New technical support for SME metalformers

Dr Peter Standring at Industrial Metalforming Technologies

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These are partnered with leading edge companies in aerospace, automotive and energy – with much of the work being funded through contracts 'won' in competitive proposals. If, as recent events have demonstrated, traditional industrial sectors such as the UK steel industry can't obtain government support (there is no Catapult support for steel), what chance has the UK metalforming sector and particularly the SMEs, which make up its largest number of companies?

This fact has been recognised for many years by those – largely SMEs – that struggle to keep the UK metalforming supply chain afloat. In an attempt to provide a measure of technical support, Industrial Metalforming Technologies (formerly The British Cold Forging Group established in 1951 to promote the adoption, development and use of cold forging technology within the UK) has linked with the Confederation of British Metalforming (CBM). As a non-affiliated, non-commercial informal body, IMfT – which has its own wide ranging library of technical knowledge– has agreed to work with the CBM to set up a 'hands on' technical support system primarily for metalforming SME companies. The following article describes a 'test case' problem of die failure provided by Wigan-based Smith Bullough Ltd to kick the scheme off.

The challenge

Smith Bullough wanted to hot forge a rectangular bolt head, 2.25 x 1.25 x 0.98 (inches) from a 1.25 diameter bar of EN24 material. The forging temperature was 1,200°C obtained by induction heating and the process was carried out on a 125 tonne double blow press.

Figure 1 – bolt head hot forging sequence from right to left (courtesy of Smith Bullough Ltd)

Figure 2 – formed, trimmed and machined bolt

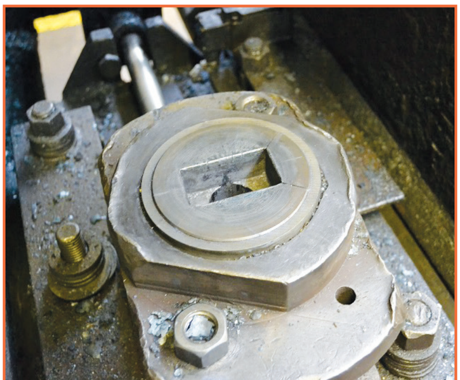

Figure 3 – bolt head die showing corner cracking

As shown in Figure 1, the sequence of operations consisted of preforming, forging and trimming. An example of the forged head obtained is shown in Figure 2.

Two dies were made from D2 material and heat treated to 60 and ~53 RC respectively.

Both dies cracked in the same manner after forming 20 parts as shown in Figure 3.

The cause

Like any flowing material, ductile metal will always take the path of least resistance. The sole purpose for any forging is to change the geometry of the original starting stock from its simple readily available shape and by doing so, adding value. Where a complex forged geometry is required, a conventional process may include a number of preforming stages using different dies to accomplish the task in a stepwise manner. This effectively 'persuades' the material into gradually achieving the desired configuration and as such minimises the die stress and material waste.

Waste occurs when the billet material extends above the die cavity and during the deformation process, flows in between the two dies to form a flash. As the flash gets thinner and covers a larger area, the frictional conditions increase. It is at this stage of the deformation process that the forming force increases often dramatically. Higher forces cause larger stresses and since when forming flash, little further die cavity fill is achieved, this is basically 'redundant effort'.

In the Smith Bullough case study, the preform used in Figure 1 meant that material overhung the die wall cavity and increased the area on which the upper tool worked by ~2.9 times that of the bolt head. The trimmed flash illustrates the excess material distribution and indicates the wasted absorption of

press energy during its formation.
The solid die cavity in Figure 3 has internal right angle corners. The failure of the De Havilland Comet jet aircraft was traced to it having rectangular shaped windows, which cracked at the corners through low cycle fatigue caused by pressurising the passenger cabin. The solution was to use rounded not square corners to help minimise the local stress. This type of solution cannot be used in metalforming because the shape of the final part dictates square corners are required. So a different solution must be found.

A possible solution

The tool material D2 used by Smith Bullough is a cold forming steel harder (brittle) and more wear resistant as required in the cold forming process. In this situation tougher, hot forming die material is preferable, such as H13.

The most important factor given that the company only has access to a 125 tonne press, is to ensure that the forming process only works on the billet material and does not waste its energy by producing flash. For many years, the cold forging industry has been using 'precision' forging methods, sometimes known as 'flashless' forging. In these operations, the volume of the 'upset' billet has to exactly match that of the die cavity. Too much material will overstress the tooling, too little and the part will not be fully formed.

The third issue is the tool design. Where high local stresses are likely to lead to cracking, it is often wise to use multi part tools. In such cases, the separate tool sections should correspond to the planes on which the fracture occurs. In short, begin with a cracked tool and use compression rings to hold the individual tool elements together.

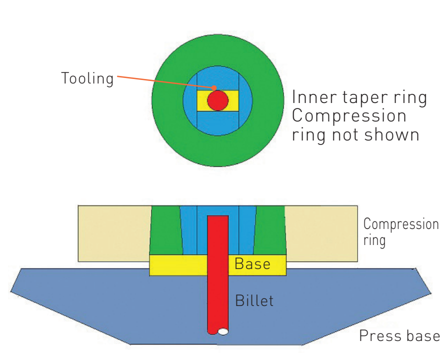

Figure 4 – proposed lower tooling

The Smith Bullough case was considered and a possible solution proposed. This, shown in Figure 4, consists of a four piece rectangular die cavity pressed into a tapered die support ring to compress the four elements together. This is then pressed into the back of a tapered compression ring needed to counter the lateral forces produced in the forging operation.

As can be seen in Figure 4, the upstand height of the round, non-preformed billet, is contained inside the die walls.Although not shown, in this embodiment, the upper tool has the same geometry as the plan view of the bolt head and fits snugly inside the rectangular die cavity.

During the deformation process the billet is axially upset, which causes barrelling of the material along the plane of the major axis until it hits the two end walls. Further axial movement of the upper tool working only over the cross section of the bolt head will continue until the part is fully formed. No stresses can be produced in the corners of the die or its base because the tooling elements in these regions are not continuous.

At a forging temperature of 1,200°C the yield stress (σy) of EN24 is ~100 MPa. Since the area of bolt head is only ~1.86 x 10-3m^2 it follows that the minimum forging force should be less that 20 tonnes. However, redundant work due to internal friction will increase this by at least 2.5 times and then additional die wall friction needs to be considered. The fact that a bolt head can be produced with a flash 2.9 times larger in area than the bolt head, demonstrates that forming the part without flash is possible and perhaps at a lower forging temperature.

The die elements shown in Figure 4 do not have 45° surfaces reflecting those of the cracked dies. They could have and if they did, would function perfectly well. The simplified die elements of Figure 4 have been selected to ease manufacture and will function in exactly the same way. These can be machined as a simple ring – heat treated – and then wire EDM'd to cut them into the four pieces prior to grinding and assembly.

The machining process selected must allow the four die elements to be held together in their final working configuration whilst they have the taper angle ground on the outside diameter.

The four die elements are then pressed into the taper holding ring, which is itself pressed into an outer reinforcing armour ring to complete the die.

Physical modelling

Currently available numerical modelling software tools for bulk and sheet metalforming are very good and can provide excellent analysis of most conventional deformation processes.

However, the problem facing most metalforming SMEs is to find the justification not only to buy the software codes and the kit to run them but also to employ the personnel who can use them effectively. For many SMEs these costs are prohibitive.

The use of physical models can also be very effective in providing a quick and simple answer to a practical problem. Moreover, when used in conjunction with a mathematical analysis this can produce right first time results.

A half scale physical model used in this case is shown in Figure 5.

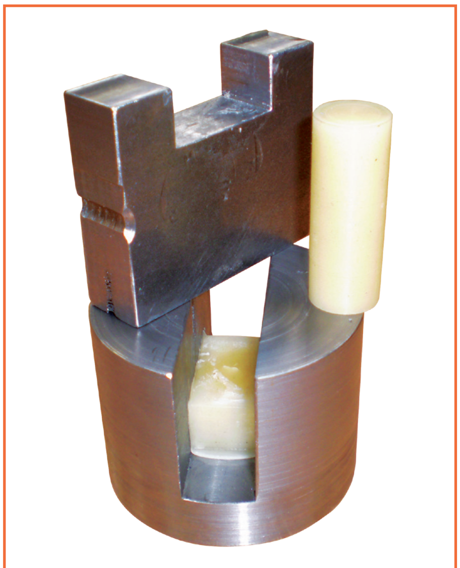

Figure 5 – physical model of the bolt head forming process

This consists of a wax billet located in a slot in the lower die, which represents the long axis of the bolt head. The upper tool is the same width as the slot in the lower die. It also has a short slot that contacts the top of the billet. The two end elements represent the short surfaces of the bolt head and the slot depth represents the bolt height. Squeezing the billet on a fly press allowed the part to be formed. More importantly, the model provided a stepwise progression of the billet deformation to be obtained to identify any requirement for possible set up changes due to the formation of the folds or laps.

Conclusion

The case study described above is the kick-off activity to give a technical support facility to SME metalforming companies in the UK. If a need for such a service can be shown to be a restriction to business growth and development, this would be a justification for seeking government support for the traditional UK metal forming community. It is common sense that if the UK Government is to use its Catapult Centres to establish a presence in high added value manufacture, it must also support its SME companies to help them become part of the same supply chain and to be able to offer a service within it.

Funding high-tech R&D inside the UK and then finding out that what UK based high-tech industries require can only be supplied from overseas is a sure fire way to score a huge 'own goal'. UK steelmakers may be the single largest representation of traditional metalforming at present but the government should be aware that in terms of turnover, employment and general metalworking business, steelmaking is simply the tip of a very large and, although the powers that be aren't perhaps close enough yet know it, an extremely important iceberg. Maybe the self-help scheme described in this article will create a focus for some government attention? After all, every SME in the UK has a Member of Parliament who is there to look after their interests. If you think it matters, why not send them a copy of this article to make them aware of its content.

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