# Cold Forging Process and Tool Design

How to use the simulation method most effectively

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**Abstract:**

Simulation technology is widely spread in Industry today. But the right understanding is still in question. Some people think that they have to simulate everything and therefore would get the perfect solutions. Others think that after using simulation the real process has to be found during practical testing on the machine anyway. Both views are extreme and both for sure are not right but they show how much the right use of simulation techniques is still in question. It shows the conflict between technological understanding and experience and blind pure believe in modern technology. Especially some so called design systems coming into the market recently suggest that simulation would be not necessary because these systems could provide all necessary technology.The truth is in between.

This article will show examples to propose a proper way of usage of empirical knowledge together with simulation technology.

**Keywords:** FEA, Process Design, Tool Design, Layout optimization

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# 1. Process Design in Cold Forging

## 1.1. Principle of Process Design

Starting from the product drawing the engineer has to design the forming sequence, chose the machine and designs the tooling.

Traditionally he starts his work from some initial design and orders the tooling. After arrival of them he starts with the try out. After some trial and error cycles the engineer works out the final process and tool design.

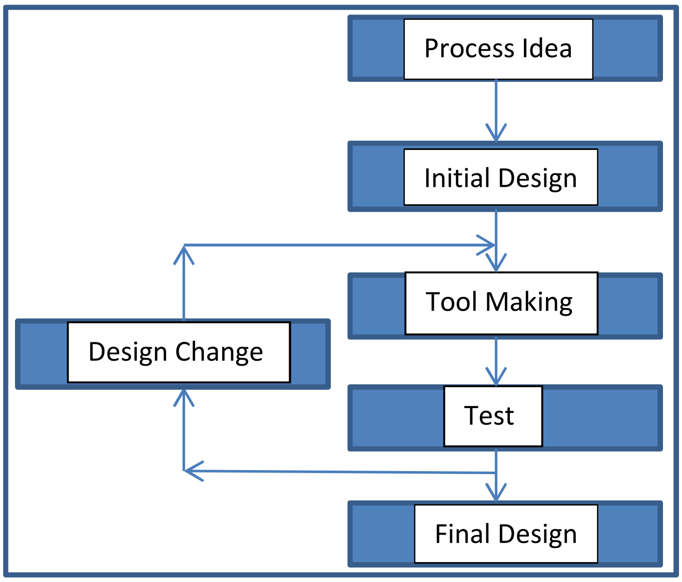


Figure 1: Principle of process design /1/

## 1.2. Process Idea

The process idea comes from the design engineer. He may generate it from his own knowledge and experience or from books and information from third parties.

## 1.3. Initial Design

Normally the engineer adjusts existing designs to the requirements of the new part. More rarely he develops a new process design form the roots. Available design packages based on empirical basic technology and/or on stored example progressions may help him as well. However the engineer has to come up with an initial design layout.

## 1.4. Try out and adjustment

In the traditional procedure the engineer will order tooling and after arrival will start with the try out on the machine. Very often the process will not work sufficiently. So the engineer has to run several trial and error loops to find out a suitable progression. This cost time and tooling and is therefore quite expensive. In some cases all the testing is wasted and the product cannot be produced.

## 2. The role of Finite Element Analysis (FEA) in Process Design

The FEA can help to avoid these costs and to support the engineer to generate better designs.

Instead of ordering the tooling the engineer will model his ideas in FEA and will find out whether his process idea will work. In addition he will get useful technological information (Stresses, Strain, Flowlines etc) that will enable him to generate optimized designs. In case that his ideas will not lead to success for various reasons he can try other ideas or can give it up before wasting money for testing. In case of success he can study the tooling layout and can optimize that as well.

Like this he can find an optimized design before even making any try out. The first trail on the machine will normally be successful and only small adaptions may be necessary due to not perfect modeling /2/.

## 3. The most common misunderstandings about the use of FEA

Some engineers believe that the FEA method as such is not precise enough so that they would have to make trial and error loops anyway. So cost savings may not be so big and simulation may be wasted time and would slow down the development time at the end. Therefore they stay away from trying FEA even.

Others think that the FEA can even mislead them so that they are in danger to generate insufficient solutions for which they may be blamed later. So they decide to relay on their “firm” knowledge and avoid FEA. They are also sometimes afraid that use of FEA would show the gaps of knowledge available because necessary input information may not be available or not precise enough.

Both positions are not helpful.

At first: If the provided information for the modeling of the process is good enough the FEA delivers very accurate results. The rumors about bad material data or unknown friction values making FEA results useless are exaggerated. After 25 years of FEA in use in forging industry these things are solved (may be not scientifically but practically) or at least can be handled in a sufficient way for industrial applications to get good results. Furthermore even a not 100% precise result will show most of the problems that are of practical relevance.

The fear that FEA will not reduce the trial and error procedures drastically is obsolete. Long time users of FEA from cold forging industry confirm that after having used FEA consequently during process design reduced the danger of fatal failure in the try out close to zero /2/. Normally only final minor adjustments may be necessary due to tolerances in results or human error.

The danger of misleading an engineer is also marginal only. The opposite is the case. Due to simulation the engineer understands the processes and their technological background much better so that he becomes much more sensitive for wrong conclusions compared to the so called experienced practical engineer.

For sure: To have a good understanding about the practical obstacles when starting to use FEA helps to avoid failures and helps to model straight forward to get useful results.

The following examples deal with two very simple cases to show the advantage of use of FEA. They may look too simple but they are reality. Both cases happed recently with customers that are long time in the market and have a sound reputation as good technology company.

## 4. Examples of FEA Application in Process Design

### 4.1. Design of a Process to form a Cylinder Head Bolt

The following bolt had to be produced:

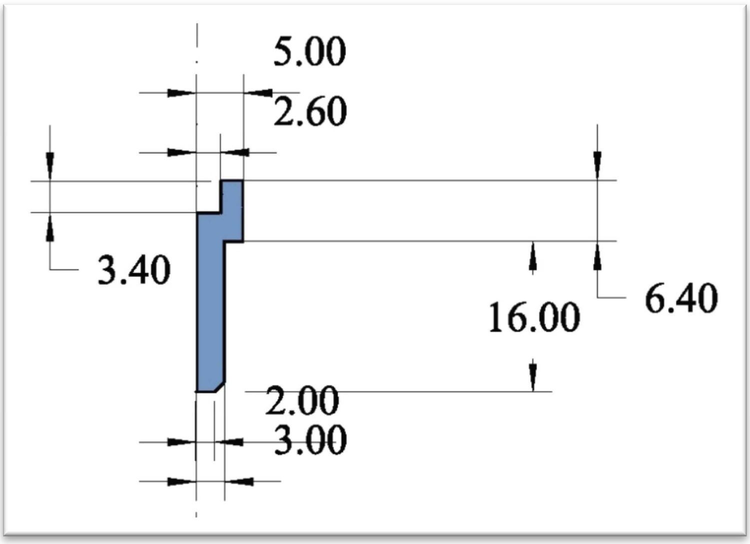


Figure 2: Bolt to be produced

Using his knowledge and/or some support tools the engineer came up with his first approach to produce the fastener.

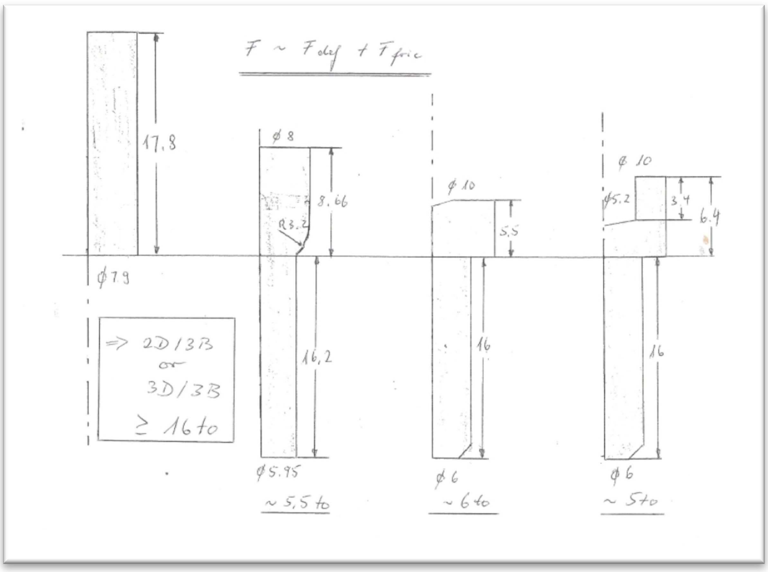


Figure 3: Planned progression

He had decided how to distribute the volume and about the basic cold forging operations to be used like upsetting, reduction etc. He calculated the expected loads as well using empirical formula. Like this he decided as well to use a three station machine.

The try out showed that the head of the bolt was not plain. The bolt was not perfectly rectangular below the head as well. From his experience the engineer tried to make a relieve on the punch: without success. Then he tried to make another preform in operation two. Again this did not lead to a significant success. Finally he asked for help.

Some simulations were performed /3/ and showed the same results.

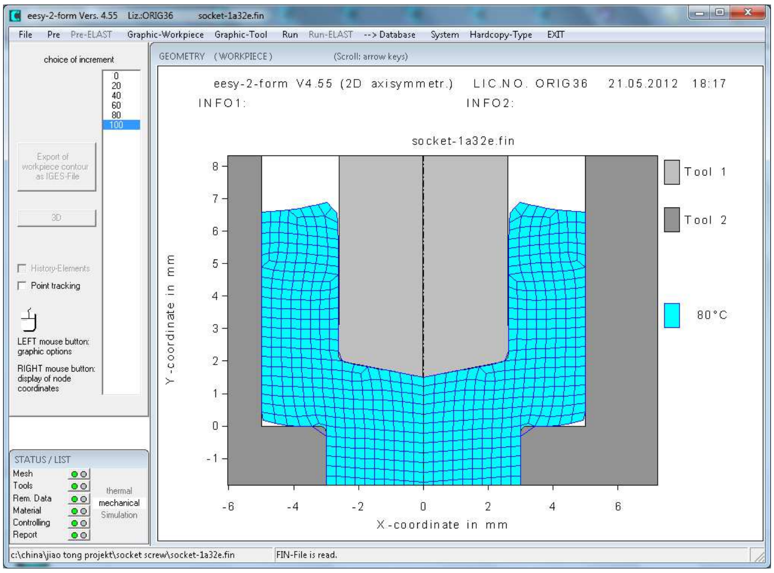


Figure 4: Not successful results of the first try out (failures shown in a simulation performed later)

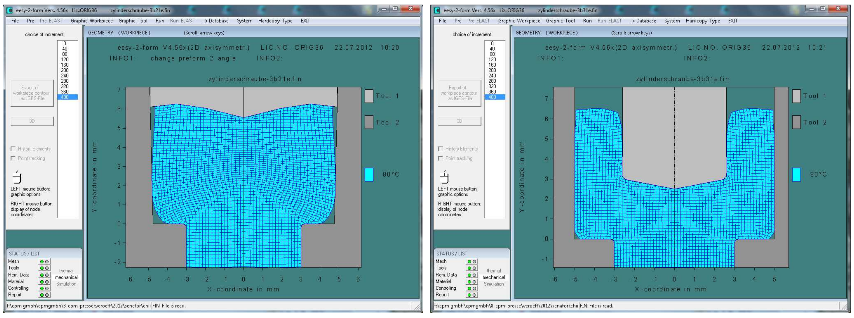

Figure 5: Not successful empirical variation

Starting from interpretation of the simulation results and detailed studies of the material flow in the trials a new design was developed and successfully tested.

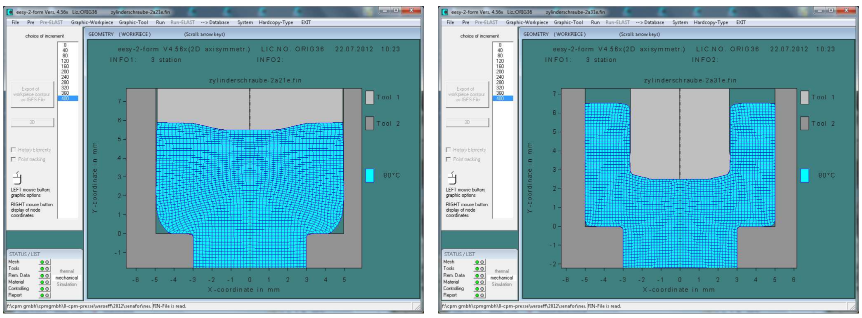

Figure 6: New design tested successfully

This example shows very clear that any process planning based on experience, developed out of other progression drawings of similar parts or even those developed using available design systems (provided by machine suppliers and others) has to be checked by a precise simulation to avoid costs in the try out and to be sure to be on the wright track in development. Only simulation can give the engineer the necessary insight view of the process that enables him to come up with a good solution from the beginning systematically (– not by chance only).

## 4.2 Tool Design in a Preforming Operation

The customer designed a sizing operation to make the product symmetric in the first station.

By chance he used a standard design without further checking. Later in the first production test the tool failed directly in the lower right corner.

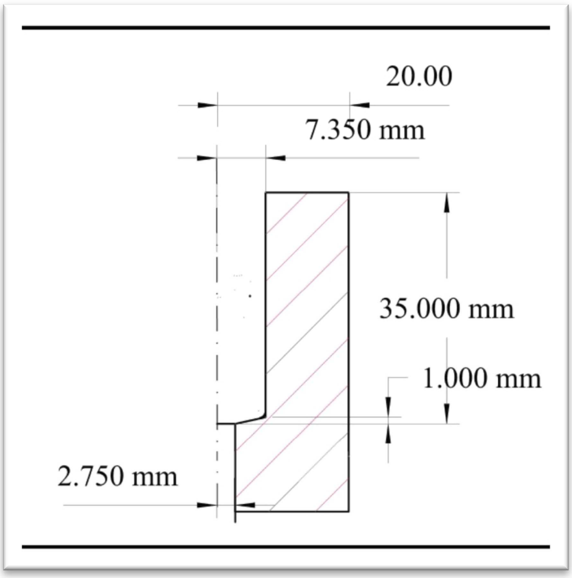


Figure 7: Initial die design

Again this problem could have been avoided if the engineer would have simply checked his layout in simulation /3/.

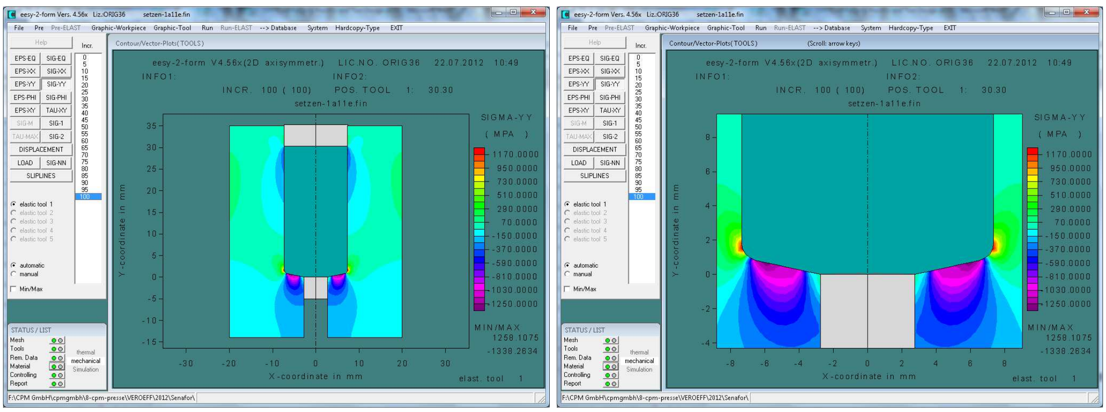

Figure 8: The simulation shows very high axial stress in the carbide indicating the failure

Due to the very high pressure in axial direction at the bottom of the die axial stress is generated inside the die. This very high stress will lead to tool failure especially as a carbide material was chosen.

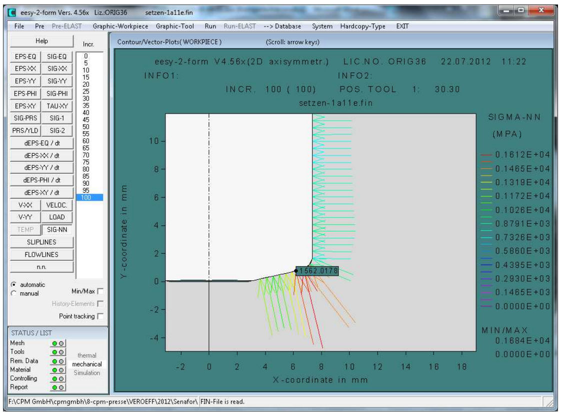


Figure 9: Pressure distribution in the die

By realizing the pressure situation in the die simple changes in the tooling could have avoided the trouble from the beginning.

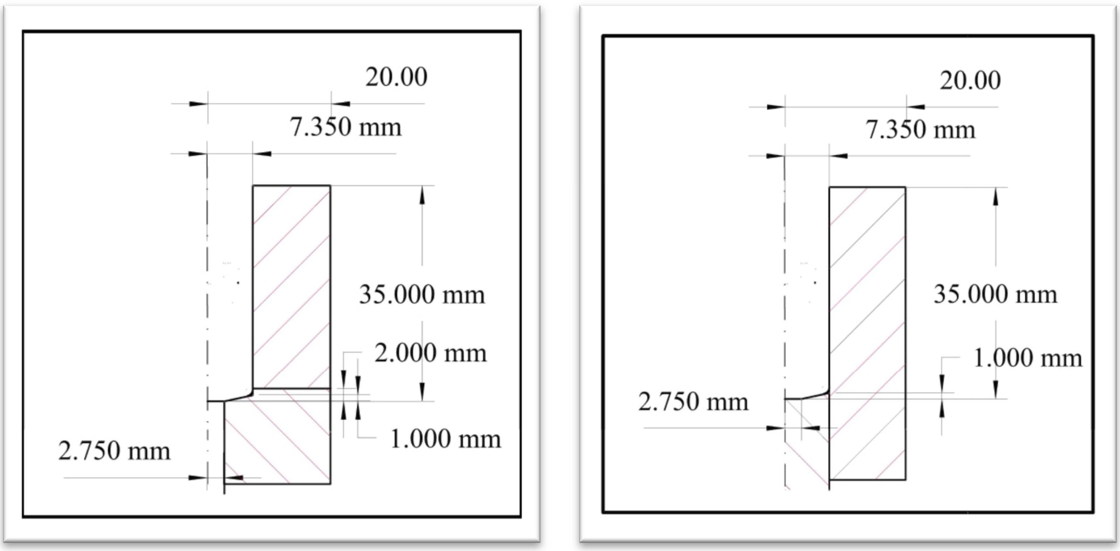


Figure 10: Alternative tool design to avoid cracking

Figure 10 shows alternative tool layouts that could avoid the problem of cracking. Either the carbide insert could be split or the carbide could be made cylindrical and the ejector would be changed. The later solution requires adequate material for the ejector to hold the high loads.

## 5. Conclusion

After 25 years of usage of FEA software to analyze plastic material flow there is still a discussion about the sense or nonsense of using simulation in forging industry. Some argue that the systems are too complex to be used others think that they are not precise enough still. Scientists often mention that the data and algorithm used are scientifically not really correct.

Despite all these discussions FEA is a very useful tool for industry. It helps to avoid a lot of costs. It helps to improve technology. And finally despite of some certain "weakness" of FEA it opens the user areas of technology that he would not reach otherwise.

## 6. Acknowledgements

The authors thank their customers for providing them with relevant information about the practical cases and about their general comments about using FEA in their daily work /2/. This information and the comments are very helpful to improve FEA software and promote its use in articles like this.

## 7. References

/1/ Gerhard H. Arfmann
Rechnereinsatz in der Umformtechnik unter Einbindung von Expertensystemen
Diss. RWTH Aachen
Verlag Stahleisen mbH, 1989

/2/ Reports of Users of CPM Simulation Software
Personal reports, CPM 2011

/3/ Eesy-Software
CPM Training Material
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