DEFORM™ Application #205

Forging Die Wear

Background:

FormTech Industries, formerly part of Metaldyne, is a Tier One supplier of automotive components. FormTech forges a precision spindle, which experienced excessive punch wear.

Wear Modeling:

The simulation of tool wear is an advanced application of process simulation due to the lack of proven quantitative wear models. One of the most commonly used wear models for hot forging tooling is the Archard model.

$$W = \int K \frac{p^a v^b}{H^c} dt$$

In this model, tool wear (W) is a function of the interfacial pressure (p), the sliding velocity (v) and the hardness of the tool material (H). The coefficients a,b,c and K are experimentally determined. Once the coefficients are calibrated, the amount of tool wear can be estimated with reasonable accuracy.

The FormTech staff successfully estimated die wear for different preform shapes using the Archard model in DEFORM-3D.

Standard Preform:

In production, the spindle was formed in three stations, using a "standard" FormTech preform design. The billet was flattened in the first station. The majority of deformation occurred in the second station. The third station was essentially a coining operation to refine features. The punch from the second station was exhibiting very high wear.

A model of the spindle is shown after the final forging operation.

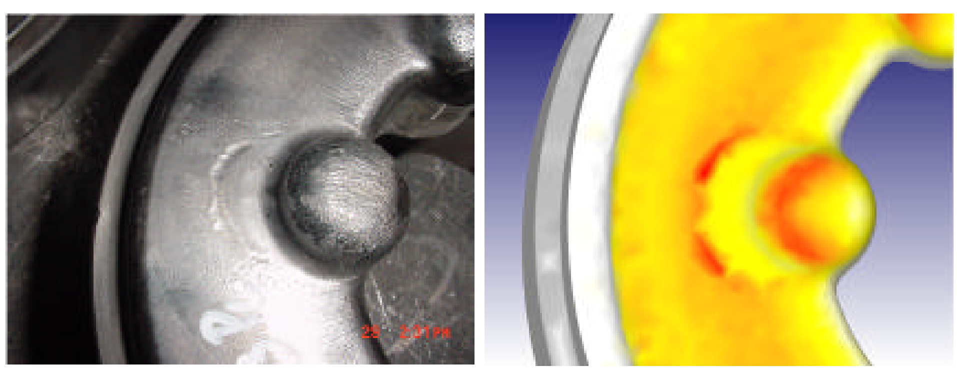
The forging process was simulated in DEFORM-3D, including die wear modeling. The simulation accurately predicted the wear pattern seen in production with astonishing accuracy. The wear on the protrusion was anticipated, but the half-moon shaped wear region was less intuitive.

The "standard" production process offered room for productivity improvement. The large deformation in the second station resulted in a high forging load. This prevented parts from being formed in stations 1 and 3 at the same time due to press limitations.

Cone Preform:

A "cone" preform was designed to investigate the punch wear. This design required more deformation in station 1, and therefore less deformation and load in station 2. Both press stations could be forming simultaneously in this two-hit design. The productivity of the press would be doubled if this design was successful.

Unfortunately, the simulation showed that the wear in the final station was even worse than that seen in production using the standard preform. In spite of enticing productivity enhancements, the cone preform was not implemented. This design moved the problem to a different die rather than solving it for the entire process.



The high wear areas on the second station punch are shown (left). The wear rates predicted by DEFORM (red is higher) match the wear pattern on the punch.

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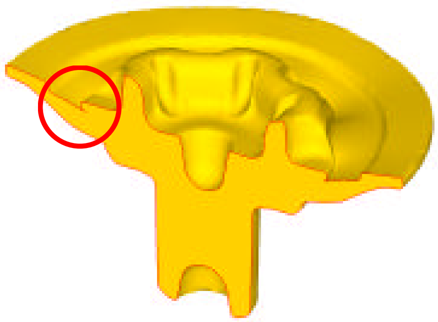
Round Preform:

The next iteration was based on a "round" preform. This process offered the same press productivity as the original process. The design intent was focused on punch wear reduction. Wear became a non-issue when DEFORM predicted a serious fold in the final station.



The model predicted the formation of a lap with the round preform.

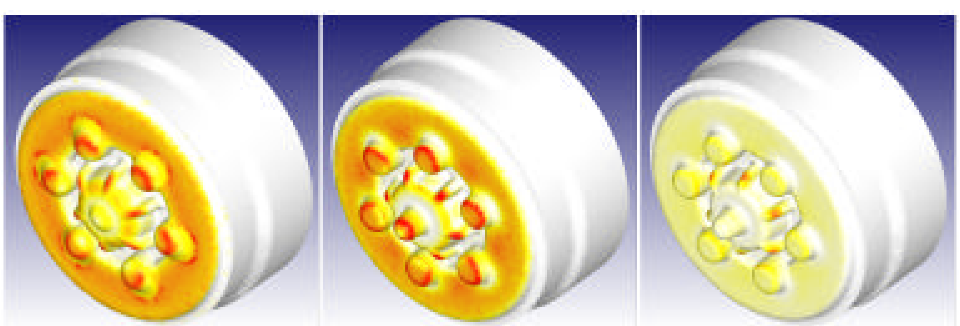
Modified Round Preform:

Until the fold developed, the tool wear using the round preform looked promising. Therefore, a modified "round" preform was developed to eliminate the lap. The simulation results were very promising. There were no defects, die fill was as expected and the die wear was reduced significantly.

When the tools from the three different preform simulations are compared, it is easy to see that using the round preform significantly reduced the amount of wear in the tools. The original preform (below left) depicts the highest wear areas in red. The second iteration (below middle) shows a higher wear in critical regions. The wear in the final design (below right) is significantly improved.

The FormTech staff noted that the optimal process would actually involve a preform combining features from both the cone and round shapes. With such a geometry, the productivity benefits of the cone preform and the wear benefits of the round preform could be realized in one process.

Existing die wear models are empirical in nature. While this is a limitation to the purist, they can be calibrated to provide useful results in a production environment. With a reasonable model, DEFORM can be used to optimize tool life for various preform designs. Die life failure analysis can contribute to very significant cost savings through increased die life without expensive production trials.



The punch wear is shown for the standard design on the left. The red areas represent highest wear. The cone design indicated a higher wear rate than the production process, as shown in the center. The modified round preform, on the right, results in a significant reduction in die wear.

Types of Die Wear:

Tooling wear is frequently classified as adhesive wear or abrasive wear.

Abrasive wear occurs when a tool comes into contact with a hard material. The hard material slides against the tool, wearing the tool surface down. The Archard model, which has been implemented in DEFORM, is based on abrasive wear. This model is extremely important in the modeling of die wear, as it captures the combined effect of sliding velocity, contact pressure and material hardness.

Adhesive wear occurs when two objects are pressed together under load, and the small asperities on the surfaces adhere to one another. It can be associated with a form of diffusion activity at the mating surface, and is most common at elevated temperatures. When sliding occurs, the asperities break off, causing damage (wear) to the surfaces. The Usui model, which has been implemented in DEFORM, is used to model this wear mechanism. Inserts in metal cutting applications undergo large amounts of adhesive wear.

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