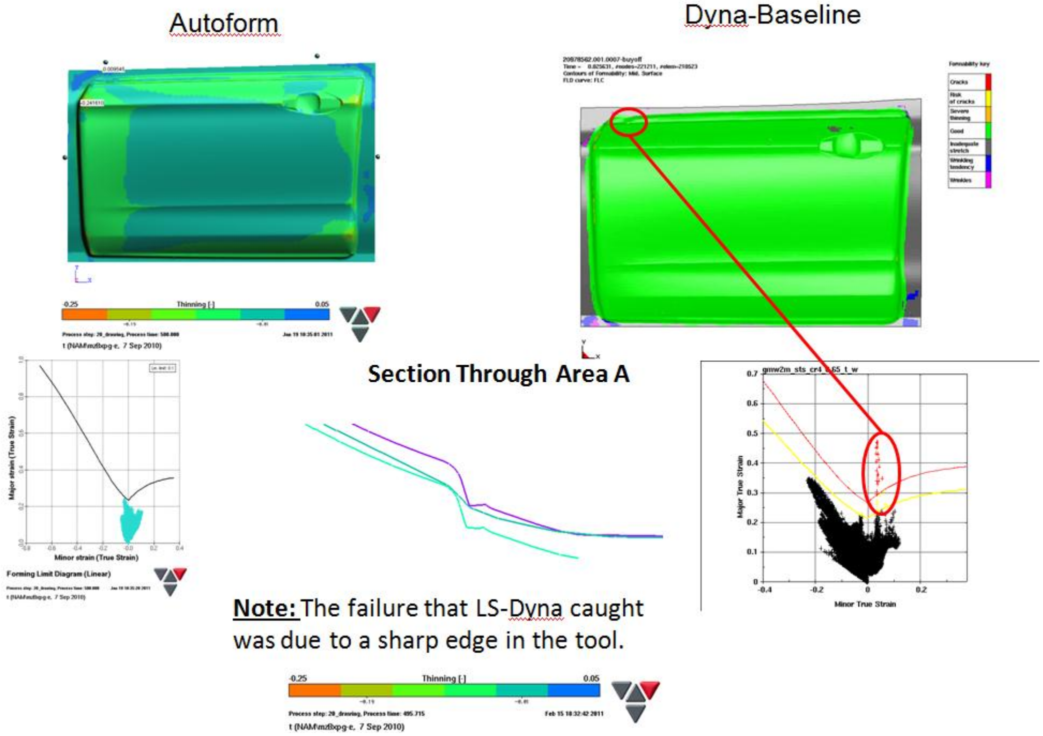

Figure 3. Autoform and LS-DYNA-Baseline Comparison for a Front Door Outer

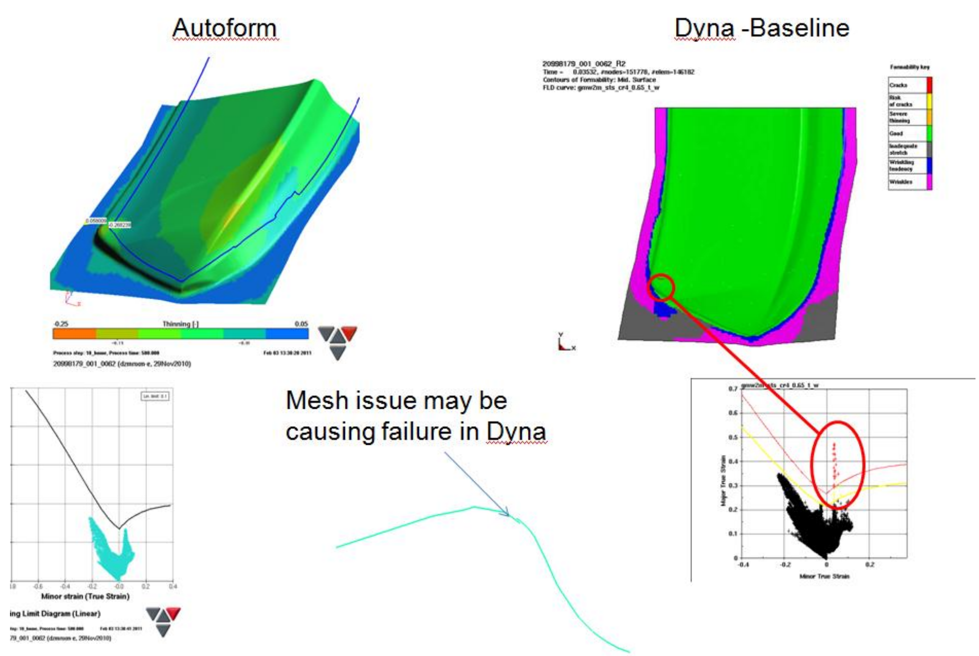

Figure 4. Autoform and LS-DYNA-Baseline Comparison for a Deck Lid Outer

Discussion

There were two main metrics that were being scrutinized in this study to assess the feasibility of using LS-DYNA to evaluate both early product feasibility and detailed formability analysis. They are CPU run time and analysis results. As far as the CPU run times are concerned, the LS-DYNA runs were not prohibitively slow to allow the production use of LS-DYNA. This is evident in the cases outlined in Table 1. By utilizing the GM HPC, even the slowest running jobs completed in less than half a day.

From a macroscopic level, the analysis results were similar between Autoform and LS-DYNA in the majority of the cases studied. The main enabler for achieving similar results between Autoform and LS-DYNA was to match the draw-in amounts as closely as possible. In several cases, the initial LS-DYNA run had considerably different results than the associated Autoform file. Once an effort was made to equalize the draw-in amounts, the results often became closer. There were some discrepancies in the results, but they were usually explainable upon further review. In one instance, there was a sharp edge in the tool mesh that resulted in a LS-DYNA failure that passed Autoform. This example can be seen in Figure 3. One would expect that in reality this sharp edge would cause a failure, so LS-DYNA may have highlighted a failure that Autoform didn't. A similar discrepancy can be seen in Figure 4 and it seems to be related to the tool mesh. The tool meshes, used in all of the cases studied, were created in Autoform and are by no means intended for machining purposes. Hence the discrepancies seen in Figures 3 and 4 would not be seen using high quality surfaces.

To fully evaluate whether LS-DYNA is capable of replacing Autoform for early feasibility studies at GM, one other major factor must be considered. This is the considerable capability of Autoform to produce analysis models using only the product surface as an input. The die modeling features of Autoform are critical to the formability work that GM currently performs, especially with respect to providing timely feedback to the product community. The flexibility and ease with which die geometry can be created or modified using Autoform is irreplaceable with regards to quick and accurate formability evaluations. For LS-DYNA to be fully capable of replacing Autoform, it would need to have the same capabilities.

References

LS-DYNA® Keyword User's Manual, Version 971, LSTC