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Influence of geometry and the sequence of surface texturing process on tribological properties

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ABSTRACT

The aim of this study was to investigate the influence of geometry and the sequence of surface texturing process on tribological properties of contact surfaces. Textures in the form of pyramid, cone and concave shape were introduced before and after hard TiAlN coating deposition. Textures with pyramidal shape resulted in the worst tribological behaviour, while laser textures provided the best results. It was found that the sequence of surface texturing has an effect on tribological behavior. If texturing is done after coating deposition, friction is lower regardless of the texturing type because of the better wettability of steel in comparison with coating.

1. Introduction

Manufacturing industry is faced with demands for greater productivity and lower costs, which on the one hand require better sustainability of tools and on the other hand the use of cheaper tool materials. With the use of new high-strength materials, tools are facing very demanding contact conditions, including high impact loads, high contact pressures, elevated temperatures and high wear [1–3]. All that put a lot of stress on the contact surfaces, exposing them to combination of cyclic, mechanical, chemical and tribological loads, which can result in fatigue, chipping and wear of the tool [4–6]. The growing operation performance requirements of mechanical systems require the use of new advanced materials and surface technologies to enhance the efficiency of mechanical systems and simultaneously reduce energy consumption. Efficiency of mechanical systems can be improved by reducing friction and wear in tribological contacts, which can be achieved by changing the shape of elements, use of hard protective coatings, improving surface roughness and surface topography [7–9] or by the generation of specific surface structures, known as surface texturing [10]. While the possibility of changing the geometry is very limited and linked to their function in the system, the use of hard protective coatings on machine components and dynamically loaded forming tools is problematic and limited to the lower loads. Main problems are the load carrying capacity of coatings and compatibility with the existing lubricants. On the other hand, by changing the topography or introducing surface textures, change in lubrication regime and consequently the significant improvement in tribological properties of contact surfaces can be achieved.

Surface texturing [11], as a way of changing the surface topography by generating micropores or microchannels is aimed at facilitating elastohydrodynamic lubrication and reducing friction in very demanding operating conditions. Surface texturing has been successfully used in the application of sliding bearings, machine components in sliding contacts, cylinders of internal combustion engines and mechanical seals [11,12].

The use of hard protective coatings [14–18] is practically unavoidable in modern industry. Already for some time protective coatings are an indispensable component of high performance cutting tools. With a variety of coatings, cutting tool life can be extended, processing parameters and surface quality improved, friction reduced and the corrosion and oxidation resistance increased. For each type of workpiece material, certain type of protective coating is needed, thus ensuring optimal function of the tool.

On the other hand, the use of protective coatings in manufacturing industry, where tools are exposed to more severe dynamic loadings such as fine blanking operation, is limited to the simple tool geometries and only to a few coatings, mainly due to the demanding conditions of dynamic impact loading, wherein even the smallest error on the tool surface can cause a failure.

Merging technologies of surface texturing and protective coatings has already been proven to be a promising way of reducing the amount of lubricants and increased wear resistance in different applications [19,20]. It was also shown that combining hard coating and texturing can have beneficial properties in high performance cutting [21,22] and sheet

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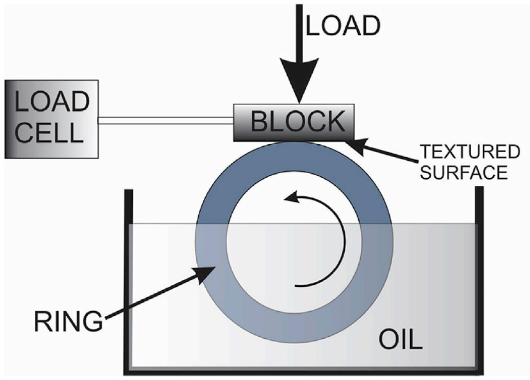


Fig. 1. Schematic presentation of block-on-ring configuration.

forming dies [23]. Surface textures can also lead to significant increase of contact fatigue life due to local increases of mixed lubrication film thickness [24]. Unfortunately very little is known about the behaviour of coated surfaces under dynamic loading and impact of surface structures, defects and cavities on the dynamic properties of the coated surface. It was shown that hard coating can prolong fatigue life [25]. With the implementation of dimples or canals, we enter the tensions into the surface, which can act as the crack initiation points under the dynamic loading. This can lead to coating failure and loss of tool functionality.

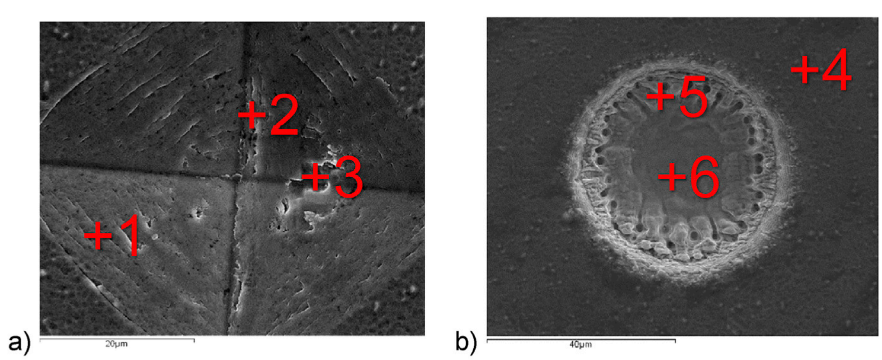
Although manufacture of different surface textures on the tool surface has mutual effect on the fatigue life and tribological behaviour, only tribological aspect is presented in this research. Therefore, purpose of this study was to investigate the influence of different geometries and the sequence of texturing process on tribological properties. Imprinting or laser ablation was chosen due to different input of residual stress into the surface which can have influence on fatigue properties.

2. Experimental

2.1. Surface texturing

For this investigation, plate samples (20 × 20 × 8 mm) from the P/M cold work tool steel were used. The P/M tool steel had the following composition (wt%): 0.85% C, 0.55% Si, 0.40% Mn, 4.35% Cr, 2.80% Mo, 2.10% V, 2,55% W, and 4.50% Co. Before the coating deposition, the tool steel was vacuum heat treated with adjusted process parameters so to obtain maximum fracture toughness of 11 $MPam^{1/2}$ at working hardness between 63 and 64 HRc which was found to be optimal ratio between toughness and hardness from aspect of impact wear resistance [25]. Details about the vacuum heat treatment are given in Ref. [26]. Based on the good practise experience, commercially available monolayer TiAlN coating, ~3 μm thick and hardness of 3300 HV, deposited using magnetron sputtering PVD procedure was used as a hard protective coating. Coating was deposited on polished and vacuum heat treated samples (R_a = 0.05–0.10 μm) at the substrate temperature of ~450 °C. Roughness of the substrate was selected based on the good practise experience and the fact that powder metallurgy cold work steels have low fracture toughness and therefore need smooth surface in order to prevent surface initiated cracks under dynamic loadings. All samples were coated in the same batch. Details of the coating deposition process are given in Ref. [27].

Surface texturing was done using different shapes of imprints and laser texturing due to different input of residual stress into the surface which can have influence on fatigue properties. To achieve cone like and pyramid shaped imprints Rockwell-C and Vickers indentation tips were used, respectively. Picosecond laser was also used for obtaining dimples with the parabolic shape. Indentation and laser ablation were chosen also due to different residual stress introduction into the surface. Spacing and depth of the textures was chosen based on our previous investigations [28,29] where laser surface texturing was investigated. Aldo surface texturing has many influencing parameters as size, depth, spacing, area



c)

Point \ Elements analysed	N	Al	Ti	Cr	Fe	Co	Mo
Spectrum 1	32,42	26,23	40,37		0,99		
Spectrum 2	3,38	1,2	1,35	4,5	76,82	4,64	1,77
Spectrum 3		1,31	1,43	4,44	84,29		2,32
Spectrum 4	36,89	25,32	37,79				
Spectrum 5	2,18	1,1	1,37	4,45	78,28	4,64	2,17
Spectrum 6				4,35	81,57	2,05	2,57

Fig. 2. Surface textures done after coating deposition: a) pyramid indent, b) laser dimple and c) matching EDS analysis.