International Journal of Machine Tools & Manufacture 114 (2017) 60–71

Contents lists available at ScienceDirect

International Journal of Machine Tools & Manufacture

journal homepage: www.elsevier.com/locate/ijmactool

Analysis of the wear of forging tools surface layer after hybrid surface treatment

Marek Hawryluk[a,*], Zbigniew Gronostajki[a], Marcin Kaszuba[a], Sławomir Polak[a], Paweł Widomski[a], Jerzy Smolik[b], Jacek Ziemba[a]

[a] Wroclaw University of Science and Technology, Department of Metal Forming and Metrology, Lukasiewicza Street 5, 50-370 Wrocław, Poland
[b] The Institute for Sustainable Technologies – National Research Institute, K. Pułaskiego Street 6/10, Radom 26-600, Poland

ARTICLE INFO

Keywords:
Hybrid layers
Wear
Tool life
Hot forging

ABSTRACT

The performed research involved a thorough analysis of the phenomena occurring at an early stage of performance of selected forging tools – stamps (up to 4000 manufactured forgings), used in the second hot forging operation of a lid-type forging, which made it possible to point to the hybrid layer with the highest wear resistance, in order to increase tool life. Three different coatings were applied: AlCrTiSiN, Cr/CrN and AlCrTiN. The coatings were tested on 19 tools, and 3 representatives for each coating were selected, followed by their through research analysis. In particular, the analysis concerned the manner of wear of the hybrid layers and their resistance to specific degradation mechanisms. Based on the performed studies, it was possible to select the most optimal hybrid layer, which allows one to improve tool life.

The preliminary results showed that the best effects for the whole tool working surface were obtained for the Cr/CrN layer, characterizing in high adhesion as well as the lowest Young's modulus E and hardness. In the case of high tool forces and the related friction, the best results were obtained for the AlCrTiN coating, which, beside its good adhesion properties, also characterizes in the highest abrasive wear resistance.

1. Introduction

The tools used in hot forging processes are exposed to the operation of many degradation mechanisms, which cause their accelerated wear. The most important ones are: thermal shocks, periodic varying mechanical loads and strong friction with high tool forces. These factors affect mainly the tool's surface layer and so, the research aiming at improving tool life concentrates on these areas.

The concept of forging tool life, on the one hand, can refer only to the number of properly manufactured forgings, as it is assumed by the forging industry, whereas, from the scientific point of view, tool life is connected with resistance to degradation factors present during performance. This approach leads to a thorough analysis and evaluation of the degradation mechanisms causing tool wear as well as to the recognition of why they occur and how they work, rather than merely stating the fact of the tools' wear, which excludes them from further operation. Examinations of the tools' resistance to degradation mechanisms are especially important at the moment of introducing tools made of different materials and by a different manufacture technology [1–3].

Improving the life of forging tools assigned to work at high temperatures is the subject of research at many scientific centers all over the world. The most popular as well as best-mastered, low-cost, method of improving the life of forging tools are thermo-chemical treatment – plasma nitriding, plasma diffusion treatment and usually gas nitriding, which, however, does not always give a clear effect of improving durability [4–6]. That is why it is necessary to search for new methods of improving the life of tools used in forging. Among the most recent methods, hybrid technologies are being developed, which consist in the use of several surface engineering techniques at the same time. In the case of hybrid layers, it seems advisable to combine PVD (*Physical Vapour Deposition),* CVD *(chemical vapour deposition)*and their development coatings with the traditional thermo-chemical treatment (gas or plasma nitriding). This technology provides the surface with the desired performance properties and forms a barrier which effectively limits the effect of degradation factors [7,8].

The PVD coatings are commonly applied for the improvement of the life of machining tools [9,10], owing to which the latter exhibit elevated abrasive wear and crack resistance [11]. In this field of applications, there are many studies concerning the selection of PVD

* Corresponding author.
E-mail addresses: marek.hawryluk@pwr.edu.pl (M. Hawryluk), zbigniew.gronostajski@pwr.edu.pl (Z. Gronostajki), marcin.kaszuba@pwr.edu.pl (M. Kaszuba), slawomir.polak@pwr.edu.pl (S. Polak), pawel.widomski@pwr.edu.pl (P. Widomski), Jerzy.Smolik@itee.radom.pl (J. Smolik), jacek.ziemba@pwr.edu.pl (J. Ziemba).

http://dx.doi.org/10.1016/j.ijmachtools.2016.12.010
Received 11 September 2016; Received in revised form 15 December 2016; Accepted 22 December 2016
Available online 23 December 2016
0890-6955/ © 2016 Elsevier Ltd. All rights reserved.

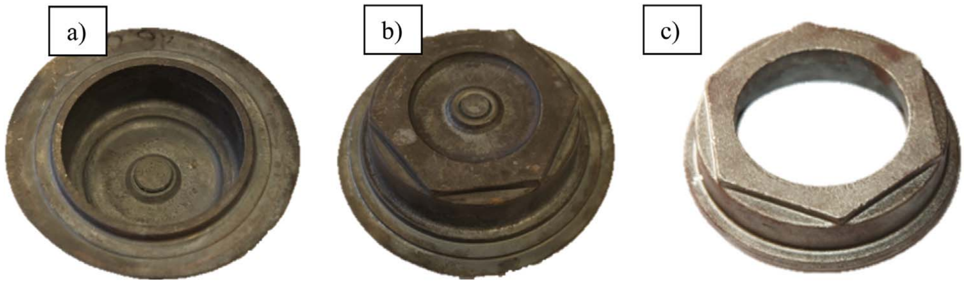

Fig. 1. A view of cold forgings: a) bottom side, b) upper side and c) ready lid forging after piercing and trimming.

coatings [12,13], as well as optimization of the number of their components and the manner of their application [14,15]. So far, studies have been performed on the use of nitrided tools coated with a single- or multi-layer PVD coating [15,16], which have been tested in respect of thermal fatigue [17], especially for the application in steel casting moulds for aluminum and bronze casting [17,18]. The abrasive wear resistance of the PVD coatings was also tested [19–21] under normal conditions and at elevated temperatures, from which we can conclude that the coatings containing titanium nitrides (TiN) exhibit the highest resistance, whereas the coatings with chromium nitrides are the least resistant to abrasion, while exhibiting a higher resistance than the traditionally used tool steels [21]. Hybrid layers have been also successfully used on tools for metal injection (thixoforming) [22]. Among the numerous studies concerning the coating application technologies and coating properties, some refer to the possibility of the application of coatings on forging tools in order to improve their durability [23,24]. The authors point to the elevated resistance of a hybrid layer being a combination of a PVD coating and a nitrided layer to the simultaneously occurring degradation factors, that is thermal and mechanical fatigue as well as friction. In this field of research, it is the resistance to the combined operation of many factors that is important, rather than to individual ones. In Slovenia, attempts have been made to apply PACVD and PVD coatings for tools used in forging operations on hammers [25–27], whereas in North Korea, examinations have been performed of the durability of nitrided tools with multi-layer TiBN coatings of the PECVD type (chemically deposited from the gaseous phase) [28], assigned for hot die forging, whose resistance turned out to be over five times higher than the resistance of the tools used so far and three times higher than the nitrided ones. The research concerning the application of hybrid layers for forging tools has been conducted in several locations in the world. Under laboratory conditions, thermal fatigue tests have been made as well as test forging was performed on plasma nitrided dies with TiN/Ti(C,N)gradient, (Ti, Cr)N, (CrN/TiN)×3, (Cr/CrN)×3 and CrN coatings, which exhibited good results for the multi-layer (CrN/TiN)×3 coating [29]. Studies on monolithic CrN coating showed the optimal thickness of the CrN coating (equaling 4÷8 μm) [31]. Also, performance tests have been conducted under the industrial conditions, where hybrid layers with CrN and TiAlN coatings were applied for hot forging dies, with nearly triple increase of the life of this tool which was obtained [31]. Other performance tests conducted on PVD coating properties obtained good thermal and corrosion resistance of TiAlCrN and CrN coatings [32–36].

In view of the clear demand for technologies improving tool durability as well as the increasing interest in hybrid surface engineering technologies, including the PVD and CVD technologies combined with gas and plasma nitriding, further research has been undertaken aiming at the development of these technologies as well as selection of the appropriate hybrid layer by way of tests conducted under the industrial conditions of Kuźnia Jawor S.A. The studies included analyses of the effect of various hybrid layers of the nitrided layer +PVD coating type on the durability of stamps used for the hot forging of a lid forging at an early stage of performance. In particular, the analyses focused on the manner of wear of the hybrid layers and their resistance to specific degradation mechanisms. For the determination of the degree of tool wear (material loss on their surface in the normal direction), during performance tests, the reverse 3D scanning method was applied, consisting in a periodic collection of forgings during the forging process, on which the loss of the tool material was represented. The analysis of the mechanisms was performed based on structural tests, as well as a geometrical analysis of the tool shape and numerical modeling. The applied methods allow one to perform an objective evaluation of the effectiveness of hybrid layers in the initial period of performance, the aim of which is to apply them on higher durability tools assigned for the industrial forging processes.

2. Description of the analyzed process

For the tests, the process of forging a lid forging was selected (Fig. 1), realized on the crank press P-1800T (ram stroke: 280 mm, nbr of strokes/min: 70), nominal force 18 MN, in three forging operations; upsetting, roughing and finishing forging (Fig. 2). The elements were forged from steel C45, from billets with the dimensions: φ=55 cm, l=95 mm and weight 1,77 kg. The temperature of the charge material equaled 1150 °C. The tools are preheated to a temperature of around 250 °C. A lid forging cover after forging, normalizing and machining is

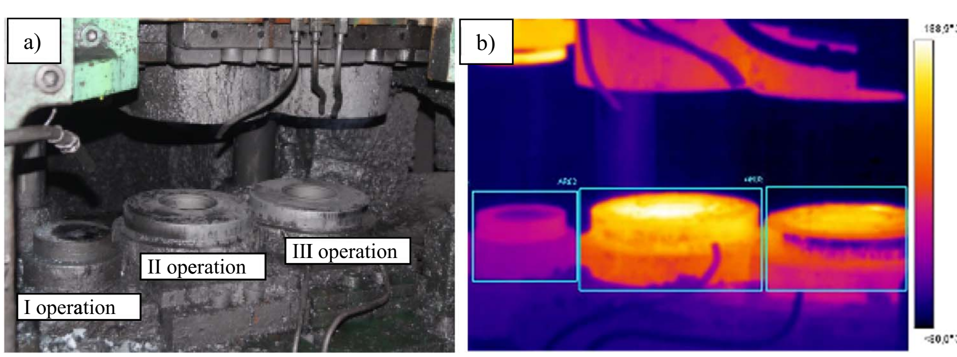

Fig. 2. The process of forging a lid a) successive operations, b) temperature distribution on the tools before forging.

Download English Version:

https://daneshyari.com/en/article/5015737

Download Persian Version:

https://daneshyari.com/article/5015737

Daneshyari.com