Serbian Tribology Society

SERBIATRIB '13

13th International Conference on Tribology

Faculty of Engineering in Kragujevac

Kragujevac, Serbia, 15 – 17 May 2013

INCREASING OF TOOL LIFE FOR HOT FORGING USING SURFACE MODIFICATION

Milentije Stefanović[1], Dragan Džunić[1], Vesna Mandić[1]
Srbislav Aleksandrović[1], Dragan Adamović[1], Slobodan Mitrović[1]
[1]Faculty of Engineering University of Kragujevac, Serbia, stefan@kg.ac.rs, dzuna@kg.ac.rs, mandic@kg.ac.rs, srba@kg.ac.rs, adam@kg.ac.rs, boban@kg.ac.rs

Abstract: *Techno-economic indicators in the hot forging of steel and other materials are highly dependent on the total life of forging tools, that is, the number of forged parts requires accuracy of regeneration after etching. Key influences on the life of tools, like in every tribo-system are: the pieces of material, geometry and material tools and machines for forging and environmental conditions. Characteristics of hot forging high temperatures are in contact materials and tools, and local high working pressures, the dynamic character of the load tools etc. Tool life is usually limited to the complex mechanisms of wear and tear, as a consequence of cyclic loading, such as abrasive and adhesive wear and, thermal and mechanical fatigue, and plastic deformation. This paper presents an overview of opportunities for increasing the life of forging tools by modern techniques for modifying the working surfaces of tools, according to comparative results of different methods, and gives appropriate recommendations.*

Keywords: *Hot forging, tool life, wear, coatings*

1. INTRODUCTION

In general, forging entails the sequential deformation of the workpiece material through a number of different processes. Furthermore, each forging operation comprises all the input variables such as billet material, dies, the conditions at the die-workpiece interface, the mechanics of shape change in the workzone, and the characteristics of the processing equipment, as illustrated in Fig. 1 [1]

Thus, in designing and developing bulk metal forming processes, key technical problem areas that must be addressed include:

- workipiece material-shape and size, chemical composition and microstructure, flow properties under processing conditions (flow stress in function of strain, strain rate and temperature), thermal and physical properties
- dies or tools-geometry, surface conditions, material and hardness, surface coating, temperature, stiffness and accuracy
- interface conditions -surface finish, lubrication, friction, heat transfer
- workzone - mechanics of plastic deformation, material flow, stresses, velocities, temperatures
- equipment used -speed, production rate, force and energy capabilities, rigidity and accuracy .

The understanding of these variables allows the prediction of the characteristics of the formed product, i.e., geometry and tolerances, surface finish, microstructure and properties.

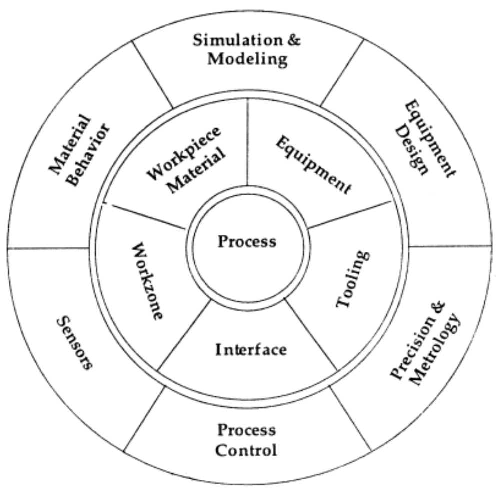

Figure 1. Variables of a bulk forming process [1]

Tools for hot forging are used in extremely difficult conditions: impact and very high mechanical load, variable partial and general thermical load, friction on the surfaces of tools and more. Each tribological system in the field of hot forging is characterized by the following elements [2]:

- contact pair, which consists of tool and workpiece-metal that is plastically deformed, with appropriate structural and mechanical properties,
- lubricant with properties relevant for hot process,
- a machine that implements processing,
- micro and macro environment

The final characteristics of the finished piece-forgings, such as size, shape, surface quality and structure depend on the values of system parameters. Figure 2. shows a global approach to the modeling of machining processes, whereas the quality of lubricants is main output.

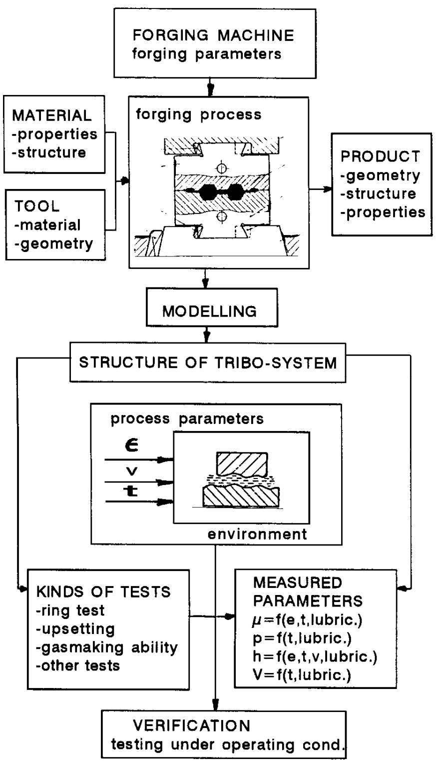

Figure 2. Tribo-modelling of hot forging process [2]

2. CAUSES OF DAMAGE TO THE TOOLS

Tools for hot forging function during cyclic mechanical and thermal loads. The complex process of tear occurs as a result of the two loads. Due to the high pressures and inadequate lubrication regime, the intensity of wear and tear due to friction is high. The main causes of damage to the tool, Figure 3:

- Wear as a result of tribological processes
- Plastic deformation,
- Thermal cracks,
- Mechanical fatigue crack growth,
- Breakdowns (die failures).

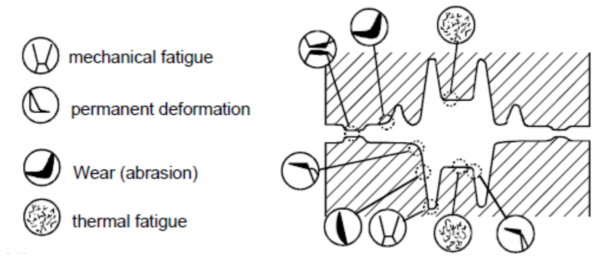

Figure 3. Failure and damaging of forging dies

Tool wear. This type of wear occurs as a result of relating the material particles from the surface of tools. Consequence of the occurrence of abrasive and adhesion processes and the formation of welded layers that are later destroyed.

Plastic deformation occurs under the influence of high pressure to the tool. As a result of resist materials, the deformation of the walls of tools and measuring tools changes.

Thermal cracks. They are caused by cyclic thermal change and show it as a grid cracks on the surface etching. Microcracks are connected and grow into large thermal cracking. They can grow on the surface and in depth.

Mechanical cracks are caused by mechanical loading tools. Consequence of fatigue, pre-treatment and initial thermal cracking. These are called large cracks.

Failure of tools is the result of hidden defects, bad thermal processing, errors in design, irregular exploitation and so on.

Generally, due to the forging temperature being well above 1000 ◦C, the temperature of the surface of the tool temporarily exceeds 500 ◦C and thus the tempering temperatures of conventional hot work tool steel. In such a case, the hardness of the tool is reduced and the mechanical impacts during forging operations can easily cause plastic deformation as well as abrasion of tool material, Figure 4 [3].

Life of forging tools is a complex function of several parameters, the most important being: structural, method design and exploitation conditions. Figure 5. demonstrates an interaction between these parameters.

Based on the analysis of tool wear, we can give the following recommendations for the design of tools [4]:

- The choice of tool material with high resistance to abrasion,
- The application of appropriate methods for improving surface properties of tools,

- Reliable exploitation tools, primarily because of the importance of lubrication,
- Use of an active role of friction,
- New design tool that allows the hydrostatic or hydrodynamic lubrication.

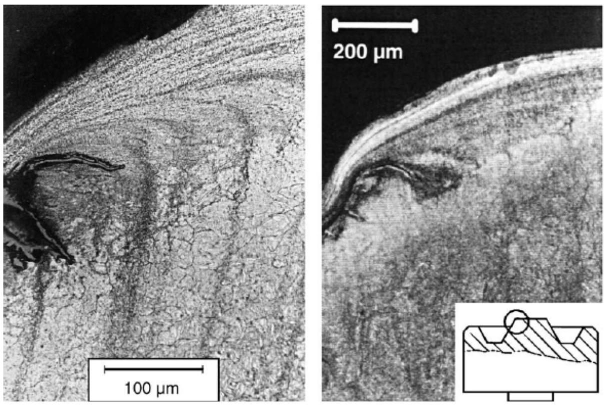

Figure 4. Microstructure of the convex radius of different hot work tool steels after 1000 forging cycles. Tool temperature, 200 ◦C; forging material, C45; forging temperature, 1100–1150 ◦C; lubricated contact; cycle time, 13 s; hardness of tools, 47 HRC.[3]

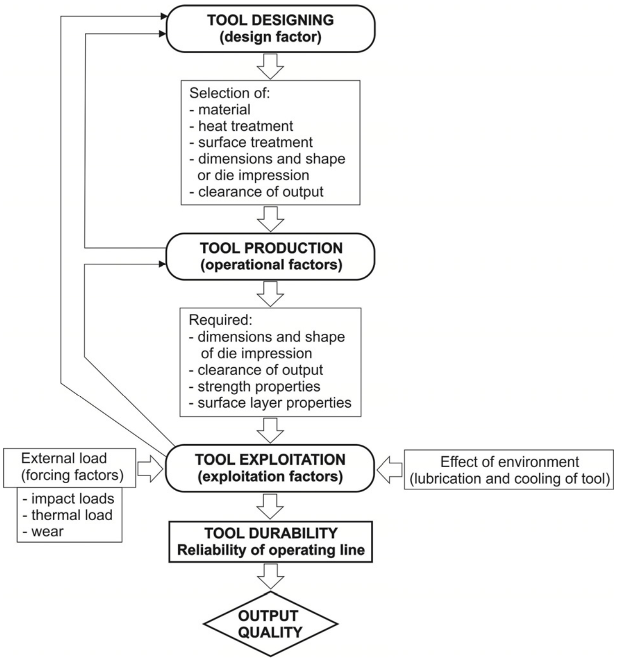

Figure 5 . The interaction of construction, technology and the industrial conditions of working tools [4]

3. METHODS OF INCREASING THE LIFE OF TOOLS

The predominant causes of damage are the result of tool wear and thermal and thermal-mechanical damage. Forging dies are exposed to high mechanical loads, which are accompanied by extreme thermal and tribological load for a very narrow surface layer. As a result of preheating steel parts at temperatures above 1000 ° C, the size of the hard oxide particles come in contact zone causing very strong abrasive wear. At elevated temperatures tribological conditions are very favorable for the processes of adhesion and a transfer of material to and from the surface of the tool. During execution of cyclic forging process heat is transferred due to contact with the heated work pieces followed by cooling lubricant tools in the form of spray, which is performed at room temperature. In this way, thermal shocks occurring within the tool material, resulting in high internal stresses initiate cracking. Further development of the cracks formed in parallel to the contact surface may lead to its peeling, when these cracks meet with cracks normal to the contact surface. In case of insufficient cooling of tools, it is possible to slightly release tool steel [5].

To increase the life of hot forging tools, different surface modification techniques are used such as welding, thermal application, electrodeposition, diffusion method and other combined methods. These special methods of surface modification increase the hardness, wear resistance and corrosion resistance of the tool at high temperatures. One possible way to satisfy all the conditions of hot forging process is a combination of thermo-chemical surface modification process (ie, carbonization and nitriding) with coating processes (ie, PVD, CVD, or PACVD), which is known in the literature as duplex modification process surface [6].

Figure 6 shows the results of testing the wear alloy tool steel to functioning in a warm envirnment (WNL-55NiCrMoV6) using various surface treatments: nitriding, sulphurizing, diffusion chroming, Cr plating, plasma spraying with metallic coatings of Cr, WFe, WC-types, burnishing [4].

Using spray-metal coatings leads to triple reduction of wear compared to conventional treatment tools. It also shows that the wear of the tool depends directly on the oxide that is generated on the surface of pieces and to a lesser extent on the oxide surface tools. Cr and WC plasma sprayed coatings should be applies to hot working tools. These coatings are characterized by considerable wear ressistance and thermal and imact fatique resistance.

According to the investigations [7] the best results for die service life were obtained for weld overlay coated dies, Table 1. Compared to received dies, the results showed an increase of 892%. The results were 206% better than TOKTEK Coatings, which held the second place.

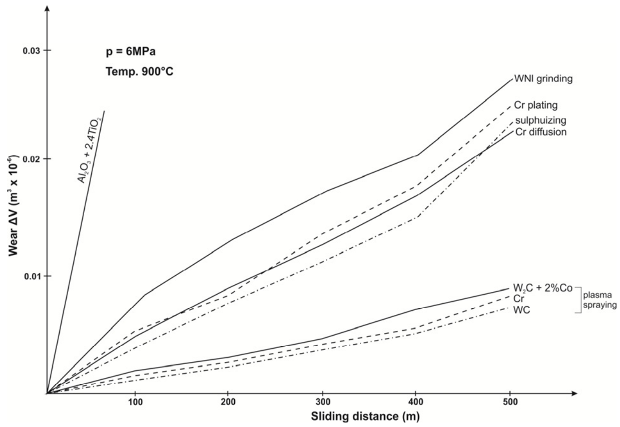

Figure 6. The influence of surface treatment and working on wear [4]

The dies can be ranged from the best to worst as weld overlay coated dies, multilayer dies TOKTEK coated, single layer AlTiN coated dies, plasma nitrided dies and dies as received. This range is also valid for the die polishing life, with the exception that it is equal for TOKTEK and AlTiN coatings.

Table 1. Number of polishing and total number of parts obtained with experimented dies [8]

Opera-tion	Number of Forged Parts					
	As receiv.	Nitri-ded	AlTiN coated	TOK TEK	Weld overlay coated	
					1st forg.	2nd forg.
1st polishi ng	1440	3920	4810	4660	8690	8330
2nd polishi ng	1260	2140	1980	2030	8160	8410
3rd polishi ng	1320	2110	1860	1750	8240	7830
4th polishi ng	-	-	1720	1830		
5th polishi ng	-	-		1780		
Total prod.	4290	9420	12280	1321 0	27810	2593 0

4. CONCLUSION

Tools for hot forging are applied in extremely difficult conditions: impact and very high mechanical load, variable partial and general thermical load, friction on the surfaces of tools and more.

With these tools, a special kind of coating on contact surfaces is regularly applied, in order to extend their working life. There are very different methods for modifying the tool surface. The most common are different types of heat treatment, which significantly affects the hardness of the surface layers.

Shown results are related to single-layer and multilayer coatings. It's hard to make a general conclusion regarding the most influential parameters, but it is certain that the surface roughness has a significant effect on the adhesion characteristics of the coating. Also the surface hardness to which the coating is applied is very important as is the ability to carry the load in question.

Coatings based on Cr and WC, and welding procedures show the best results. From the standpoint of economy of the process of forging, welding is the best. The temperature and the percentage of nitrogen in the nitration are very important for tribological characteristics of contact layers.

The ratio of alloying components of chromium (Cr), molybdenum (Mo), and vanadium to carbon ratio (H/C) is highly significant influence on the change of tribological behavior of tool material regarding wear resistance.

ACKNOWLEDGEMENT

The authors wish to acknowledge the financial support from the Ministry of Education and Science of the Republic Serbia through the project TR 34002.

REFERENCES

[1] V. Vazquez, T. Altan: *New concepts in die design - physical and computer modeling applications*, Journal of MPT 98, pp. 212-223, 2000.

[2] M. Stefanović, R. Stanković: *Importance of Tribological Investigations in the Hot Forging,* YUTRIB 1995 Herceg Novi, pp, 181-182, 1995.

[3] Barrau, C. Boher, R. Gras, F. Rezai-Aria: *Analysis of the friction and wear behaviour of hot work tool steel for forging,* Wear, Vol. 255, pp. 1444–1454, 2003.

[4] M.Gierzynska-Dolna: *Effect of the Surface Layer in Increasing the Life of Tools for Plastic Working*: Journal of MWT 6, pp. 193-204, 1982.

[5] J. H. Beynon*: Tribology of hot metal forming*, Tribology International 31, pp. 73–77, 1998.

[6] B. Navinsek, P. Panjan, F. Gorenjak: *Improvement of hot forging manufacturing with PVD and DUPLEX coatings,* Surf. Coat. Technol. 137, pp. 255–264, 2001.

[7] M. Bayramoglua, H. Polat, N. Geren: *Cost and performance evaluation of different surface treated dies for hot forging process,* Journal of MPT 205, pp. 394–403, 2008.