DEFORM™ Application #102

Optimizing Forming Load

Manufacturers are concerned with forming load for a number of reasons. Load is the enemy of our dies. High loads result in wear, fracture and fatigue failures. Forming pressure is directly related to tool stresses. Additionally, the forming equipment (header or press) will experience wear and deflection directly proportional to loads. In multi-station machines, a load balance between stations may pose an additional requirement. The force required for deformation translates into a bigger more expensive piece of equipment at a higher operating cost. The area under an X-Y plot of load vs. stroke is the deformation energy. This is a direct variable cost in the manufacturing process. High forming equipment and tool deflections from high pressures result in less control of final part tolerance.

A common goal in manufacturing is to economically produce parts with the minimum forming load while balancing the load between stations. Manufacturers desire infinite tool life, fast production rates and a robust process while meeting all other requirements.

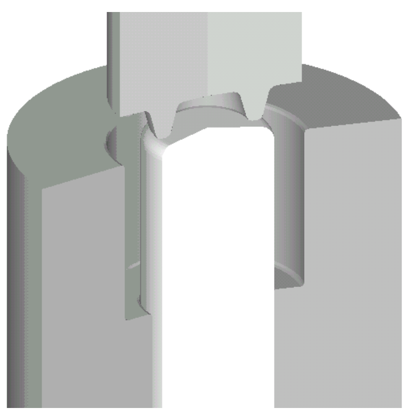
Analysis:

To produce a given part, four variables will typically control the forming load. These are preform/progression design, the flow stress of the material, friction and rate of deformation. It has been shown that the rate of deformation and friction play a relatively small role on overall forming load for most cold forming processes. Flow stress can have a significant influence on the load, but the customer material selection usually controls this with little room to maneuver for the forming engineer. On the other hand, progression design can result in significant differences in load as will be shown.

Design Alternatives:

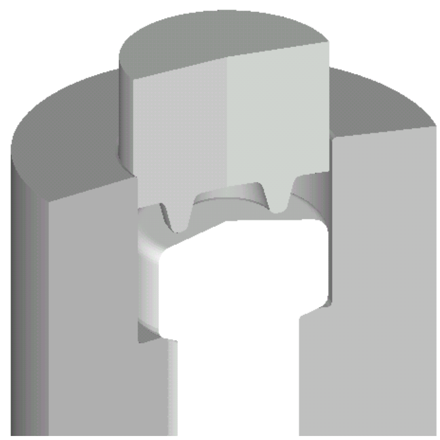
A large diameter steel part is headed from a medium carbon steel.

1. In some parts, a one-hit operation is considered as an option during the process development. In this case, the loads are excessive when heading the part without a preform.



load = 2090 tons

The load in this case is excessive due to the center area filling first and material being forced to flow through a decreasing gap between the punch and die to fill the corners on the outside diameter. With a less than optimum design, excessive shear deformation occurs as material fills the cavity. Also, during deformation, the flow stress increases due to strain hardening. Even though this peak load is at the end of the stroke, it is detrimental to tooling and forming equipment.



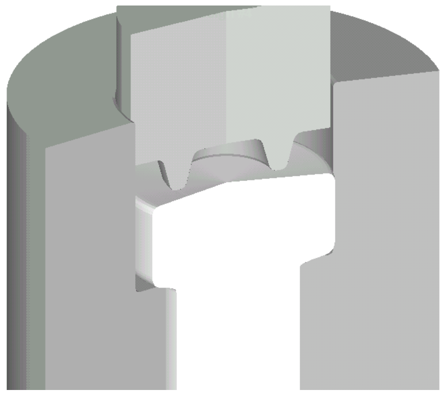
load = 625 tons

2. The use of a preform results in a lower forming load, even without much design optimization. The load with a preform is reasonable for the part (size, geometry, material and process) being formed. The outside corners are still the last to fill. While the volume distribution at the end of the stroke is significantly improved, it is not optimum. This is where most companies stop their development. While the process, the real cost of a less-than-optimum process is generally not known or even considered.

DEFORM™

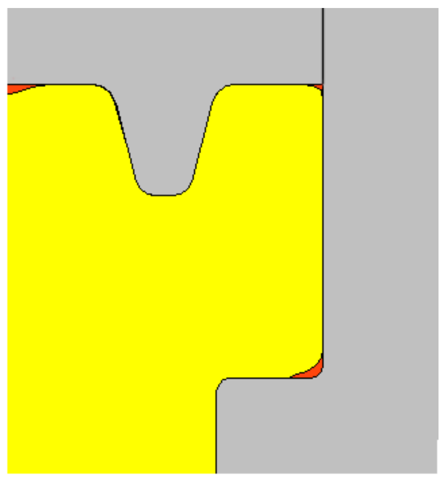
Design Environment for FORMing

3. The process using a preform was simulated using DEFORM™, to observe the material movement during die fill. As a result of the information developed, an improved preform was designed that required 550 tons to fill the die cavity. In spite of very subtle geometric differences, the new preform reduced the load through an improved volume distribution.



load = 515 tons

4. The final design was one of a number of options simulated using DEFORM™. The preform shape was adjusted until all critical corners were filling the die cavity at the same time during the die stroke. This optimum preform design resulted in a load that was significantly lower than the original design and the two intermediate improvements. The final load was 515 tons, or a 22% improvement over the first preform design. It is clear that this process will be more robust and experience longer die life.



This image shows the last areas to fill in red. The underfilled regions (shown in red) fill the die cavity almost simultaneously.

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