Proceedings of the ASPF 2003 (The 8th Asian Symposium on Precision Forging), October 15 - 18, 2003

# IMPROVEMENT OF TOOL LIFE IN COLD FORGING

**Soo Young Kim, Masahito Yamanaka, Tatsuo Arima, Toru Matsuda**

*Yamanaka Eng. Co. Ltd., Japan*

## Summary

Tool life in cold forging is influenced by tool quality as well as forging conditions and quality of forging material. This paper presents some typical examples of tool life improvement in aspect of tool quality depending on tool design and tool manufacturing parameters. For the purpose of improving tool life, suggestions should be based on accurate understanding of tool operating conditions in cold forging process. FE simulation known as CAE is effective in order to make clear the conditions by some numerically calculated result.

Keywords: cold forging, tool life, tool quality, tool design, FE simulation

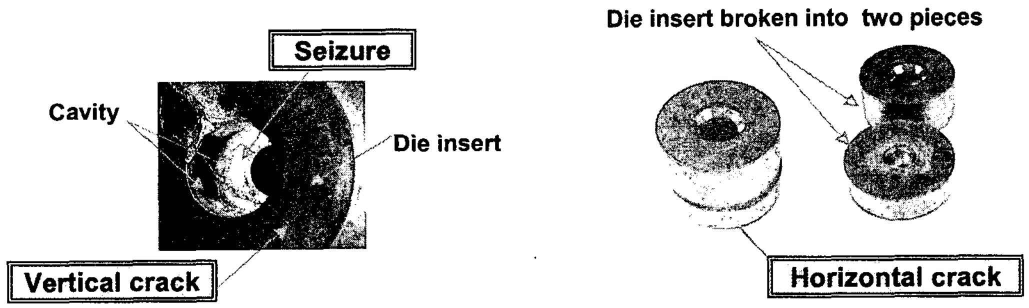
## 1 Introduction

Cold forging is an effective and widely used process for producing parts, because it has some advantages including low cost. The process cost depends on the tooling cost which is influenced mainly by tool life. Improvement of tool life contributes to the economical advantage of the process, and it is a principal role for our company, Yamanaka Engineering as a leading Japanese tool supplier to satisfy the customers with the long tool life. Advanced technology of tool design and tool manufacturing are indispensable to gain the customers' satisfaction.

## 2 Procedure of tool life investigation

Fig.1 shows typical types of defect of tools used in cold forging process. Tool life mainly depends on tool operating conditions and tool quality. Forging conditions including lubrication and quality of work piece correspond to tool operating conditions.

On the other hand, tool quality closely relates to tool life and is influenced by such factors as



(a)Die insert; vertical crack and seizure (b)Die insert; horizontal crack

*Fig.1 Typical type of defect*

tool design, tool manufacturing, etc [1]. There are many factors which affect tool life. It is the best way to take account of all the factors overall but there are cases that tool life was extended by optimizing tool performance [2]. Procedure of investigating tool life is shown in Fig.2. Firstly, used tools shall be observed. In case the types of tool failure are mixed, it is important to make sure which type occurs initially.

Secondly, geometry, hardness, surface roughness of tools relating to pattern of the failure shall be inspected. If inspected tools do not satisfy specifications on drawings, countermeasure shall be planned by means of making clear the reasons of the imperfections and why tools were delivered without noticing it beforehand. Meanwhile, it is necessary to investigate tool life as a matter of tool design, in case tools are manufactured as per the specifications on drawing and adverse conditions are not found in inspected tools. It is indispensable for the improvement to understand mechanism of tool failures. Recently, FE simulation known as CAE is effectively utilized. Since load and generating stress on tools are numerically and visually demonstrated, FE simulation will be of great help to understand cause of tool failures.

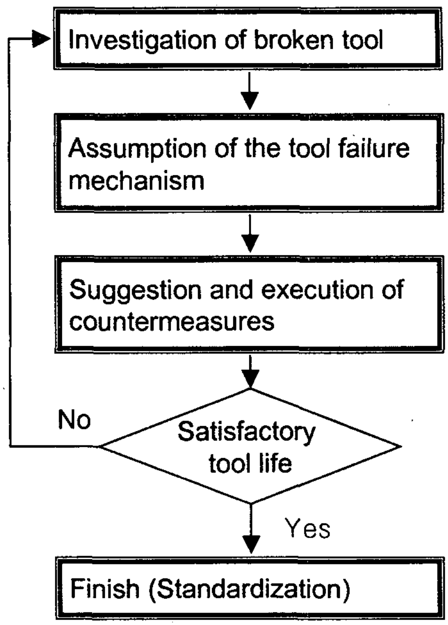


*Fig.2 Procedure of investigation*

# 3 Examples

## 3.1 Bevel gear die

Fig.3 shows general pattern of fracture of the bevel gear dies in cold forging. In most cases, crack initiates at nook around toe surface. It is supposed that high tensile stress is generated to the perpendicular direction against the direction of the crack due to high variation of forming pressure direction at the cracked area. Fig.4 shows the calculated result of forming pressure distribution. From the above, the following points can be confirmed.

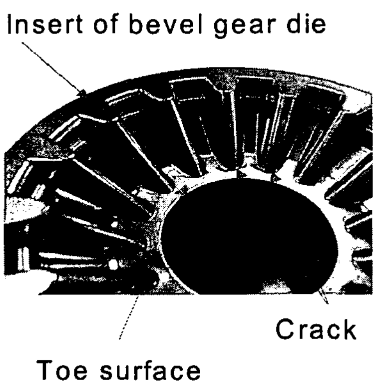


*Fig.3 Bevel gear die*

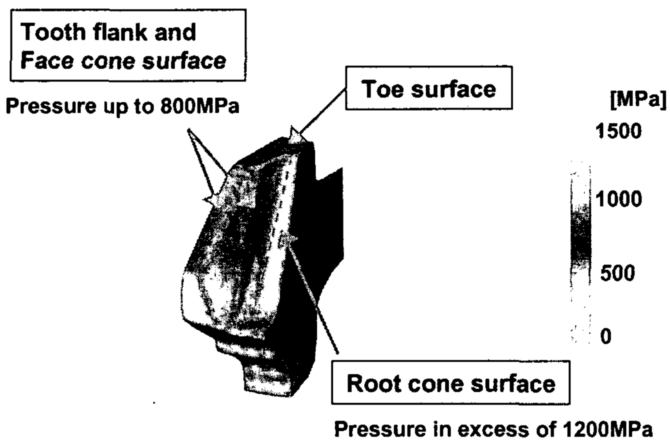


*Fig.4 Pressure distribution in bevel gear*

① Filling up to dies starts from the toe side of gear in both cases of the actual forging and result of FE simulation. Since nook around toe surface is under pressure from the beginning of forming, it is an unfavorable position in aspect of tool life.

② Forming pressure becomes high at the whole root cone surface. On the other hand, it is comparatively low at flanks where accurate geometry is required for die.

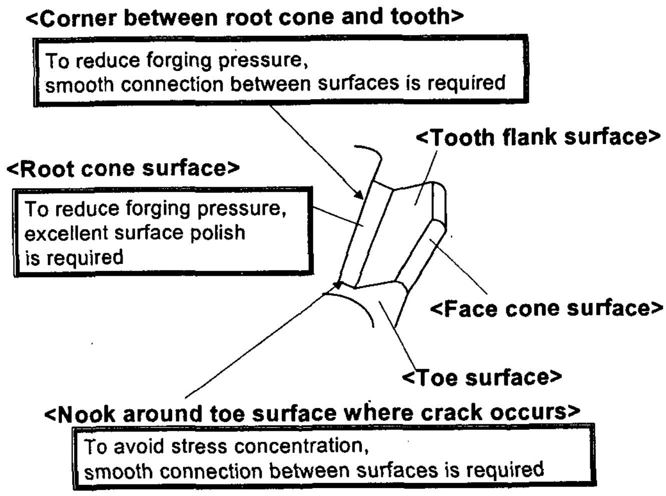



*Fig.5 Points in polishing bevel gear dies*

Although the above-mentioned calculated result could be forecasted to some extent, FE simulation for the first time made it clear, especially concerning the pressure distribution. From tool manufacturing viewpoint, tool life can be extended by securing better surface roughness at the root cone surface and smoothness of connecting shape at the nook. After normal polish, additional polish to those important areas is made as shown in Fig.5, which brought improvement of tool life. Stable tool life for all kinds of bevel gear dies is successfully attained after standardization of points in polishing as the above.

## 3.2 Die used in forward extrusion process

It is necessary for a tool designer to have knowledge beforehand on expected tool life in the typical forging processes. In case of FE simulation, it is possible to confirm tool life under extreme conditions such a heavy load on tools by numerical analysis. An example of the forward extrusion die with area reduction rate is taken up as shown in Fig.6. Fig.7 shows distribution of forming pressure as the acting load to tools. The pressure becomes the maximum in extrusion part. Die insert is divided into top and bottom parts. The following is influences depending on the divided positions of the die. Axial stress becomes the maximum

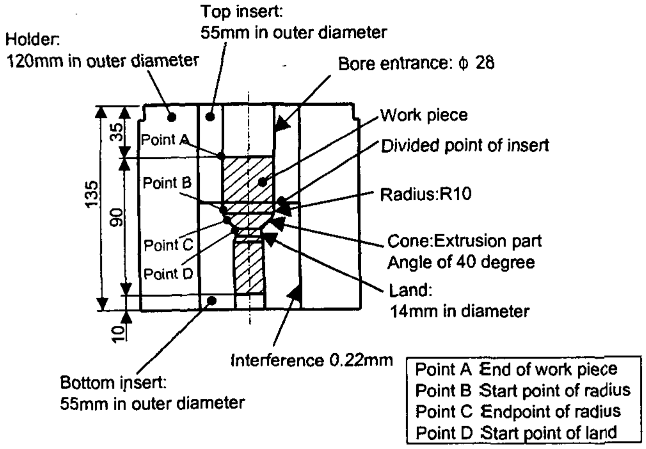



*Fig.6 Die used in forward extrusion process*

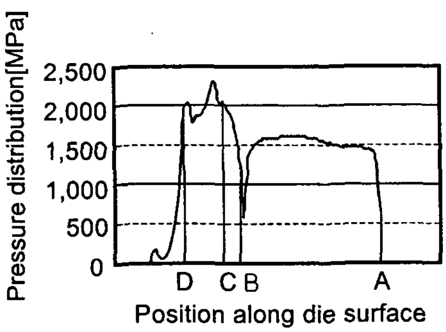



*Fig.7 Pressure distribution along die surface*

tensile stress at position of upper side than extrusion area, which will be the starting point of the horizontal crack. Main purpose of the division of insert into top and bottom parts is to avoid the horizontal crack, and as shown in Fig.8, the stress can be reduced if the straight area is shorter. Fig.9 shows distribution displacement (elastic deformation amount) in the radius direction. If insert is divided into top and bottom parts, elastic deformation amount becomes discontinuous at the dividing section. It is considered that displacement becomes discontinuous due to the difference in rigidity between the top and bottom parts, which also means possibility of flash. As shown in Fig.10, the difference in step becomes bigger as the straight area is shorter, which is opposite to the horizontal crack. Regarding flash generation, the connecting shape at dividing section of the top and bottom inserts should be applied to the cavity.

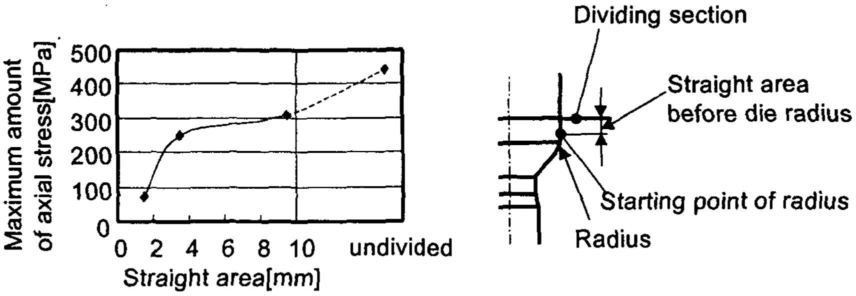



*Fig.8 Relation between straight area and maximum amount of axial stress*

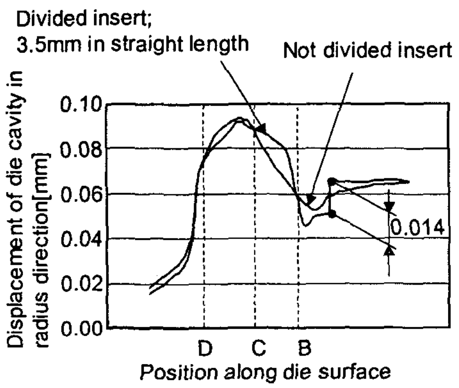



*Fig.9 Displacement of die cavity in radius direction*

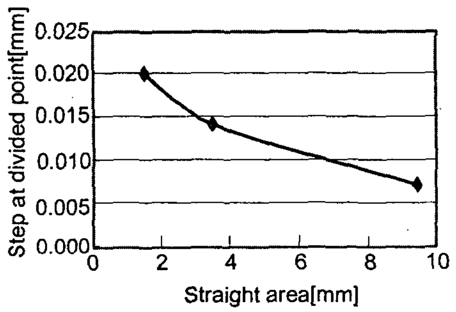



*Fig.10 Step of die cavity at dividing section*

## 4. Conclusion

Until now, a lot of tool life has been improved by application of FE simulation as shown in the typical examples, and now it is possible for a tool designer to know mechanism of tool failures. Evaluation of tool design can be judged by means of key parameter calculated by FE simulation. Stable and long tool life would be based on accumulated experiences in tool life improvement, standardization, digitization and system development including interface with the customers.

## Reference


[1] Lange,K: Modern Metal Forming Technology for Industrial Production, 3rd International Cold and Warm Forging Technology Conference(1996) Columbus, Ohio, USA

[2] Rodic,T;Gresovnik,I;Hansel,M;Meidert,M: Optical Prestressing of Cold Forging Die, Advanced Technology of Plasticity 1(1999)253-258