Stamping Part Surface Quality Improvement Through Process Optimization

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ABSTRACT

The surface quality of an outer skin part of a vehicle, smooth and with no waviness, is becoming more and more important in today’s more and more competitive automotive industry. Strain analysis has been used for formability evaluation and trouble shooting and process optimization has been used for formability improvement in stamping. In this work, diffracto analysis is used to evaluate the surface quality of a stamping part, the strain magnitude and the strain distribution of a part are examined to analyze the root cause of the waviness in the part and process optimization, including optimization of press tonnage, nitrogen pressure and shut height, is used to improve the surface quality of the part. Test results from using different input parameters are compared in this paper. The optimized process parameters have been used in production resulting in more stable and high surface quality and less scrap cost.

INTRODUCTION

The typical operations to form a sheet metal part are drawing, trimming and piercing, flanging and restriking. The formability of a sheet metal part is usually decided by the drawing operation and less affected by the subsequent operations. The dimensional variations and the surface quality are affected by all of the above operations.

The formability of a sheet metal part is very important because it ensures that the part can be formed without splits and/or buckles. The formability is often evaluated by a forming limit diagram [1]. To draw a forming limit diagram of a stamping part, either a forming limit curve of the sheet metal from dome tests [2] or a simplified one derived from a tensile test [3], has to be obtained. In addition, the strains on the part have to be measured and drawn on the diagram against the forming limit curve of the sheet metal. If the strains fall out of the safe zone in the forming limit diagram, into the marginal zone, or even the necking zone, either the die or the process, or both, have to be modified to improve the formability of the part. The die modification has been regarded as an art and very little has been reported in this respect. With the development of computer, measurement and control technology, and the understanding of sheet metal forming principles, process control and its effect on formability have been more and more studied [4-6].

Dimensional variation of sheet metal parts can affect their assembly process as well as the appearance of the assembled product. This was not well emphasized until the last few years. Coordinate measurement machines are now used to measure the shapes of sheet metal parts and statistical methods are used to evaluate their variations. Although dimensional variations of sheet metal parts are affected by numerous sources, such as material, stamping process, die and press condition, lubrication and automation [7], the reported research is mainly in tonnage and speed control of a press [8. 9].

The surface quality of a sheet metal part usually does not affect the function and the assembly process of that part. But the appearance of a part, especially an out-skin part, such as the door outer of a car, does play a more and more important role when a customer chooses a car in today’s very competitive market. Diffracto analysis has been used to evaluate the surface quality of sheet metal parts and their assemblies. The surface quality is usually improved through die modification. There is no report about surface quality improvement through process optimization.

In this work, strain distribution in a draw panel is used to help diagnose the surface quality problems of the panel. The tonnage and the shut height of the draw press and the nitrogen pressure of the trimming die are optimized to improve the surface quality of the panel.

STAMPING OPERATIONS AND PROBLEMS

The two front door outers of the minivans made by Chrysler are formed together through three stamping
operations: drawing, trimming and piercing, and flanging and restriking. The two doors are symmetrically arranged in the drawing operation, as shown in Figure 1. They are drawn in a double-action toggle mechanical press. The handle holes of the two outers are formed in this operation.

![Figure 1](image1.png)

*Figure 1. Arrangement of the two front door outers in the drawing operation and the locations of the scribed circles.*

The drawn panel is turned over between the first press and the second press. In the second stamping operation, trimming and piercing are performed. The drawn panel is cut into two separate panels, right and left. The materials in the handle holes are punched out. The panel is held by a panel holder driven by nitrogen pressure to prevent the material from flowing in this operation.

![Figure 2](image2.png)

*Figure 2. History of the handle hole area severity rates from diffracto analysis.*

Flanging and restriking are performed in the third stamping operation. The two panels, right and left, are held by panel holders driven by nitrogen pressure. In addition to the peripheries of the two outers, flanging is also performed inside the two handle holes.

Based on the analysis of the stamping operations, it can be seen that the tonnage of the outer slide and the shut height of the inner slide in the drawing operation affect the material flow and the depth of the part. The level of nitrogen pressures in the second and the third operations may allow the material flow if too small. These all play an important part in the surface quality of the panels.

These variables were not optimized or well controlled. The surface quality was not stable, especially the waviness and mouse ears around the handle hole area which caused constant quality concerns. The history of the severity rates of the handle hole area from diffracto analysis, which indicate the surface quality, is shown in Figure 2. It clearly indicates this situation. The average monthly scrap cost was $12,229 in 1996 for the two front door outers. It was very high.

A strain analysis was done for the original process. Because the strain was very small, a general circle grid of 5 mm in diameter could not be used. Instead, circles of 100 mm in diameter were scribed onto the blank. The distribution of the circles is shown in Figure 1. The strain distribution is shown in Figure 3. It is apparent that the strain is too small in some areas. The total or thickness strain (which is negative) can be as low as 2.3%. Although the arrangement of the two outers is symmetrical, their strain distributions are not, especially the right side. Some distortion exists. Low strain distributions and the distortions have caused the waviness and “mouse ears” around the handle hole areas. Strain has to be increased and distortion has to be reduced.

![Figure 3](image3.png)

*Figure 3. Strain distributions of the draw panel using the original stamping process.*

### EXPERIMENTS AND RESULTS

While there are many variables that can affect the surface quality of the panels, only a few variables were examined. In the following sections, optimization experiments for the tonnage of the outer slide and the shut height of the inner slide in the drawing operation and the nitrogen pressure in the second and the third stamping operations are described and their results illustrated. The variations of the parameters are shown in Table 1. When one parameter changed in the experiment, other parameters kept constant unless otherwise specified. Only surface quality around the handle hole area was evaluated using diffracto analysis due to its primary importance.
Table 1. Variable variations in experiments

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Values used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tonnage of the outer slide in the drawing operation</td>
<td>ton</td>
<td>336, 376, 429, 470, 522, 566</td>
</tr>
<tr>
<td>Shut height of the inner slide in the drawing operation</td>
<td>inch</td>
<td>77.89, 77.90, 77.91</td>
</tr>
<tr>
<td>Nitrogen pressure in the second die</td>
<td>psi</td>
<td>800 (low), 1250 (high)</td>
</tr>
<tr>
<td>Nitrogen pressure in the third die</td>
<td>psi</td>
<td>1100 (low), 1400 (high)</td>
</tr>
</tbody>
</table>

TONNAGE EXPERIMENT – The outer slide tonnage of the drawing operation was changed from 336T to 566T while the shut height of the inner was 77.90 inches and the nitrogen pressure was high for both the second die and the third die (see Table 1).

Figure 4. Effect of outer slide tonnage in the drawing operation on the surface quality of the panels.

The experimental result is shown in Figure 4. The surface quality is improved, or the severity rate of the handle hole area is reduced with the increase of the tonnage until a split occurred for the left front door outer, which caused large distortion for both panels. The best tonnage that should be used is about 500 tons, considering the tonnage variation caused by other factors that may cause splits. The strain distribution using an outer slide tonnage of 523T is shown in Figure 5. The strain becomes larger and better distributed, compared with Figure 3, especially for the right side panel, which gained a great improvement in surface quality through process optimization.

Figure 5. Strain distributions of the draw panel using an outer slide tonnage of 523T.

SHUT HEIGHT EXPERIMENT – Three different shut heights were tested when the tonnage was about 520T for the outer slide and the nitrogen pressure for both the second die and the third die was high, as listed in Table 1. The result is shown in Figure 6 indicating that 77.9 inches gives the best surface quality among these three shut heights of the inner slide.

Figure 6. Effect of inner slide shut height in the drawing operation on the surface quality of the panels.

NITROGEN PRESSURE EXPERIMENT – The nitrogen pressure in the second die was changed from 800 psi (low pressure) to 1250 psi (high pressure) and the nitrogen pressure in the third die was changed from 1100 psi (low pressure) to 1400 psi (high pressure) when the tonnage of the outer slide was about 520T and the shut height of the inner slide was 77.90 inches in the drawing operation. The effect of the nitrogen pressures on the severity rates of the handle hole area is shown in Figure 7. The nitrogen pressure has a larger effect on the surface quality of the left front door outer than on that of the right front door outer. Higher nitrogen pressure is required for both the second die and the third die to
obtain the best surface quality. Although the nitrogen pressure in the second die has a larger influence.

Figure 7. Effect of the nitrogen pressures of the second die and the third die on the surface quality of the panels: 2low means the nitrogen pressure in the second die is low, 3low means the nitrogen pressure in the third die is low, 2low+3low means the combination of the above two, and so on.

RESULT FROM PRODUCTION – The optimized parameters have been used in production. The history of the handle hole area severity rates shown in Figure 2 indicates a great improvement in surface quality, especially the right side. It also shows that if the optimized process is not used, or the production is not carried out in the home line, low surface quality may be produced. A byproduct of the effort in surface quality improvement is the great reduction in scrap cost shown in Figure 8.

CONCLUSIONS

1. Stamping part surface quality depends not only on the stamping dies, but also on the stamping process parameters used in production.
2. Strain analysis generally used for formability improvement in stamping has been applied to diagnose the surface quality problems of stamping parts in this work.
3. The process optimization technique generally used for formability improvement and dimensional variation reduction in stamping has been applied for surface quality improvement in this work.
4. The surface quality of the front door outers of the Chrysler minivans has been improved and stabilized through process optimization.

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REFERENCES