Hot forming simulation software FORGE for copper and copper alloys

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ABSTRACT: The use of material processing numerical simulation has spread widely in recent years in the forging industry, but in case of brass, complexity of shape and thinness of flash have made things more difficult. This paper aims to demonstrate that these difficulties are now behind us and that it is even possible to go further using automatic optimisation.

KEYWORDS: Brass forging, Automatic optimisation, FORGE software, Complex shape, Thin flash,

1 INTRODUCTION

Thanks to their numerous qualities, copper or copper alloy forged parts are used for many applications. They are found especially in the following areas:

- Automotive
- Electrical
- Electromagnetism
- Mechanics, Locksmiths, Tools
- Fitting, valves, transmission fluid or gas

Most of the examples presented below belong to the last category which requires among others the following qualities:

- Good mechanical properties are required to withstand the stresses applied during assembly and possibly shock.
- Excellent resistance to corrosion of the material is essential to deal with the multiplicity of applications: brake system, fuel line, freon pipe, air conditioning or circuit oil return steering.
- A good compactness helps to seal assemblies

The brass often used perfectly fills that office. In addition, its compatibility with both forging and machining makes possible to achieve large series.

In this paper, we present first several direct simulations of different kinds of parts with increasing difficulties. Chapter 2 demonstrates that the Forge simulation tool can manage part and process complexity. Description of Forge scientific bases can be found in [1] and [2]. Chapter 3 shows how simulation can predict major defect as folding for instance and Chapter 4 focuses on automatic optimisation which is a way to go further.

2 TUBE CONNECTING PART

2.1 Elbow

From the simulation perspective, the specificity of this type of forging is often the shape complexity which makes very difficult the task of remeshing. This difficulty is exacerbated by the type of forging often practiced which produces very thin flash.

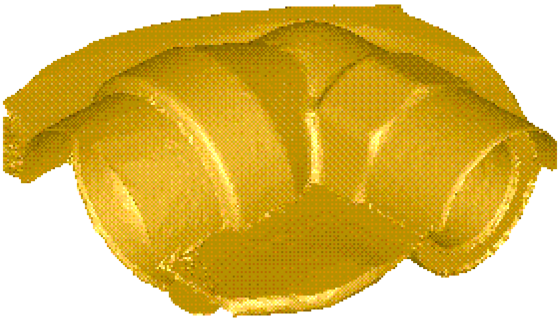

Figure 1: Forging of an Elbow

Figure 1 represents the forging of a relatively simple piece, an elbow. The computation result shows a phenomenon observed in reality: the asymmetry of the flash relative to the horizontal plane which is caused by the manufacturing process.

Figure 2 illustrates the process. The tooling is made of 4 moving parts. The lower die upon which the piece is lying is mounted on springs. When it descends under the pressure generated by moving upper die, a cam system moves the two punches. When the lower die reaches its final position, the flash thickness is extremely thin. Note also in Figure 1 the flash created

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by the material that went over the punch when the die set was still partially open and which is squeezed between the punch and the upper die.

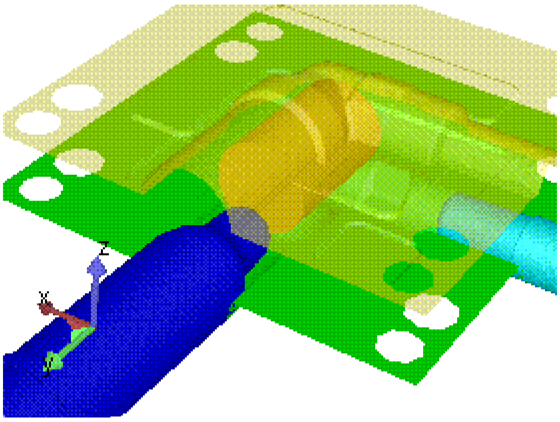

Figure 2: Typical brass forging.

Figure 3 displays dies and the part in a semi transparent mode at the end of the process.

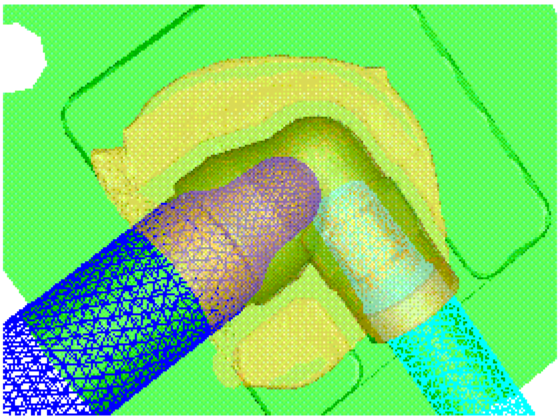

Figure 3: End of the forging.

2.2 More complex parts

The following example is quite similar to the previous one but includes four punches instead of two. The same kind of difficulties have to be overcame but, with a higher degree of solver efficiency to make the computation relevant from an industrial point of view. Thanks to the scalability and stability of Forge parallel version, this computation can be achieved overnight. Figures 4, 5 and 6 show initial and final situations.

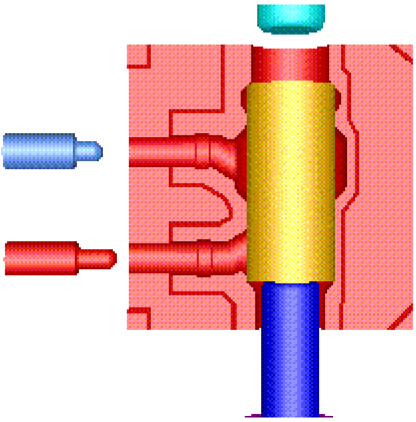

Figure 4: Four punches forging

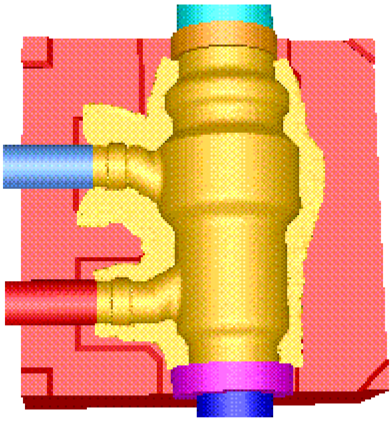

Figure 5: End of the forging

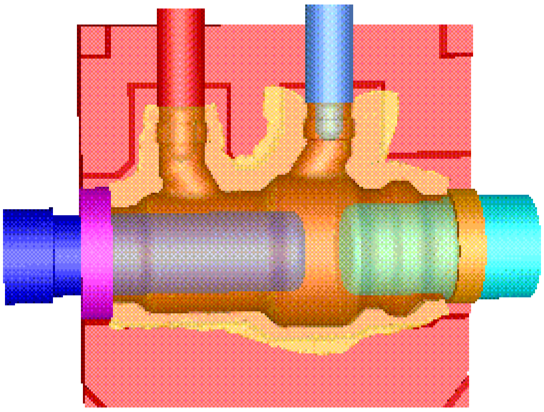

Figure 6: End of the forging/ transparent mode

With brass parts, it is always possible to go further in term of geometrical complexity and Figure 7 is just one step beyond with 5 punches. For this part, number of elements reaches 1 million at the end of the computation.

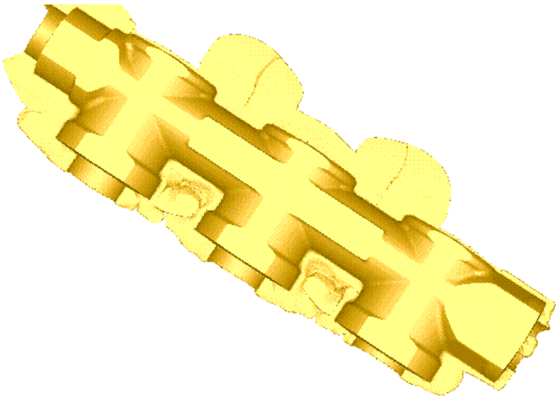

Figure 7: A more complex part

Flash management can be also tricky. In some cases, some dies areas are designed to prevent the flash to extend too much. The consequence is that the flash creates some waves with a lot of self contact areas.

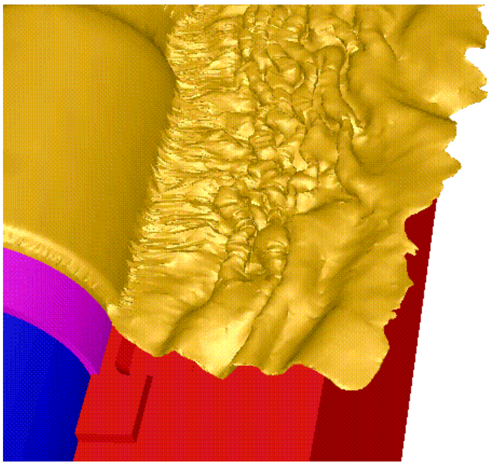

Figure8: Folding of the flash

3 OTHER BRASS PART

Gear synchro rings are made of brass, bronze or steel, either sintered, machined or forged. Usual technique with brass being to forge in one step, it is then tempting to try it with a gear synchro, just starting from a ring. Figure 9 shows initial containing die, punch and ring.

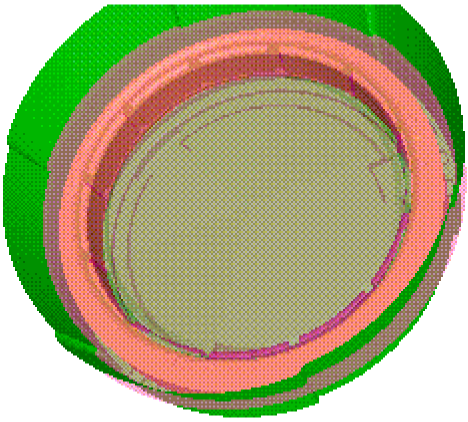

Figure 9: Forging of a synchro ring

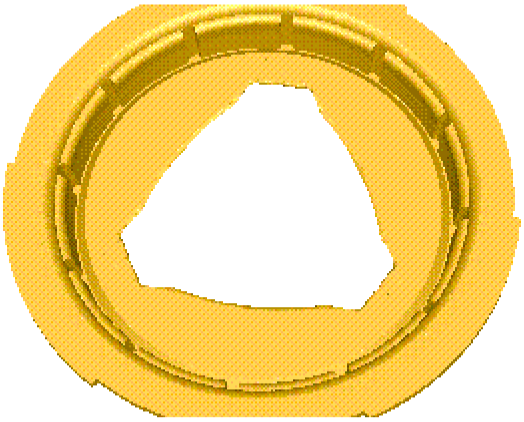

Figure 10: Final shape

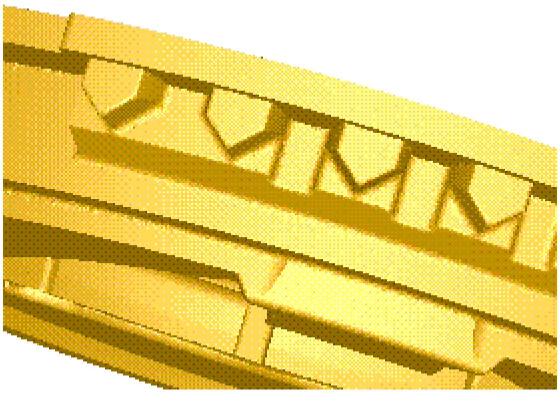

Figure 11: Detail of the external area

At first sight (Figure 10&11), the situation is very satisfying but displaying of folding area (in red on Figure 12) leads us to reconsider our opinion.

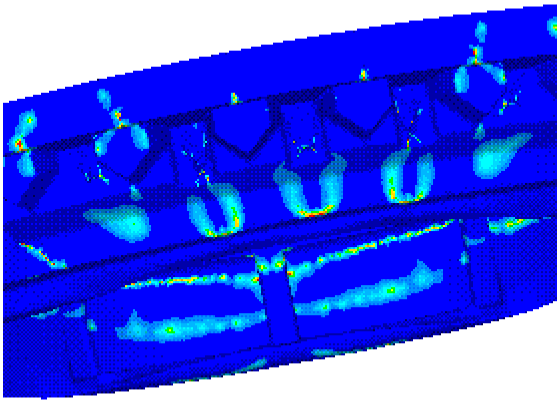

Figure 12: Folding area

The huge of folds demonstrate both that

- Direct simulation is robust enough to work even in the worst situation
- Direct simulation doesn't change a poor design in a good one. It is just a way to check it.

The next step is to ask the software to do the design and is called automatic optimisation

4 AUTOMATIC OPTIMISATION

If numerical simulation is now systematically used in many forging companies it has not really changed the strategy for designing forging processes. People still use the classical trial and error method. The only difference is that the trials are made virtually. Recent progress made both on software and hardware sides create the opportunity to make one step further using automatic optimisation. This is a very good new because, with the typical brass business complex geometries, it is very difficult to right guess the flow and find the good settings at the first trial. More detailed description of the algorithm which has been introduced in Forge 2009 can be found in [3]. The idea is to let the user define ***optimality criteria*** (use the smallest billet, reduce die wear, …), ***constrain(s)*** (achieve die filling, keep press force bellow a given value, …) and ***modifiable parameter(s)*** (billet shape or position, process parameters, …) and let the software manage the trial strategy until the optimal parameter set is reached.

This feature has been applied here to the forging of a brass T. Figure 13 shows vertical cylindrical billet on the lower die. The objective here is to reduce billet mass (***optimality***) while filling both dies cavities (***constrain***) with 3 ***parameters*** (billet diameter and length, Billet displacement along y axis)

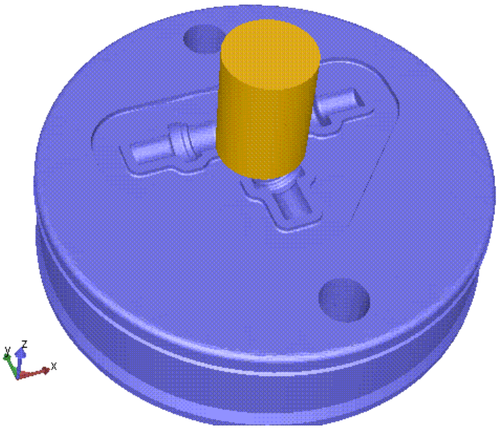

Figure 13 Billet on lower die

The optimum result is shown on Figure 14. If the billet was smallest the two long branches opposite extremities would have been under-filled.

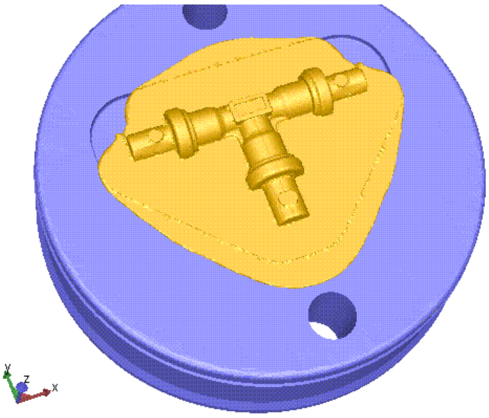

Figure 14 Final shape

Unfortunately a closer analysis shows a major fold in each branch which can be seen in Figure 15 inside the red line.

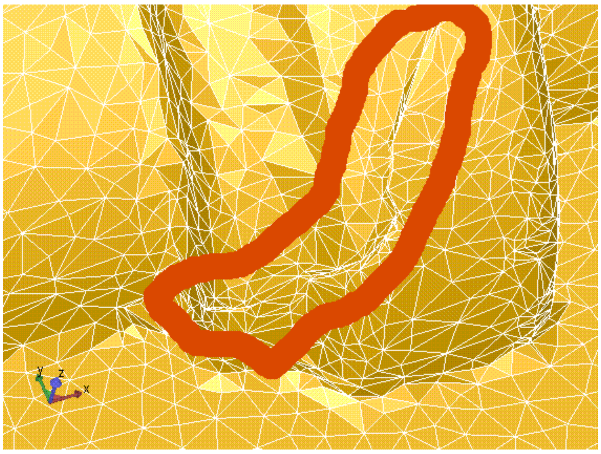

Figure 15: Major fold

The whole optimisation process has been then restarted adding a new ***constrain*** which is 'no fold'.

Figure 16 displays the same area for the optimum design in case of added constrain.

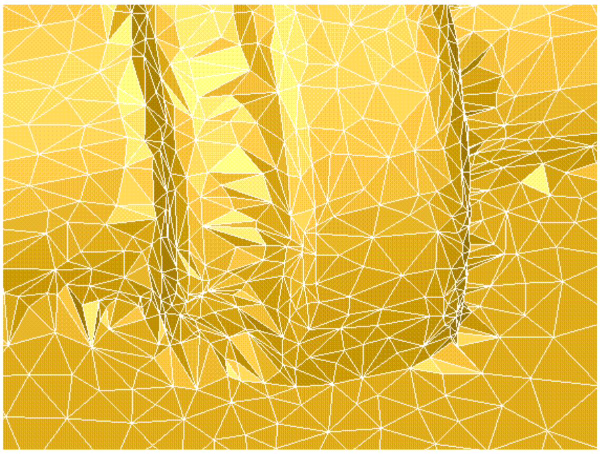

Figure 16: Part without fold

Figure 17 shows final shape in both cases:

- blue with fold
- Gold without fold

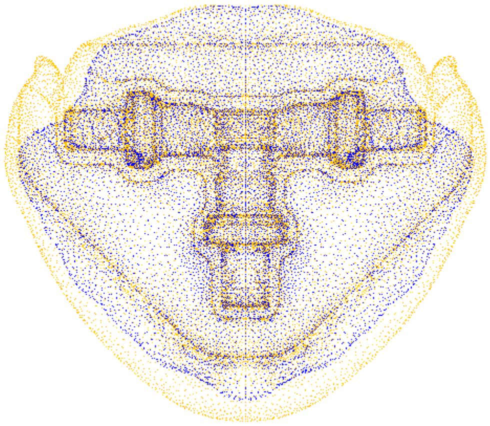

Figure 17 Final shapes comparison

It is not very surprising to see that the gold one is bigger than the blue one. Adding more constrains disqualifies the smallest billets.

5 CONCLUSION

Even if progress can always be done, fold and shape prediction through FEM forging simulation can be considered as solved. It is then time to go further using automatic optimisation which is the perfect match for direct simulation.

6 REFERENCES

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