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High-Precision Finishing Hard Steel Surfaces Using Cutting, Abrasive and Burnishing Operations

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Abstract

This paper presents the technological and functional capabilities of surface textures produced by high-precision cutting, abrasive and ball burnishing operations on hardened steel parts of about 60 HRC hardness. Special focus was placed on surface textures generated by hard turning, belt grinding and ball burnishing operations which are characterized by the Sz roughness parameter of about 1.3 μm and distinctly different values of the Sa parameter. Apart from the standard 2D and 3D roughness parameters, the fractal and motif parameters were analyzed.

Keywords: Hardened steel , hard turning, belt grinding,, ball burnishing, surface roughness, surface texture

1 Introduction

Strong technological demands on the quality, functionality and reliability of machined parts have influenced the visible progress in surface metrology. As a result, the functional surfaces produced by modern manufacturing processes (including hard part machining) can be characterized with a higher accuracy using a number of the field parameters (S-parameters and V-parameters sets) (Jiang and Whitehouse, 2012). A marked achievement in this area has been seen in the standardization of 3D roughness parameters (Jiang and Whitehouse, 2012; De Chiffre et. al., 2000; Lonardo et. al., 1996). Among innovative machining technologies, precision machining with Rz =2.5-4 μm and high-precision machining with Rz<1μm of hardened steels (45-60 HRC) with CBN cutting tool materials seems to be the leading one. They have been developed with a special consideration to automotive, hydraulic and die and mold industry sectors (Tönshoff et. al., 2000; Klocke, 2011) due to high

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flexibility, possible complete machining, lesser ecological impact and higher MRR (König et. al., 1993; Davim 2011). Initially, hard machining was introduced as a replacement of more energy consuming and environmentally hazardous grinding (Klocke et. al., 2005). In this aspect, the functionality of the machined surfaces produced by cutting and grinding operations should be taken into account. This is because hard turning and grinding, as well as other abrasive finishing operations, generate different surface structures which influence distinctly their functional properties. Previously, investigations were based on 2D height and amplitude parameters and the relevant BACs shapes (Klocke et. al., 2005). However, a dissimilarity between the hard turned and ground surface topographies was revealed although the values of the Ra or Rz parameters are comparable. The 2D and 3D comparison of precision hard turning and belt grinding with a contribution to bearing area parameters was established by Grzesik et al. (Grzesik et. al., 2007). Further, it was extended to superfinishing and ball burnishing operations (Grzesik and Żak, 2012) in order to investigate their influence on the modification of the texture of a CBN turned surface. It is evident that future investigations of surface finish and surface texture induced by sequential machining processes should be developed (Grzesik et. al., 2007; Grzesik and Żak, 2012). The objective of this study is to comprehensively characterize and compare surface textures of representative hard turned, belt ground and burnished surfaces using standardized 2D and 3D roughness parameters supporting by fractal dimension and motif parameters. The quantitative comparative criterion assumes the Sz roughness parameter of about 1.35 μm for all textures generated. It should be noticed that previous investigations of the authors concerned the comparison based on the same value of the Ra(Sa) roughness parameters (Grzesik and Żak, 2012; Grzesik et. al., 2014; Grzesik et. al., 2015).

2 Experimental Details

2.1 Workpiece Material and Machining Conditions

Specimens were shaped in the form of rings made of a 41Cr4 (57±1 HRC) steel in order to reduce their mass during roughness measurements. They were initially turned to 0.4 μm Sa roughness and subsequently CBN turned, belt ground and burnished in order to generate surfaces with the Sz roughness of about 1.3 μm. The machine tools were Okuma Genos L200E-M CNC precision turning center, special belt grinding device described in (Grzesik et. al., 2007) and ball burnishing head mounted in a turret head of a CNC lathe described in (Grzesik and Żak, 2012).

Machining conditions for cutting and abrasive operations performed were as follows:

1. High-precision hard turning (HT) (Fig.1a) using TNGA 160408 S01030 chamfered CBN insert, cutting speed vc=150 m/min, feed rate f=0.05 mm/rev, depth of cut ap=0.05 mm. Previously, surfaces were turned using the same cutting tool with the feed rate of 0.1 mm/rev and depth of cut of 0.15 mm.

2. Two step oscillation belt grinding (BG) using abrasive belts with 30 μm and 9 μm grains. Rotation speed of the workpiece was 900 rev/min, belt feed was 0.06 mm/rev, oscillation frequency was 12 Hz, oscillation amplitude was +/- 0.5 mm, roller pressure was 2 bars. Belt grinding (Fig. 1b) was performed during 9s with supplying oil mist produced by a MQL system.

3. Ball burnishing performed using special burnishing tool equipped with Si_3N_4 ceramic ball of 12 mm diameter, as shown in Fig. 1c. The burnishing load was exerted by means of controlled spring-based pressure under static ball-workpiece. Burnishing was performed with supplying a small amount of a BP Energol CS 100 machine mineral oil with the viscosity of 100 mm^2/s at 400C, produced by BP Lubricants UK Ltd. The burnishing head was mounted in the turret (Fig. 1c) and due to this fact the burnishing operations were included into CNC program along with CBN turning passes. The surface finishing by means of burnishing conditions was carried out using the burnishing speed of 25 m/min and burnishing feed (fb) of 0.075 mm/rev. In order to generate the required burnishing load, the tool