Predicting off-center loading in sheet metal forming operations, Part II

Stamping using a transfer die set

BY HITANSH SINGHAL, NEIL PARKER, JAMIE BOWMAN, DAVID DIAZ-INFANTE, AND DR. TAYLAN ALTAN

Editor's Note: This is Part II of a two-part series. Part I, which appeared in the September/October 2019 issue, discussed how to predict off-center loading when forming with a single tool.

In a transfer die forming operation, a blank/initial part is transferred to several individual dies/stations to form the final part. As illustrated in Figure 1, differences between the forming and cutting forces and the distances of the individual stations from the press center can generate an off-center load, which leads to an imbalance (trying to tilt the press bolster). Because the press is large, the magnitude of this imbalance produced by each station also is large. Therefore, off-center loading is a more critical issue in a transfer die forming operation than in a single die forming operation.

Case Study: Transfer Die Set

Researchers at The Ohio State University's Center for Precision Forming studied a part provided by Bowman Precision Tooling. The transfer die set for forming this part was about 6,000 by 1,700 millimeters, comprising seven individual dies (see Figure 2). The distance between the centers of each station was 800 mm.

The aim of this case study was to develop a methodology for predicting off-center loading in a transfer die set using a commercially available finite element (FE) software package (Auto-Form R8 in this case), and to estimate the forces on the four columns of the press. The off-center loading calculation was done only at bottom dead center (BDC).

Develop a Methodology. The methodology developed through this case study involved five steps:

1. Calculate the net load (sum of all forming and cutting loads) for each station at BDC.
2. Locate the net load (point B in Figure 1).

Figure 1

In a four-station transfer die (left), variations in the forces in each station (right) can generate an off-center load. Courtesy of D. Boerger.

Figure 2

For the case study, the transfer die set was about 6,000 by 1,700 millimeters, comprising seven individual dies. The distance between the centers of each station was 800 mm. Courtesy of Bowman Precision Tooling.
ure 3) at BDC. Divide the total moment about a known reference point (point A in Figure 3) produced in a station by the corresponding total force to obtain the location of net load in the station (distance D in Figure 3).

3. Determine the distance of net force location for each station from the press center (see Figure 4).

4. Multiply the net load for each station (determined in Step 1) by the corresponding distance of these net forces for each station (determined in Step 3) to calculate the moment produced by each station at BDC. Add the moments produced by each station to obtain the off-center loading in the press at BDC.

5. Compensate for the off-center loading by using the “false load” method. Install nitrogen cylinders at the extreme end of the transfer die to maximize the moment produced by each nitrogen cylinder. Devise the total moment caused by off-center loading by the distance from press center to the nitrogen cylinder to determine the total force required. Divide this total force by the force capacity of each nitrogen cylinder for the total number of cylinders required. Other methods for balancing the off-center loading can be found in Part 1 in the September/October 2019 issue.

**Estimate Forces.** Researchers divided the net moment on the press by the net force (sum of forces on all stations) to obtain the distance of net force (D₁ and D₂ in Figure 5) from the press center. To calculate the forces on the four columns, the net force (F) and the value of distances (D₁ and D₂) can be substituted in the formulas below:

For force on post 1 (F₁) = \( F = (L+D₁)(W-D₂) / 4LW \)

For force on post 2 (F₂) = \( F = (L+D₁)(W+D₂) / 4LW \)

For force on post 3 (F₃) = \( F = (L-D₁)(W+D₂) / 4LW \)

For force on post 4 (F₄) = \( F = (L-D₁)(W-D₂) / 4LW \)

Where: D₁ = Distance of net force location from press center in feeding direction

D₂ = Distance of net force location from press center in transverse direction

**Table:**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Net Form (ton) (Forming + Cutting)</th>
<th>Location of Force From Press Center (mm)</th>
<th>Moment About Transverse Direction (ton.m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP-20</td>
<td>157</td>
<td>-2,362</td>
<td>-370</td>
</tr>
<tr>
<td>OP-30</td>
<td>665</td>
<td>-1,564</td>
<td>-1,040</td>
</tr>
<tr>
<td>OP-40</td>
<td>341</td>
<td>-763</td>
<td>-260</td>
</tr>
<tr>
<td>OP-50</td>
<td>139</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>OP-60</td>
<td>121</td>
<td>876</td>
<td>107</td>
</tr>
<tr>
<td>OP-70</td>
<td>375</td>
<td>1,600</td>
<td>600</td>
</tr>
<tr>
<td>OP-80</td>
<td>118</td>
<td>2,444</td>
<td>290</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,916</strong></td>
<td><strong>-672</strong></td>
<td><strong>-</strong></td>
</tr>
</tbody>
</table>

**Figure 5**

This schematic shows the calculation of forces on four columns in the press.

These are the estimated forces and moments caused by off-center loading.
It’s your world. Shape it as you please.

In the hands of skilled craftsmen, our steel becomes the parts, components, and products that make the world run. For over 66 years, fabricators and manufacturers big and small have trusted Admiral Steel to help them leave their mark on the world. For any size order from 10 lbs to 10,000 lbs, you get first-class quality, on-time delivery, and personalized service from Admiral. Contact us for a quote today!

Admiral Steel
AdmiralSteel.com

452 West 123rd Street, Alsip, Illinois 60801
Ph: 708-522-7055 Fax: 708-522-9177 email: sales@admiralph.com

Admiral is a registered trademark of Admiral Steel Co., Alsip, Illinois
Reg. No. 226469. All rights reserved.

---

R&D UPDATE

2L = Length of the press bolster in feeding direction
2W = Width of the press bolster in transverse direction

Case Study Results

Figure 6 shows the calculated values of net force, force location from press center, and the moment produced by each station for this case study. To compensate for the moment produced by off-center loading, researchers installed 11 nitrogen cylinders, each producing 22 tons of force, at the extreme end of the transfer die set and balanced the press.

This methodology also can be used to predict off-center loading in a transfer die set for simulations developed in an alternative FE package, such as PAM-STAMP. AutoForm R8 has the capability to directly calculate the off-center loading in a progressive die.

Jamie Bowman is president and Neil Parker is engineering manager of Bowman Precision Tooling. Hitansh Singhal and David Diaz-Infante are graduate students and Dr. Taylan Altan is emeritus professor and director of the Center for Precision Forming (CPF), The Ohio State University, 339 Baker Systems, 1971 Neil Ave., Columbus, OH 43210, 614-292-9267, https://cpf.osu.edu.