Measurement 88 (2016) 176–185

Contents lists available at ScienceDirect

Measurement

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

Metrological changes in surface morphology of high-strength steels in manufacturing processes

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ARTICLE INFO

Article history:
Received 1 February 2016
Received in revised form 14 March 2016
Accepted 25 March 2016
Available online 31 March 2016

Keywords:
Surface metrology
Surface morphology
Surface topography
Hardox
High-strength steels

ABSTRACT

In this paper the surfaces of high-strength steels were analyzed using an optical 3D measurement system to investigate into the surface morphology and parameters of surface topography. Analyzed surfaces were generated by the most commonly used in the production facilities of manufacturing processes. The study was conducted for 400 HB plates. It was established that the behavioral changes in the manufacturing process influence the surface characteristics to a great extent. Comprehensive parametric analysis was conducted for dry production conditions. It has been observed that there exists a close correlation between mesh grit size and parameters of surface roughness *Ssk* and *Sku* in abrasive blasting processes. Furthermore the results show that the surface morphology in turning process depends to a large extent on the direction of feed motion. The study was performed within a production facility during the machining of components subject to wear.

1. Introduction

The ever increasing demand for improved surface quality and tighter geometric tolerances in production processes of components subject to wear has resulted in the augmentation science research in the domain of manufacturing science and technology. The manufacturing of machine components by machining is accompanied by inherent characteristic changes of the surface integrity resulting from the thermal and mechanical loads of the production processes [1–4]. The vast machining operations in industrial facility are based on the lubricated machining. But costs of this processes, like ecological and human health problems was caused by the cutting fluids. Therefore, the objective of science and industrial works is to investigate more appropriate eco-friendly cutting conditions for dry cutting [5–7]. The process performance can be improved by selecting the optimal combination of process parameters and cutting conditions. The shape of cutting tools influences on the surface quality and precision of the workpiece dimensions [8,9]. Wojciechowski et al. [10] presented analysis of various factors affecting on machined surface texture in milling process. They investigated the surface roughness in a 3D array, and measurements they conducted parallel to the feed motion direction. Zebala and Kowalczyk [11] focused on the cutting force and surface roughness, described by the 2D surface roughness parameter *Ra*. Maruda et al. [12] presented the results of the research into the impact of anti-wear added to emulsion mist on the geometrical state of the machined surface of stainless steel after turning process. Pusavec [13] presented experimental study of high

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http://dx.doi.org/10.1016/j.measurement.2016.03.055
0263-2241/

Nomenclature

Sq	root mean square roughness
Ssk	skewness
Sku	kurtosis
Sp	maximum peak height
Sv	maximum valley depth
Sz	maximum height of surface
Sa	average roughness

performance cryogenic machining of porous tungsten, which is classified as a difficult-to-machine material. In this paper the quality of the machined surface porosity was one of the most important objectives. Kuczmaszewski and Piesko [14] presented results of research on the wear of milling cutters in machining of high silicon difficulty to cut silumins.

The problems of wear of machine components concern all branches of industry where durability and reliability are issues that determine the entire production process. The process of wear condition of machine parts is affected by many factors, known as tribological and nontribological wear processes. Defects analysis is important in technical diagnostics which includes assessment of the technical condition of machines parts by studying the properties of its work processes [15–17]. Proper surface texture can minimize friction force or can be traps for wear debris to prevent abrasive wear [18]. According Mishra and Polycarpou [19] surface texturing can decrease friction force even about 75%. High-strength steels are very often used in applications requiring high surface hardness. Their mechanical properties makes them of great interest for a wide range of applications, especially in the power industry to biomass transport. The use of high-strength steels can significantly reduce the thickness of the designed elements, because resistance abrasion is three times greater than for typical metal sheet S355J2G3. Machining processes, as well as other abrasive finishing operations, generate different surface structures which influence distinctly their functional properties. The quality of the machines parts is normally judged by a tangible examination of surface roughness because surface roughness also dictates the functionality and service life of a component under hostile environments [20]. Industrial requirements regarding the geometrical features of a components are defined by several characteristical values of surface roughness, for example *Ra* or *Rz*. Even though these values are commonly used, they may not be suitable to compare workpieces or to scale the properties of a workpiece for different applications machined with different cutting procedures [21]. In this aspect, a special focus should be placed on surface morphology and surface texture induced by production operations.

The article focuses on research problems related to the surface quality. The main purpose of this study was to determine the effect of manufacturing process as a key factor in controlling surface morphology and surface topography parameters. The workpiece material is Hardox 400 because this steel is widely used for many industrial applications due to its unique properties. All test was performed with dry cutting conditions. The objective of this study is to comprehensively characterize and compare surface morphology generated in industrial production processes and three abrasively blasting surfaces using a standardized 3D roughness parameters as well as other characteristics such as structure direction and isotropy.

2. Material and methods

2.1. Workpiece material and surface generating method

The workpiece material was $100 \times 100 \times 5$ mm plates of an Hardox 400. This is an abrasion resistant steel with a nominal hardness of 400 HB. Typical applications are components subject to wear. The elemental composition of the workpiece material and surface morphology is given in Table 1 and Fig. 1, respectively. The research was carried out in production facility using manual machining machines (lathe, milling machine, planer, magnetic grinder) and manual shot blasting machine.

2.2. Surface morphology analysis

Surface morphology analysis was performed using an Infinite Focus Measurement Machine (IFM). The IFM is an optical 3D measurement device which allows the acquisition of datasets at a high depth of focus. The principle of IFM operation based on the projection a beam of white light on a relatively small area of the surface of the assessed object. The IFM method allows for the capture of images with a lateral resolution down to 400 nm and a vertical resolution down to 20 nm. Based on the combination of small depth and vertical scanning, the optical system with Focus-Variation can be used to gain 3D topography and real color information. The Mountains-Map 7.1 software version was used to collect and present the measurement data. The results were compared in five large analysis groups (one for each machining technique

Table 1
Chemical composition of workpiece materials.

Element	C	Si	Mn	P	S	Cr	Ni	Mo	B
Hardox 400 wt.%	0.13	0.25	1.34	0.009	0.001	0.40	0.08	0.051	0.002