Automated preform design for hot closed-die forging

New practical tool for forging technology development and optimisation

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In practice, very few forgings are produced in one impression. In order to achieve complete die filling, a single impression can result in excessive flash, forging defects, and large die loads. In most cases, a series of preforming operations are necessary to gradually form the billet material into a shape that is closer to that of the finishing die cavity. The number of preforming operations depends on the difference between the beginning billet shape and the finished forging shape. The optimal preform shape must ensure complete die fill with minimal flash and reduced forming load, while avoiding flow defects like laps and flow-through. Proper preform design should also minimise the die wear by reducing the metal movement in operations and achieving desired grain flow to control mechanical properties.

Despite numerous works in this field, preform design is often based on the trial-and-error method. Traditional preform design guide rules may work for simple parts like axisymmetric forgings but are often ineffective for complex irregularly shaped parts, particularly those with narrow ribs and thin webs.

There is an approach to developing a preform shape based on approximation of the metal deformation by so-called potential material flow. Potential flow is a hypothetic idealised motion of fluid that has no curl (rotational) velocity vector at any point of the domain, and by these means, it makes the formation of any laps or folds impossible. The potential flow velocity vectors are always perpendicular to so-called equipotential surfaces while these surfaces can be obtained as a solution of the Laplace equation in the flow domain. In the case of a closed die forging process, the domain for Laplace equation can be created between two surfaces representing the workpiece and the final forging, respectively. Of course, the actual material flow in forging is not a potential one, and there is a curl velocity vector in it. Meanwhile, it was found that the use of equipotential surfaces as a preliminary guess for a preform shape makes the formation of laps and flow-through defects much less likely while providing the complete fill of a finish die cavity much easier. A more detailed explanation of this method and the literature overview can be found in our work [1].

To make the above approach practically applicable in the industry, we have developed a specialised CAD program for automated optimal preform design called QForm Direct (powered by SpaceClaimTM). It finds the most suitable equipotential surfaces for the approximation of the preform shape, and creates a preform and preforming dies. This program is integrated with our metal forming simulation program QForm for verification and optimisation of the proposed preform shape by modelling the metal deformation as it happens in the real forging process.

The developed method and software have been implemented for several hot forging jobs, and all of them have proved their efficiency. Below is presented one such case where we developed the best preform shape for a hot forging of a cross-like part. The original technology used a round bar billet with a diameter of 65 mm and a height of 118 mm made of steel 20MnCr56 (1.7147 DIN) heated to 1200 C. The equipment was a 25 MN mechanical press. The first operation was upsetting the billet to a height of 60 mm. Then the billet was forged in preforming dies that were designed according to traditional guidelines, having increased drafts and radii. Thenfinally it was forged in the finish dies (Fig 1.). As we see when using the original preform design, a lap occurs in the finish forging that is clearly seen in the real part (Fig. 2 a,b) as well as clearly detected by simulation (Fig. 2c).

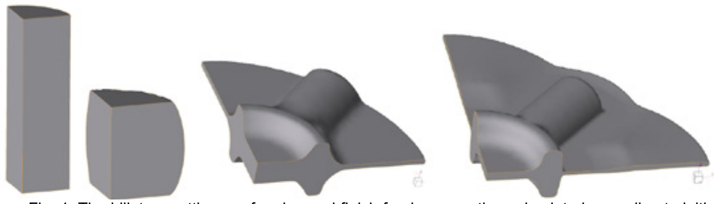

Fig. 1. The billet, upsetting, preforming and finish forging operations simulated according to initial technology.

a. b. c.

Fig. 2. Actual finished forged part: a lap on a general view (a) and magnified defect zone (b) and defect locations predicted by simulation (c) shown by red zones of Gartfield indicator.

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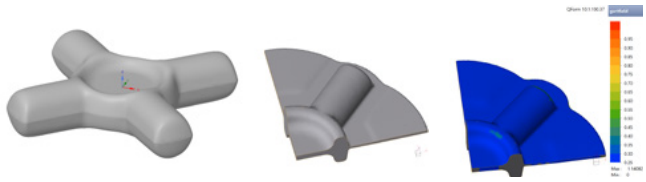
A new optimal shape of the preform was then developed using QForm Direct software. The equipotential surfaces used for its creation are shown in Fig. 3a. The forging sequence using this preform shape was simulated, and it didn't show any defect in the finished part (Fig. 3. b, c). After such verification by means of simulation, the preform dies were modified to the QForm Direct design and placed into production, while finish dies were left without any alteration. Trial forgings have shown the perfect quality of the finished part without any defect, as shown in Fig. 4. Moreover, modification of the preform allowed reducing the billet volume and saving the material by 6.7% and significantly reducing the die wear. An excellent practical result!



a. b. c.

Fig. 3. The preform shape based on equipotential surfaces (a), simulation of preforming (b) and finish impressions (c) using the proposed preform. No defects in finish forging are anticipated, as shown by the distribution of the Gartfield indicator.

a. b.

Fig. 4. Photo of the actual preform (a) and finished (b) forged parts using proposed preform shape (no material flow defects).

The proposed method and software are available for all CBM members in a test mode. If you need to develop a preform for your most complicated forging job, please, contact us, and we will provide you with a fast and effective solution. You may contact me personally for further details by email

micas@qform3d.co.uk or by phone +44 7578 576602, Nikolay Biba.

Literature

1. N. Biba, A. Vlasov, D. Krivenko, A. Duzhev, S. Stebunov, Closed Die Forging Preform Shape Design Using Isothermal Surfaces Method, 23rd International Conference on Material Forming (ESAFORM 2020)