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Surface fatigue and wear of PVD coated punches during fine blanking operation

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ABSTRACT

Performance of two different physical vapour deposited (PVD) TiCN and Alcrona® (AlCrN) coatings systems is under investigation. Coatings were deposited on the punches produced from the Böhler S390 Microclean steel. Two different surface preparation techniques were used – wet polishing (high surface roughness) and dry polishing (low surface roughness).

Industrial trials of PVD coated punches in fine blanking operation were performed and studied. Wear of punches was analysed in regard to the punch geometry, position in the die and surface roughness, and measured after maximum 100,000 cycles at high loads.

Punches with higher surface roughness seem to withstand numerous loading cycles with some traces of coating delamination and wear. On the other hand performance of PVD coatings with smaller surface roughness in a striking way was much worse.

Comparative trials of the coatings surface fatigue wear and indentation surface fatigue testing were performed in the laboratory as well. In surface fatigue wear testing coatings were dynamically indented by ball (spherical) indenters made from conventional hardmetal (WC-6 wt.%). Testing parameters were identical to those of industrial trials. The Vickers diamond pyramid indenter was cyclically pressed with 500 N load at single point during indentation surface fatigue testing. Results are in agreement with surface fatigue wear tests results.

Finally the microstructural investigations using SEM and XRD techniques were performed for better understanding of the surface fatigue and wear mechanisms during fine blanking process.

Results of both trials are in good agreement and allow predicting performance of coatings.

1. Introduction

Recent challenges in products developments lead to extensive need for more durable tooling. The use of high strength steels instead of tool steels brought out a new aims for material scientists – increase endurance of the tool materials in cyclic loading (cold forging, stamping and blanking). To solve the fatigue damage problems of high-speed steels (HSS) the powder metallurgy (PM) routes are used. As a result of the finer and more uniform microstructure that PM-HSSs exhibit, as compared to their conventionally produced counterparts, they also present enhanced cross-sectional hardness uniformity (wear resistance), fracture toughness and fatigue strength [1].

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Fine blanking is a process where clearance between punch and die is reduced in order to improve cutting surface quality [2]. Therefore fine blanking tools are under high stress in the cutting area which leads to aggravated wear. The expanding use of HSS as tool material increases contact pressures substantially, leading to tool lifetime decrease or even its break down [3].

There are several parameters jointly influencing tool life-time: (1) the fine blanking tool design is one of the possibilities to reduce tool contact stresses; (2) the sheet metal used in fine blanking is very critical component and has a direct influence to wear and tool endurance [4,5]; (3) the tool material and coating systems are another well known possibility for improvement of the tool durability. Number of studies has been done in the field of fatigue properties of HSS steels [6–8]. Mostly the research is based on laboratory experiments in order to find out best solution and industrial tests are not described. The published information about fatigue behaviour of PVD coated HSS is very scarce.

Performance of two different physical vapour deposited (PVD) TiCN and Alcrona® (AlCrN) coatings systems is under investigation. Coatings were deposited on the punches produced from the Böhler S390 Microclean steel, see Fig. 1. Industrial trials of PVD coated punches in fine blanking operation were performed and studied. Wear of punches was analysed in regard to the punch geometry and position in the die, and measured after maximum 100,000 cycles at high loads.

Comparative trials of the coatings indentation surface fatigue and surface fatigue wear were performed in the laboratory conditions as well. During indentation surface fatigue testing coatings were dynamically indented by Vickers indenter. In surface fatigue wear tests the hardmetal ball indenter was cyclically pressed onto coating surface. The approximate number of loading cycles before start of erasure of coating from the punch surface can be predicted from Wöhler like curves obtained from these tests.

Testing results analysis includes the fractographical investigations, with use of optical and scanning electron microscopy (SEM), chemical composition study by energy dispersive X-ray spectroscopy (EDS) and study of the crystalline structure of the coatings by X-ray Diffraction (XRD).

2. Materials

The hard coatings were deposited at Oerlikon Balzers Sandvik Coating AB-s. The titanium carbonitride (TiCN) PVD coating was deposited on the tool without pre-treatment. The micro blasting as surface pre-treatment was used with AlCrN coating before deposition. The coatings thicknesses were 3.0 μm for TiCN and 1.4 μm for AlCrN, measured using ball-cratering method Kalomax and Zeiss Axiovert 25 microscope.

Main properties and characteristics of studied coatings and substrate material are listed in Table 1. The hardness and Young modulus (E) were measured by nanoindentation technique. Indentation routines were carried out on the Micromaterials NaonoTest system with use of Berkovich indenter (tip radius of about 100 nm).

Coefficient of friction was determined using tribometer Wazau SVT500 by ball-on-disk method. The specimens were stationary and a load was applied to the moving ball. Steel ball was used in order to mimic the actual “friction pare” between punch and raw material.

Punches were manufactured from Böhler steel S390 (see Fig. 2) and coated by TiCN and AlCrN coatings. The two types of carbides are identified in studied steel – M_6C (M = Fe, W, Mo) or bright grains and V_8C_7 or light grey grains.

The heat treatment was carried out at UY Bodycote using a vacuum furnace. Austenization temperature required in the range of 1150–1230 °C and holding time of 80–150 s. Due to the short austenitization period and heating variations of the grip and the tip of the punch the required hardness (at least 62.0 ± 1.0 HRC) was obtained only at the tip of the punch. The chemical composition and measured hardness values for S390 steel (substrate) are shown in Table 2.

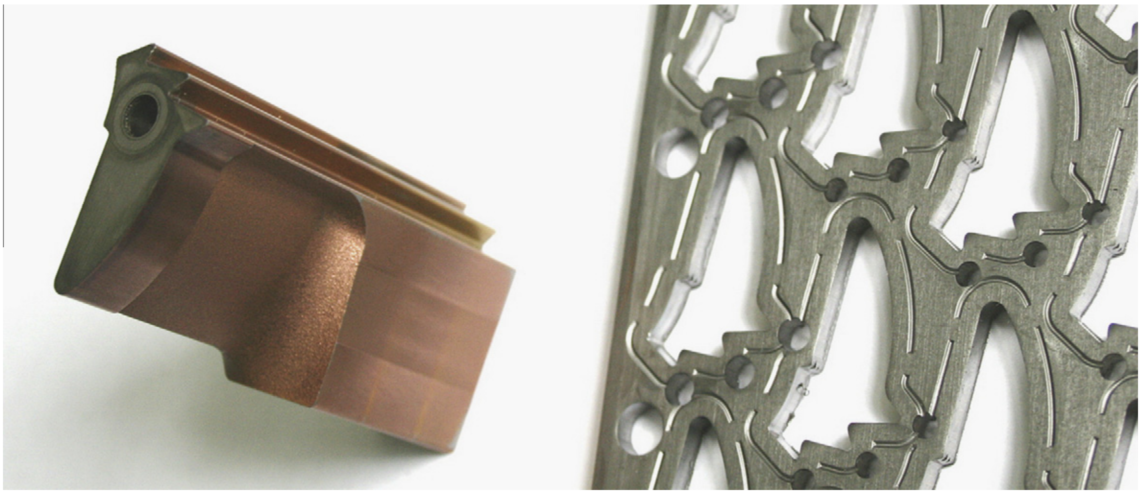

Fig. 1. PVD coated industrial punch and scrap strip.