Gear Blank Forging

Background:

Since forgings are generally used in critical service applications, the requirements for microstructure and mechanical properties can be stringent. The strength, toughness and ductility are a result of the raw material, the forging process and the heat treatment. Raw material is an element that can't be ignored. In practice, there is a trade-off between the input material cost and quality, and amount of deformation (number of operations) in the forging process. A forged billet is typically more homogeneous and has a more consistent microstructure. Unfortunately, this usually comes at a higher price.

Raw Material:

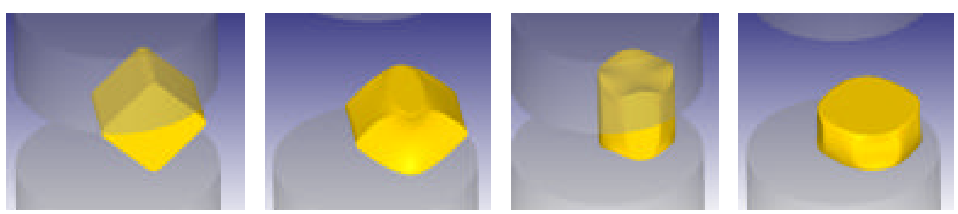
Selecting input material is a critical element in forging design. Meeting dimensional and mechanical property requirements are required. Controlling cost is paramount in today's competitive environment. Raw material is typically the highest cost component in the forging process. The cost of each operation is also important. A trade-off faced by forging designers is the use of higher priced material with fewer forging operations versus less costly material with added operations.

Deformation:

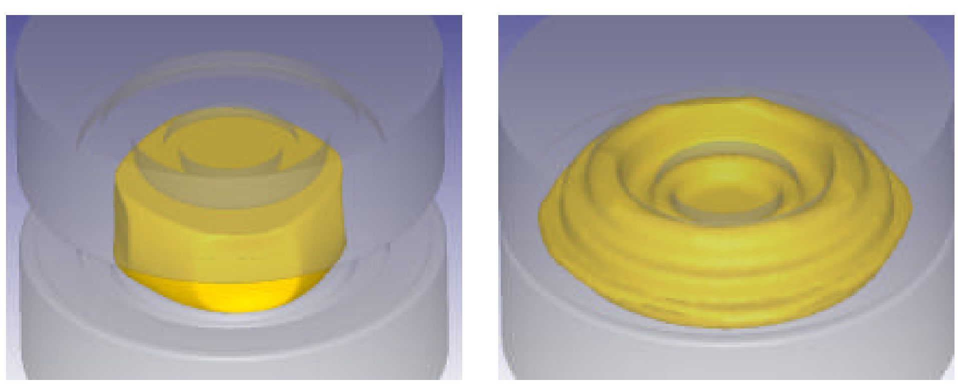
In principle, a greater degree of deformation refines the microstructure and results in a stronger and tougher part. Historically, metrics such as percent reduction and upset ratio were used to estimate the amount of hot work resulting from the forging process. With the widespread use of process simulation, this can be calculated throughout the workpiece in the form of effective strain. Effective (plastic) strain is the most common method of quantifying deformation when forging.

Gear Blank:

In this example, supplied by Caterpillar, DEFORM-3D was used to evaluate various input materials in the production of a gear blank. Effective strain was used to determine if input stock with a lower initial deformation would meet the final part requirements. By accumulating strain throughout the process, the final strain distribution can be determined. This allowed Caterpillar staff to decide whether the final deformation was adequate to allow a shift to a lower cost material with less initial deformation.



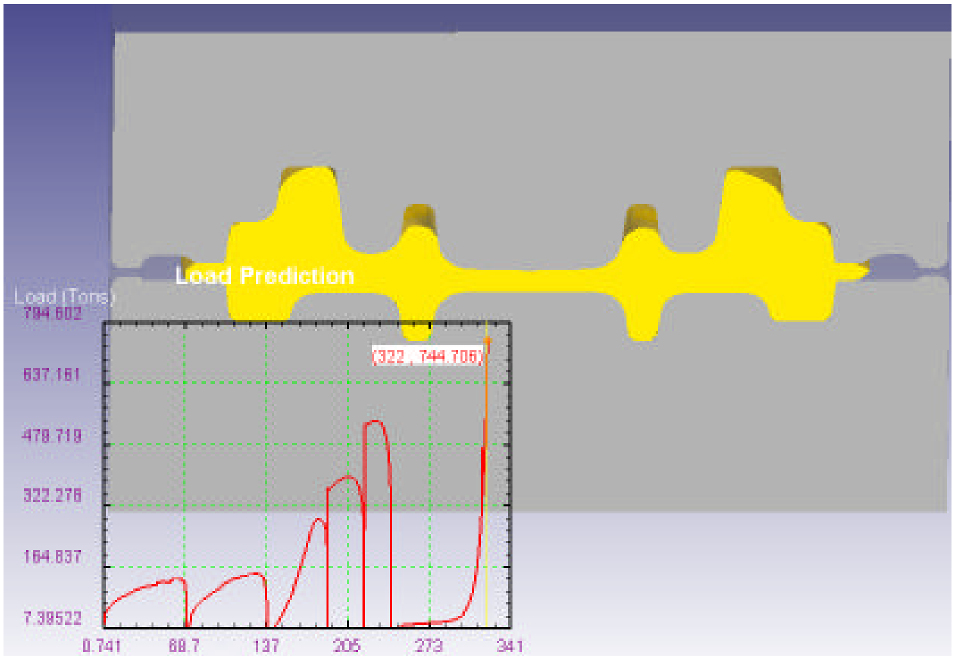
Selected images from the upsetting process demonstrate the process used to prepare the RCS billet for forging. Note that the initial operation is an upset between flat dies.



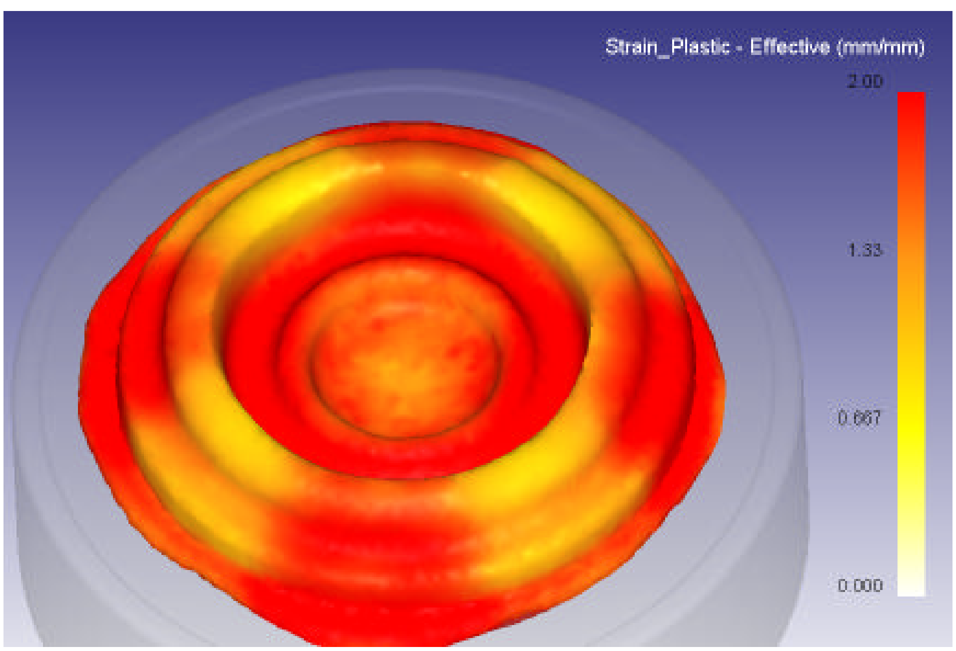
The start (left) and finish (right) of the final forging operation is shown.

Design Environment for FORMing

A sliced section of the final gear blank is shown below, along with load information for all six blows. It was determined that the die fill was adequate. The effective strain in the final gear blank is also shown. This was used to determine whether this new process could be used and still maintain the total amount of deformation required. Using simulation provided insight into the process. This data was instrumental in the decision-making process, without expensive and time consuming shop trials.



A sliced section of the final forging is shown. While the dies are not completely filled, this is adequate for the subsequent operation. On the lower-left, a load-stroke curve for the entire process is shown, which allows a user to track the load as a function of die fill.



Effective strain is shown for the forged gear blank. In spite of the round (axisymmetric) shape, the strain distribution requires a three-dimensional simulation.

Multiple Operations:

This process was simulated in DEFORM-3D using the multiple operations preprocessor. The entire forging sequence can be defined prior to running the simulation. Each hammer blow and dwell operation was specified during the initial setup. The simulation ran with 140,000 elements in 24 hours with all the positioning performed as specified between forming operations. This positioning capability includes the ability to rotate the workpiece. Multiple operation preprocessing and simulation capability allows a DEFORM User to minimize the total time required to model a complex process, such as hammer forging.

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