Requirements for a Rapid Forged Part Design Software System

By John Watton

Back in the early 1990s when I was a young engineer at a forging company, we were asked to respond to an urgent request from Boeing. They were evaluating the implementation of a full-length double-deck for the 747 in response to the then-new Airbus A380. As you might expect, many parts (and their corresponding forgings) needed to be redesigned, and quickly. But they had a surprise for all of us working with the Quoting, Design, and Die departments. It was a computer program built on top of Catia V4 that would automatically define forging envelopes for the newly designed parts. This was a huge time saver since it eliminated the need for a CAD operator to build a forging envelope just for quoting and review purposes. Well, as quickly as we spun up and puzzled over the impression die forging designs being automatically generated by the new software tool, the full-length double-deck project was cancelled, and the software disappeared. That software wasn't as turnkey as it was intended to be, but it planted the idea with me, and in the many years since I haven't found any commercially available software to fill this niche.

What features should such a domain-specific CAD system have to be of maximum use to forgers and forging consumers, like an airframe company? To begin with it should:

- Have a graphical user interface. This might be either standalone or integrated with a general commercial CAD system.
- Work in a choice of units, such as millimeters or inches.
- Work from the customer's machined part geometry as the primary starting input. The CAD system will build the forging envelope around the part shape.
- Have the ability to manipulate the input geometry, (i.e., scale, translate, and rotate) since the customer's as-machined final part geometry is unlikely to be oriented for the best die stroke direction.
- Have the ability to nest multiple parts into one forging. This is useful for combining small part families and for combining a RH and a LH version of a part together in a single forging.
- Have the ability to automatically orient the part for the best forging stroke direction, such as minimum stroke and/or minimum plan view area.
- Have the ability to adjust the forging design for:
  - the alloy family (aluminum, steel, titanium, nickel)
  - and the overall part size from a very large aerospace part down to a small fitting or fixture.
- Be easy to use, computationally fast, and mostly automated.
- Have the ability to design either closed-die (impression) forgings or open-die (hand) forgings.

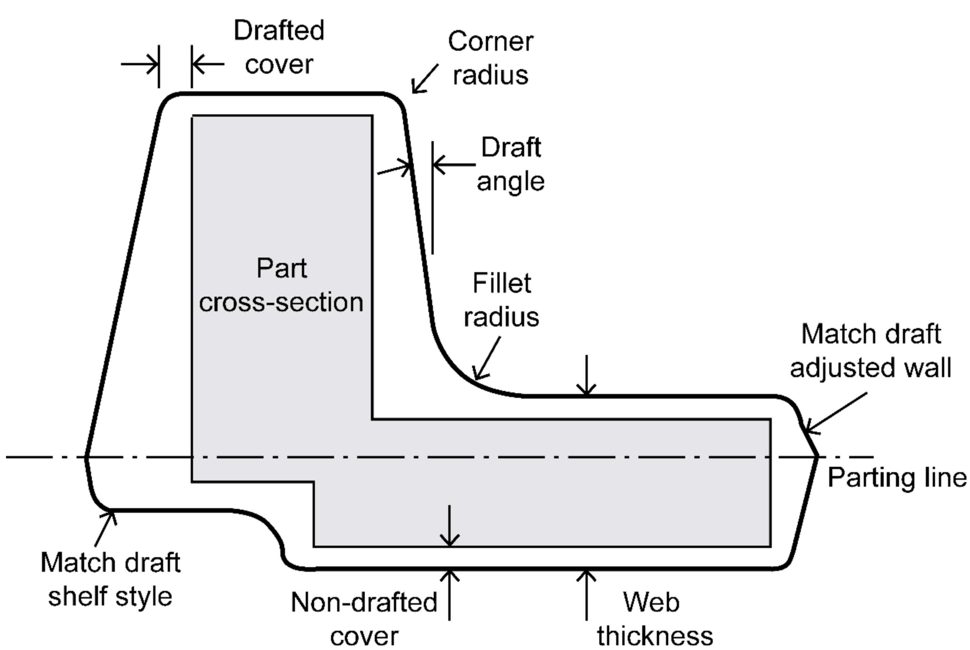

Figure 1: Common forging design terminology.

Impression Die Forging Design System Requirements

In this article, we limit ourselves to the further requirements to design two-piece impression die forgings, which is a very important forging subset. As illustrated in Figures 1 and 2, further features should include:

- The ability to detect and construct planar parting lines or lock-die parting lines. Automated lock-die construction should include those that vary in one (i.e., in the longitudinal direction), or in multiple plan view dimensions.
- The ability to generate a forging design envelope using default, but customizable, design parameters including web thickness, draft wall cover, draft wall angle, non-draft cover, plan view radius, fillet radius, and corner radius.
- The ability to match the draft on the periphery with either an optional shelf style or an adjusted wall style.
- The ability to construct a convex periphery, with a shelf, to provide realistic forging designs.

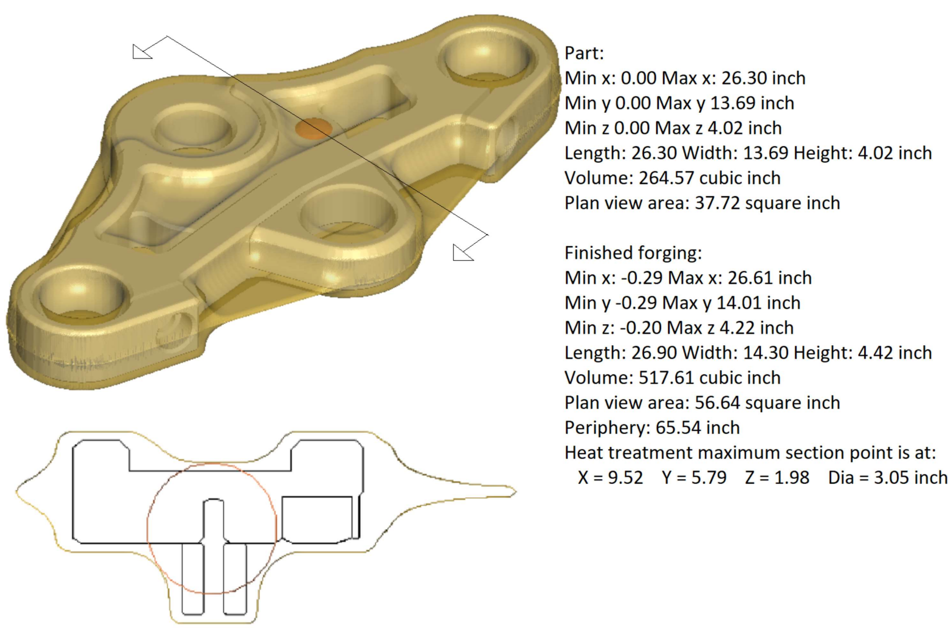

Figure 2: Desired forging design outputs: superimposed graphical displays with transparency, statistical information on as-machined part and finished forging, cross sections of forging (gold), part (gray) and maximum heat treatment thickness (orange).

As illustrated in Figure 2, the following outputs are invaluable to support the quoting process for the forger and the planning and costing activities for OEMs:

- Realistic graphical renderings of the 3D geometry of the forging envelope along with the as-machined customer part geometry.
- Forging statistics and properties, including volume, plan view area, periphery length, and other dimensional information.
- A calculation and display of the maximum heat treatment section thickness. This can be seen as an orange sphere positioned in the forging design of Figure 2.
- Cross-sectional displays of the as-machined part and the forging envelope.

Advanced Features

Once a software system is capable of generating a forging design, we can think about extending it to include other automated design features with:

- A design module for die cavities and flash gutters. Die cavities (top and bottom) along with gutters to contain flash during the forging process are often required for manufacture.
- A design module for blockers and preforms. Usually, the forging process requires prior operations before the final forging using blockers (from closed-die forgings) and/or preforms (from open die operations). Designing these shapes and tooling can be very time-consuming using a general CAD system and one can think about how to automate the process.
- A design module for cold-work stress relief die sets. Aluminum forgings are often cold-worked with another special die set used to relieve the residual stress that develops during the heat treatment process.
- A design module for hand-forgings. We've mentioned hand forgings earlier and hope to follow up with our thoughts on a design system for hand forgings in a future write-up.

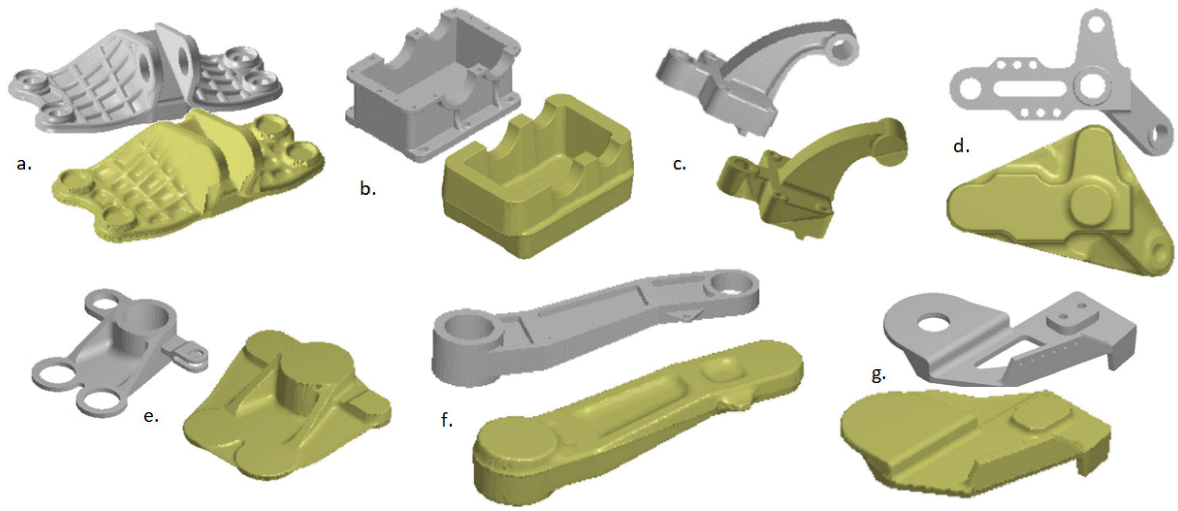

Figure 3: Example forging designs including advanced features, like matching parting lines with a shelf (b), shelf construction (d, e), optimized die stroke direction, and lock-dies (a, f, g).

There are a number of specific commercial CAD systems or add-on modules for them in specific domain areas – plant piping, injection molding, casting feeders, and electronics, to name a few. The forging industry is past due for its own CAD system and, in this article, we have outlined the basic features and requirements we would like to see. Hill Engineering provides solutions in the forging CAD space – a space that Boeing entered and then quietly disappeared from over 30 years ago. ■

John Watton is a Senior Engineer with Hill Engineering and the principal creator of the commercial Rapid Forge Design™ software system – https://hill-engineering.com/rfd. Hill Engineering is a global leader in improving the performance of materials and a trusted partner to engineers seeking solutions in design, manufacturing, operations, and sustainment; delivering expertise in residual stress measurement, modeling, mechanical design, material testing, structural integrity, and service life extension.

Phone: 916-635-5706
Email: jdwatton@hill-engineering.com