Draw-in Map - A Road Map for Simulation-Guided Die Tryout and Stamping Process Control

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Abstract. Sheet metal forming is a displacement or draw-in controlled manufacturing process in which a flat blank is drawn into die cavity to form an automotive body panel. Draw-in amount is the single most important stamping manufacturing index that controls all forming characteristics (strains, stresses, thinning, etc.), stamping failures (splits, wrinkles, surface distortion, etc.) and line die operations and automations. Draw-in Map is engineered for math-based die developments via advanced stamping simulation technology. Then the Draw-in Map is provided to die makers in plants as a road map for math-guided die tryout in which the die tryout workers follow the engineered tryout conditions and matches the engineered draw-in amount so that the tryout time and cost are greatly reduced, and quality is ensured. The Map can also be used as a math-based trouble-shooting tool to identify the causes of formability problems in stamping production. The engineered Draw-in Map has been applied to all draw die tryout for all GM vehicle programs since 1998. A minimum 50% reduction in both lead-time and cost and significant improvement in panel quality in tryout have been reported. This paper presents the concept and process to apply the engineered Draw-in Map in die tryout.

INTRODUCTION

In a traditional die development and making process, a die is designed based on previous experience, and the die is validated through a series of physical tryouts on proof tools. These tryouts are time and cost consuming and can not guarantee the success of the die developments. For a typical automotive body panel such as a fender, the tryout alone could last a few months and cost more than half a million US dollars. Today, in math-based die development process, the designs of dies can be evaluated and reshaped through electronic tryout via the advanced stamping simulation technology. Though years of integrated research, software development and production application, the accuracy of the stamping simulations or digital tryout has achieved such a high level of sophistication that GM stamping CAE engineers can predict the forming characteristics (metal flow, strains, thinning, etc.) and conventional failures (splits, wrinkles) with very high confidence (the correlations between the predictions and tryout for a large number of dies are greater than 90%). The die makers in GM tool rooms and workers in press lines believe and accept the simulations and predictions. In order to fill the gap between the math world and the physical world, CAE engineers must select and deliver a simple but critical engineering result to die makers in tool rooms and workers in press lines. Draw-in map (Fig. 1) based on draw die forming simulations is discovered as the messenger to accomplish the task [1]. Implementing draw-in map as the road map for simulation-guided tryout and production control is the most effective way to reduce die lead-time and cost and improve stamping quality.

DRAW-IN MAP

Sheet metal forming is a displacement or draw-in controlled manufacturing process in which a flat blank is drawn into die cavity to form an automotive body panel. Draw-in amount is the single most important stamping manufacturing index that controls all forming characteristics (strains, stresses, thinning, etc.), stamping failures (splits, wrinkles), surface defects (distortion, skid/impact lines), and line die
operations and automations. Insufficient draw-in causes splits or necking, and excessive draw-in amount results in wrinkles, distortions, skid lines, and other forming defects. Furthermore, the draw-in amount affects line die operations and panel handling because the trim dies and automation grippers are designed according to the predicted blank outlines after forming (the outlines are the results of the draw-in). If draw-in amount is not matched, the trim operation will have problems either trim tools interference with drawn panel or not enough metal for trim. And more, the automation grippers may have difficulty to catch the panel to move it to next die station. These often trigger serious unnecessary changes in trim die, grippers, blank or blanking die in the plants.

Figure 1 shows a typical engineered metal Draw-In Map that indicates numerically how much metal movement is required at designated locations around the perimeter of the blank to form a good panel that is free of formability and quality problems.

![Figure 1. Engineered Draw-In Map](image)

**DRAW-IN MAP AS ROAD MAP**
**IN DIE TRYOUT AND STAMPING PRODUCTION**

Intense correlation validates that the amount of metal movement, or draw-in, is an accurate indicator of the amount of metal strain in the formed part. The Draw-in Map is the road map for successful die tryout and robust stamping. Matching engineered draw-in amount is the foundation to make simulation-based die developments work successfully in physical world. It was also found that matching draw-in is the simplest way for die makers to understand and to fulfill die engineering intent in order to reproduce the engineered formability and quality for defect-free panels. Matching engineered draw-in amount is a paradigm shift in die tryout and panel buyoff, and production troubleshooting. Measuring draw-in amount is the easiest way for tryout workers to measure die performance and actively monitor the tryout progress. In order to match the engineered draw-in to reproduce the engineering results, the following tryout conditions must be maintained as closely as possible to the engineered tryout (analysis) conditions.

- Use the same **blank** (size, shape, gauging, and coating).
- Match analysis specified **blank** gauging.
- Match the **die geometry** that passed formability analysis (check the critical dimensions at analysis specified areas where product or addendum were changed several times to pass digital validations.
- Match the analysis specified **binder travel** that is measured from initial binder position to home position.
- Apply the same **stamping fluid** specified by simulation.
- Match the engineered beads (locations and size, and proper clearances and spotting).

If all above conditions are met and the draw-in amount is still off, then a minimum amount of tryout work to refine the draw beads may be needed until matching the engineered draw-in amount.

Figure 2 illustrates a production case (hood inner panel) for this process. The tryout workers download the engineered Draw-in Map and engineered tryout parameters along with the Formability Workbook from engineering website. After studying the engineering results, the tryout workers use the Draw-in Map as a simulation-based manufacturing guide to conduct the tryout. Figure 3 shows a comparison between the measured draw-in amount in the primary die tryout (in red color) and the engineered draw-in amount (in black color). It took the tryout worker only a few hours to obtain split and wrinkle free panels by using and matching the engineered Draw-in Map. The circle
Figure 2. Draw-in Map comparison (the numbers in black are engineered draw-in, and the numbers in red are Made within a few hours in primary tryout by matching engineered draw-in.

Figure 3. The panels passed circle grid measurement after matching the engineered draw-ins amount in primary tryout.

The Draw-in Map is further used in stamping production for consistent formability and quality execution from engineering to die construction and tryout and to production process control. When dies are released to production line from tool room, the Draw-in Map with both measurements in primary tryout and engineering (as indicated in Fig. 3) is electronically delivered to the press workers along with a set of tryout parameters via web technology. The press line workers review and use the same tryout parameters to reproduce the draw-in amount measured in primary tryout. Figure 5 illustrates the Draw-in Map with three sets of draw-in measurements from engineering (in blank color), primary tryout (in red color), and production (in blue color). The consistent draw-in correlations ensure the robustness of die performance. For many years, achieving such a consistent die performance and formability stability has been a dream for die engineers, die tryout workers, and press line workers. With the engineered Draw-in Map and its business applications in tool rooms and shop floors, the dream become true.
Figure 5. Draw-in Map comparisons for consistent formability execution in engineering, die tryout and production (the numbers in black are engineered draw-in, the numbers in red are from primary tryout, the numbers in blue are from production).

**SUMMARY**

The use of Draw-in Map as the stamping manufacturing index and formability measure is an invention in sheet metal forming industry to transfer the math-based formability principle and stamping simulation results to die shops and stamping floors. The applications of the Draw-In Map in GM tooling shops and stamping plants demonstrated the significant results in time and cost reductions in die tryout and improvements in robustness and quality of dies as well. It is an effective process control tool, stored at the press line and also on the stamping CAE website, (where it cannot be lost). Draw-in Map is a key element in GM multi-year strategy of reducing cost per die, simplifying the die tryout process and reducing rework.

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**REFERENCES**