Sequence design for progressive dies

Part I: Using FE-based methodology

Editor's Note: Part I of this two-part series on progressive-die sequence design discusses the development of design rules using finite element methods (FEM). Part II, which will appear in the February issue, will cover the process sequence for a new part based on design rules developed using FEM.

This column was prepared by the staff of the Engineering Research Center for Net Shape Manufacturing (ERC/NSM), The Ohio State University, Professor Taylan Altan, director.

Progressive dies perform a series of operations at two or more stations during each press stroke, which shapes a workpiece as the strip moves through the die (see **Figure 1**). This technology can be an alternative to conventional stamping, depending on production volume and part complexity.

Progressive-die design relies heavily on past experience and several prototyping runs. The most challenging issue in designing a process sequence is how to determine the minimum number of required forming stages and corresponding tooling geometry to satisfy specifications for thickness, residual stresses, and surface finish.

Progressive-die Sequence Design

Every process sequence design must include the number of forming stages, tool geometry for each stage (punch and die diameter, punch corner, and die corner radii), draw depth for each forming stage, and blank holder force (if needed) at each stage.

Process sequence design for a new part generally is based on experience–knowledge gained from producing similar parts and necessary prototyping runs. This experience-based methodology requires extensive resources and increases the design's lead-time. Finite element analysis (FEA), coupled with knowledge-based design, can strategically reduce lead-times and enhance the robustness of the progressive-die sequence.[1] A robust process accounts for variability during production, such as:

- Variations in incoming stock material properties
- Variations in process conditions (forming speed, forces, and so forth) and interface characteristics (lubrication and frictional forces)

To develop die sequence design guidelines for a new part (see **Figure 2a**), researchers conducted a preliminary FEA on an existing automotive part (see **Figure 2b**). Material parameters, process conditions, and tool geometry data were available for the automotive part's six forming stages (see Figure 2b).[2] Design rules developed from this study are meant to assist in process sequence design for new parts.

FEA of an Existing Automotive Part

Each stage of the sequence for the automotive part was simulated for the given process conditions using a commercial FE code, DEFORM™-2D software (www.deform.com). Results such as

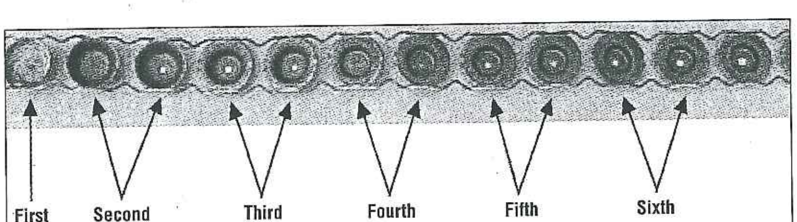


Figure 1

Progressive dies perform a series of operations at two or more stations during each press stroke, which develops a workpiece as the strip moves through the die.
Photo courtesy of Pax Machine Works.

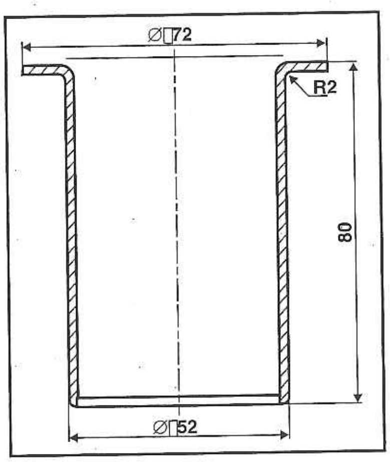


Figure 2a

A process sequence needed to be designed for this new automotive part.

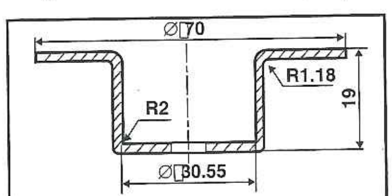
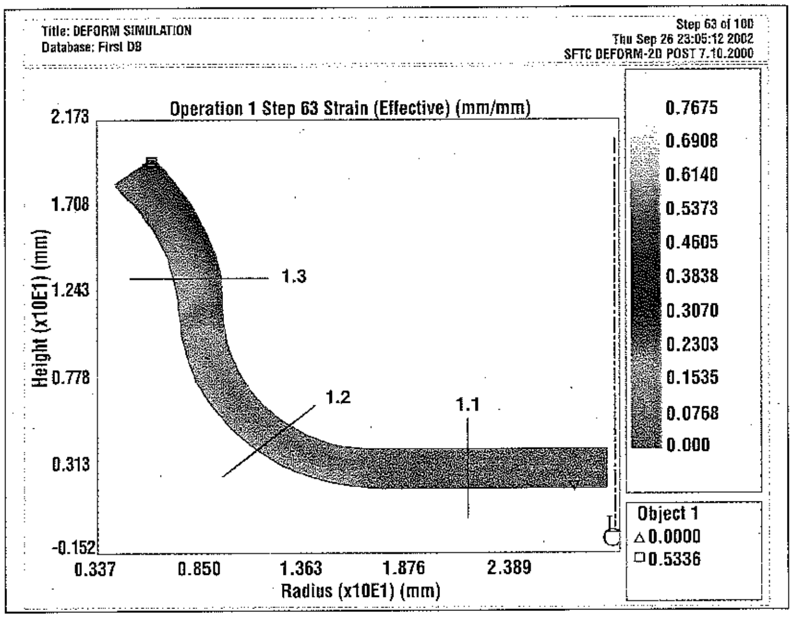


Figure 2b

An FEA was conducted on an existing automotive part in production to determine process sequence for the new part.
Drawing courtesy of Pax Machine Works.



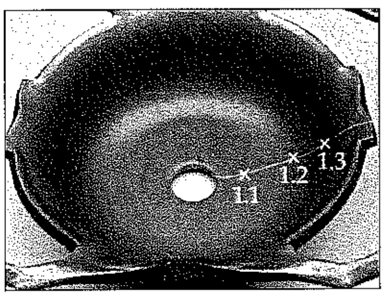


Figure 3

This figure compares the thickness measurement from the production part with the effective strain (thickness) distribution predicted by FEA after the first forming stage.

thickness distributions and strain hardening were predicted for each stage and carried over to the successive stages to account for work hardening.

Figure 3 shows the part's strain (thickness) distribution as predicted by FEA after the first stage. At each stage, FEA accurately predicted strain distribution, part geometry, and punch forces. **Figure** 4 shows the final part geometry predicted by FEA for all six forming stages.

Based on FEA of the existing automotive part, general design guidelines were created that could assist process sequence design for a new part. Some guidelines were:

- To maintain maximum wall thinning below a threshold value of 13 percent, higher draw ratios were required in the initial forming stages. This finding corroborates guidelines already followed by experienced die designers.
- Punch corner radii and die corner radii were critical parameters in the initial forming stages. The die corner radius was selected based on initial sheet thickness (about four times the incoming sheet thickness). The punch corner radius was selected based on the die corner radius (approximately equal to or less than the corresponding die corner radius).

The depth of the new part (Figure 2a) would be significantly greater than the depth of the existing automotive part (Figure 2b), so more than six forming stages would be needed for the new part.

These design rules garnered from the FEM study will be used to develop the process sequence for the new automotive part, which will be discussed in Part II.

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Notes

1. N. Jain, X. Shi, G. Ngaile, and T. Altan, "Process Sequence Design for Progressive Forming of Round Cups," ERC/NSM Report No. S/ERC/NSM-02-R-92, 2002.

2. N. Jain, X. Shi, G. Ngaile, T. Altan, B. Pax, B. Harman, and G. Homan, "Simulations Confirm Deep-drawn Die Design," Metalforming, November 2003, pp. 32-35.

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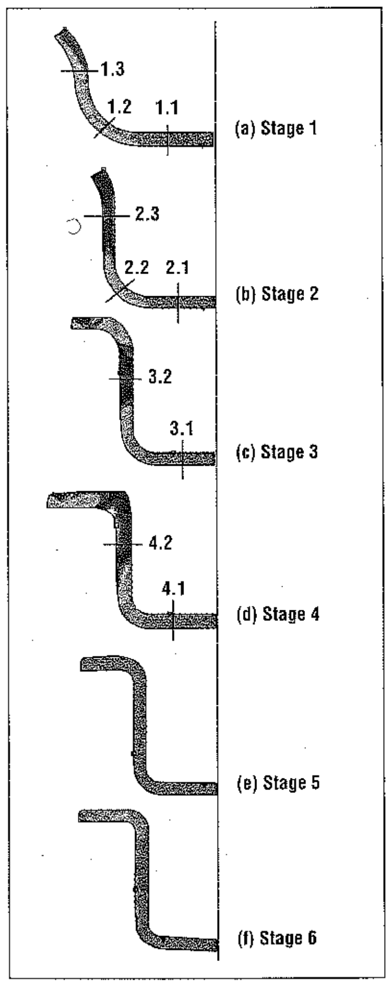

Figure 4

FEA predicted the final part geometry and the effective strain (thickness) distribution in the part after each forming stage.