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ScienceDirect

Procedia Manufacturing 20 (2018) 344–349

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

2nd International Conference on Materials Manufacturing and Design Engineering

Modeling of Roughness Value from Tribological Parameters in Hard Turning of AISI 52100 Steel

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Abstract

This paper presents the modeling of roughness value from tribological parameters in hard turning of AISI 52100 steel using different tool nose radius. The experimentation was conducted on commercial CNC machine by utilizing 0.4 mm, 0.8 mm, and 1.2 mm tool nose radius. The roughness value is measured by Mitutoyo surface roughness tester. In the experimentation process the runs (L_9) was decided by the DOE taguchi method and the linear regression method used in order to optimize the tribological parameters for minimum surface roughness. In the results, the R^2 value for 0.4 mm tool nose radius would be able to predict roughness value with an accuracy of 97.71% and subsequently the roughness values for 0.8 and 1.2 mm tool nose radiuses would be 99.92% and 99.67%. The results showed that the tool nose radius affects surface roughness more than the tribological parameters. Total 9 experimental runs were conducted using orthogonal array in order to verify the results linear regression analysis has modeled. Thus, it is possible utilization of machine and decrease production cost in an automated manufacturing environment.

Peer-review under responsibility of the scientific committee of the 2nd International Conference on Materials Manufacturing and Design Engineering.

Keywords: AISI 52100 Steel; Hard Turning; Roughness; Modeling; Tribology, Tool nose radius

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2351-9789 © 2018 The Authors. Published by Elsevier B.V.
Peer-review under responsibility of the scientific committee of the 2nd International Conference on Materials Manufacturing and Design Engineering.
10.1016/j.promfg.2018.02.050

1. Introduction

In recent past, hard turning of steel parts that are often hardened above 45 HRC became very popular technique in manufacturing of gears, shafts, bearings, cams, forgings, dies and moulds [1]. Hard machining means machining of parts whose hardness is more than 45 HRC but actual hard machining process involves hardness of 46 HRC to 68 HRC. The work piece materials used in hard machining are hardened alloy steel, tool steels, case–hardened steels, nitride irons, hard–chrome–coated steels and heat–treated powder metallurgical parts. In order to withstand the very high mechanical and thermal loads of the work piece and cutting materials with improved performances, such as ultrafine grain cemented carbides, cermets, ceramics, cubic boron nitrides, polycrystalline cubic boron nitride and polycrystalline diamonds, have been developed and applied [2]. Hard turning is a developing technology that offers many potential benefits compared to grinding, which remains the standard finishing process for critical hardened steel surfaces. Hard turning is a process which eliminates the requirements of grinding operation. A proper hard turning process gives surface finish Ra 0.4 to 0.8 µm, roundness about 2–5 µm and diameter tolerance ± 3–7 µm. Hard turning can be performed by that machine which soft turning is done. The new advancements in machine tools technology and use of new cutting tools provide the opportunity to take loads from hardened steels through processes such as lathing and milling. Recent achievements have made it possible to replace hard turning by modern turning (lathing) machines and new cutting tools for many industrial applications [3]. Hard turning is a good alternative to applications not requiring very high quality finishing, obviously works requiring high tolerances see grinding as their first choice. Hard turning of highly hardened parts is a new approach in machining science aimed at increasing productivity and yield through reducing production time and costs of the process. This method has been introduced as a suitable alternative to grinding of hardened parts [4]. Through this method the finishing process is done at the same time as the main machining process (i.e. roughing). Some decisive factors leading to this manufacturing trend are: substantial reduction of manufacturing costs, decrease of production time, achievement of comparable surface finish and reduction or elimination of environmentally harmful cooling media [5]. Soft steel must be hardened to increase the strength and wear resistance of parts made from this material. Hardened steels are machined by grinding process in general, but grinding operations are time consuming and are limited to the range of geometries to be produced [6]. Machined surface characteristics are important in determining the functional performance such as fatigue strength, corrosion resistance and tribological properties of machined components. The quality of surfaces of machined components is determined by the surface finish and integrity obtained after machining [7]. High surface roughness values, hence poor surface finish, decrease the fatigue life of machined components. It is therefore clear that control of the machined surface is essential. In turning, there are many factors affecting the cutting process behaviour such as tool variables, work piece variables and cutting conditions. Tool variables consist of tool material, cutting edge geometry (clearance angle, cutting edge inclination angle, nose radius, and rake angle), tool vibration, etc., while work piece variables comprise material, mechanical properties (hardness), chemicals and physicals properties, etc. Furthermore, cutting conditions include cutting speed, feed rate and depth of cut [8]. The selection of optimal process parameters is usually a difficult work, however, is a very important issue for the machining process control in order to achieve improved product quality, high productivity and low cost. The optimization techniques of machining parameters through experimental methods and mathematical and statistical models have grown substantially over time to achieve a common goal of improving higher machining process efficiency [9].

In this research this, an attempt has been made to investigate the effect of cutting parameters (cutting speed, feed rate and depth of cut) on the performance characteristics surface roughness in hard turning of AISI 52100 bearing steel hardened at 60 HRC with CBN tool using tool nose radius 0.4 mm, 0.8 mm, and 1.2 mm . L_9 Taguchi standard orthogonal array is adopted as the experimental design. The surface roughness of the turned surface has measured using a portable Mitutoyo surface roughness tester (surftest SJ-210) in terms of arithmetic average roughness (Ra). The combined effects of the cutting parameters and tool nose radius on roughness values are investigated. The relationship defined in between tribological parameters and roughness values through the regression analysis, the different correlations are developed between tribological parameters and roughness value for different tool nose radius. Low surface finish decrease the fatigue life of machined components, therefore high surface finish is essential. Surface roughness is an important machining performance measure, especially in finish hard turning operation. The well-known ideal surface roughness equation, which represents the best possible finish that may be obtained for a given tool shape and feed is given by the following geometric expression [10].