Developing Progressions for Nonsymmetrical Cold Forged Parts Using Design Rules & FEA Simulation

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This article covers an approach to developing the forging progression for a class of cold forged parts that are off-center or nonsymmetrical in shape. Two case examples, one of an eccentric part and the other of a nonsymmetrical part are presented. The progression design used for these two parts can be used for similar parts.

The technique for developing forging preforms for 2D round parts are well established and relatively simple. Sequence design software programs like NAGFORM can easily determine alternative forming sequence designs for round and symmetric parts. NAGFORM is linked with the FEA simulation program NAGSIM.2D, so tooling design can be easily verified and improved.

For round parts, the material naturally flows equally in the radial direction. So theoretically, only a section of the part needs to be considered for developing the forging progression. In actual production, the material flow is not completely symmetrical about the center line of the part. This is due to many reasons. Tools such as the punch and the die may not be mounted perfectly in center. The sheared blank does not have perfectly flat and perpendicular faces. The lubrication may not be uniform all round. All these factors may create some nonuniform flow. To take care of these factors, the process design rules such as unsupported length-to-diameter ratio in heading are used. These help to avoid issues such as buckling. So generally, the design can be based on commonly accepted forming rules like the length-diameter ratio in heading or the maximum extrusion ratio in open extrusion.

When the metal flow during forging is nonsymmetrical, the design of the forging sequence becomes complicated. The generally accepted rules of forming, which form the basis of sequence design may no longer apply. For complex parts, development of the forming sequence can become very time consuming and expensive if done purely through trials on the shop floor.

FEA simulation of the forging process can be used to minimize the costly trials on the shop floor to relatively inexpensive trials on the computer. The trial-and-error procedure is still used, but the changes made are in the drawings and not in the hard tools. Also, simulation of the forging process helps in understanding the material flow under the specified conditions. Changes made based on the simulation results allow much faster resolution of metal flow and tool life issues.

Forging Sequence for Nonsymmetrical Parts

Forging sequence is designed to progressively form the material to its final shape. One of the main objectives of progressive forming is to form in such a way that final geometry of the part is achieved with no scrap or minimal scrap. For most nonsymmetrical parts, this is possible only if the shape of the part is progressively changed to its final nonsymmetrical shape. There is no general design that can be followed for all nonsymmetrical parts. This article presents a class of parts where the head is nonsymmetrical with respect to the shank. The nonsymmetrical shape comes from an off-center head as shown in **Figure 1**, or the head shape is nonsymmetrical as shown in **Figure 2**. The forging progression includes gathering of the material in a sliding punch operation and then final heading in an enclosed die and/or punch to forge the final shape.

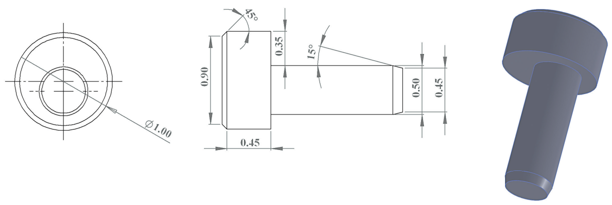

Fig. 1 — Off-center part description.

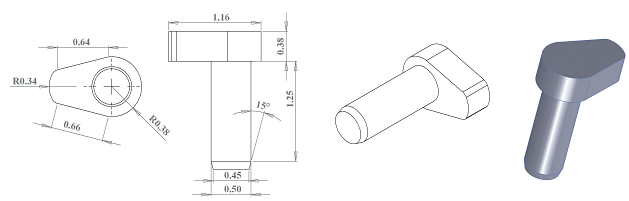

Fig. 2 — Nonsymmetrical part description.

The basic unknown in this progression is the shape of the preform forged in the sliding punch so that the final shape can be forged without flash. The initial design is based on normal forging rules and then the design is modified based on the FEA simulation in NAGSIM.2D/ NAGSIM.3D FEA simulation programs. After each simulation, the resulting preform and final shape are studied to decide on the changes needed to the tooling for the next iteration.

FEA Simulation Results

a) Part with Off-Center Head

Initially, the unsupported length-to-diameter ratio (L/D) of 1.875 was kept in the sliding punch operation, which is less than the normal heading rule of 2.0 to 2.5. For symmetric shapes, no bucking is expected for L/D ratio of 1.875. The shape in sliding punch operation has the eccentricity of 0.1, same as in final shape. The simulation results showed bending/buckling of the preform as shown in **Figure 3**. The off-center shape of the tool cavity causes the metal in the middle of the unsupported length to move out leading to a buckling type of deformation.

The shape of the preform shape in sliding punch operation was modified in two respects. The L/D ratio was reduced to 1.35 and a cone-type transition was provided at the top as shown. The idea of providing a cone transition was to keep

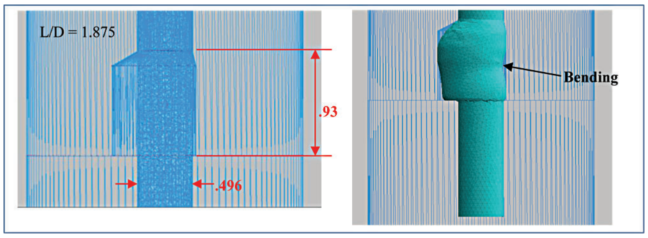

Fig. 3 — Preform bending.

the unsupported length from bending. The simulation of the forging sequence showed successful forging of this part in the two operations (**Figure 4**).

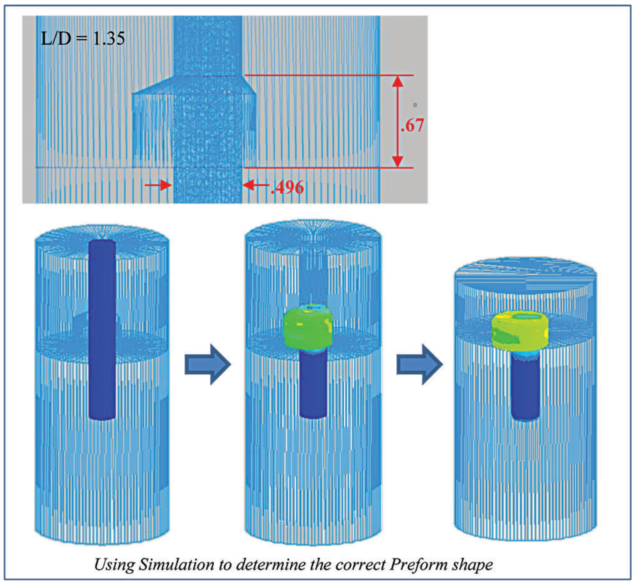

Fig. 4 — Trial 2-Reduced L/D ratio.

b) Nonsymmetrical Part

With the knowledge gained from the design and FEA simulation of the eccentric head part, the same types of changes like lower L/D ratio and the cone transition were made to the perform design shape in sliding punch operation. In the preform, the smaller end was moved towards the final shape to the extent that in final heading operation, the material moved almost equally to fill the final shape (**Figure 5**).

The presented designs may not be the optimum designs in terms of the metal flow and tool life. Determination of the optimal design requires a further series of trials with design changes and their effect on metal flow and tool stresses determined through an FEA simulation program (NAGSIM.3D).

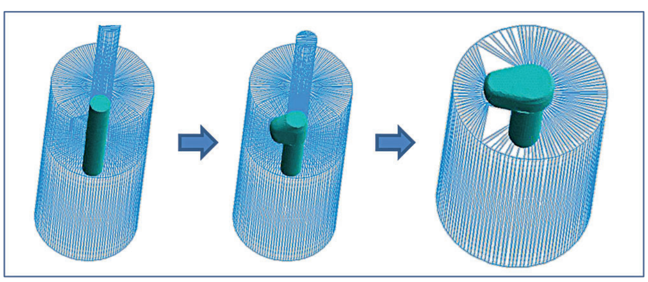

Fig. 5 — Using simulation to determne correct preform shape.

Concluding Remarks

The general rules for designing operations such as heading may not apply to forging of nonsymmetrical shapes. In order to come up with a successful design of the forging sequence for nonsymmetrical parts, an FEA simulation software is needed to avoid costly trials on the shop floor. The following are some of the benefits of using a simulation software:

- Helps in determining the correct preform shape.
- Predicts metal flow including nonfill and laps.
- Identifies high stress/strain areas in forged part (**Figure 6**).
- Helps in deciding the tooling design (**Figure 7**).
- Predicts the tool stresses so tool life can be improved.
- Provides load-stroke info for machine selection (**Figure 8**).

Contact Dr. Vijay Nagpal at **vijay@nagform.com** for more information. For technical literature on NAGFORM / NAGSIM software programs, visit *www.nagform.com* **FTI**

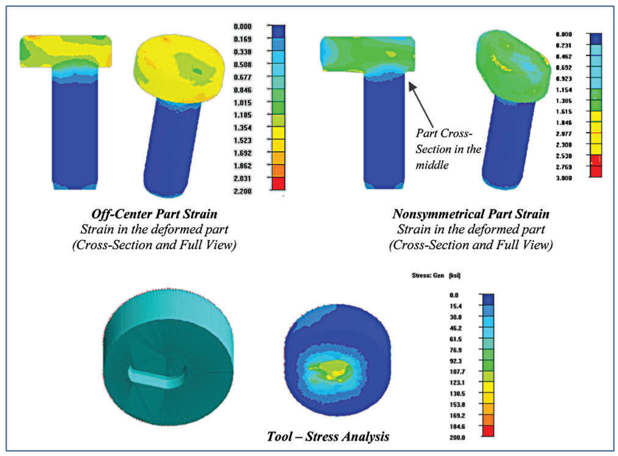

Fig. 6 — Stress strain analysis.

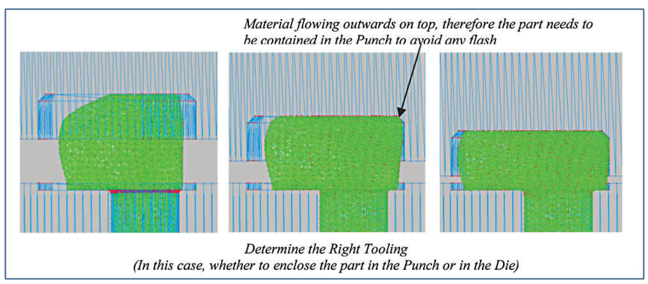

Fig. 7 — Helps decide the correct tooling.

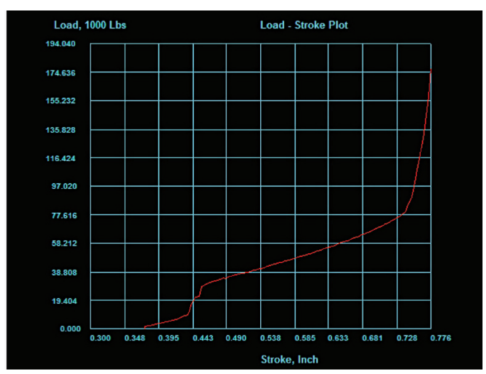

Fig. 8 — Load stroke curve.