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An Alternate Machining Method for Hardened Automotive Gears

Debabrata Samantaraya[a], Sanjay Lakade[b], Ashok Keche[c]

[a,b]*Pimpri Chinchwad College of Engineering, Sector-26, Pradhikaran, Nigdi, Pune-411044, Maharashtra, India*
[c]*Maharashtra Institute of Technology, Aurangabad-431028, Maharashtra, India.*
[a,b,c]*Corresponding authors' E-mail addresses:* d.samantaraya@yahoo.co.in, sanjay.lakade@pccoepune.org, ashok.keche@mit.asia

Abstract

This paper describes an experimental investigation on hard turning of disc type automotive gears made of 20Mn5Cr5 steel hardened to 60±2 HRC against grinding process. Experiments are conducted by using PCBN tools on a CNC turning centre without using coolant. The effect of machining parameters; cutting speed (v_c), feed rate (f) and depth of cut (a_p) on the surface roughness Ra (µm) is analyzed and optimized with the help of Taguchi design of experiment (DOE), signal to noise (S/N) ratio and analysis of variance (ANOVA) methods. The surface quality, process characteristics, some economical and ecological features of the hard turning are analyzed and compared with the grinding.

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Keywords: PCBN; Hard; Turning; Grinding; Taguchi; ANOVA; Automotive; Gear

1. Introduction

Hard Turning is one of the emerging technologies for machining of hardened steels with hardness values in the range of 48 to 68 HRC using a single point cutting tool. The popularity of hard turning is increasing day-by-day and it is becoming an important manufacturing process, particularly in automotive and bearing manufacturing industries. Traditionally, grinding has been used as a standard finishing process for the machining of hardened steels, but technological advances in the field of machine tools and cutting tool materials have made hard turning possible on modern lathes as an attractive alternative to replace many conventional grinding applications [1-5]. The factors that brought the attention of industries towards hard turning process are; substantial reduction of manufacturing costs, reduction in production time, achievement of comparable or better surface finish and geometrical accuracies and reduction or complete elimination of environmentally harmful cooling media [6-8]. Davim and Figueira [9] reported that it is possible to obtain a surface roughness of Ra < 0.8µm in hard turning with the suitable choice of

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cutting parameters. Yallesea et al. [10] reported that grinding comparable surface finish can be achieved in hard turning of 100Cr6-tempered bearing steel with CBN tool. Kishawy and Elbestawi [11] investigated the surface integrity of AISI D2 steel of 62 HRC with cutting speeds in the range 140–500m/min, feeds 0.05–0.2mm/rev, depths of cut 0.2–0.6mm using the PCBN tools with edge preparations and reported that at the cutting speeds above 350m/min, the surface roughness increased with increase in tool wear due to material side flow. Therefore, an attempt has been made in the present research to find out the optimum combination of cutting parameters that would yield minimum surface roughness using PCBN tool.

The majority of the researchers have carried out their researches on hard turning on the various steel material test pieces (round bars). However, in the present research, authors have chosen an actual part – an automotive disc type gear as the research object, hence the results obtained from this research can be used as a ready reference in the industries engaged in the manufacturing of similar parts.

2. Experimental Details

2.1. Workpiece material chemical composition and dimensional specification

The chemical composition of workpice material 20Mn5Cr5 is given in Table 1, which is hardened to 60±2 HRc. The workpiece photo and drawing with dimensional specifications are shown in Fig. 1.

Table 1: Chemical composition of 20Mn5Cr5 Steel (wt %)

C	Si	Mn	Cr	P	S
0.17-0.22	0.15-0.35	1.0-1.4	1.0-1.3	0.035	0.035

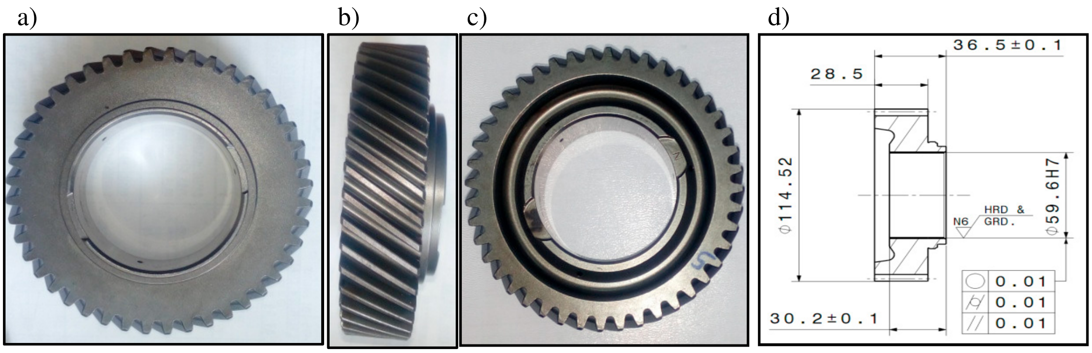

Fig. 1. Workpiece & its dimensional specification: (a) RH side view, (b) Front view, (c) LH side view, (d) part drawing

The experiments were conducted on Jyoti CNC Turning Centre (FM200 Model, spindle power 6.6KW and spindle speed 5500 RPM) with PCBN insert of ISO designation TNMA 160408 BN350 (Sumitomo make) in dry condition. The inserts were mounted on ISO tool holder PTFNL 16 S32S. The combination of the insert and the tool holder resulted an axial rake angle γ = -6° (negative), cutting edge inclination angle (radial rake) λ = -10° (negative) and cutting edge approach angle Kr = 91°. Mitutoyo make surface tester was used for measuring surface roughness-Ra (µm). The surface roughness measurements were repeated three times at three different zones positioned at 120° apart for each turned workpiece and the average of three readings are given in Table 3. Klingelnberg P–40 gear measuring and inspection machine was used for measuring the cylindricity, circularity and straightness of the machined bore hole dia. 59.6H7. Three sets of cutting speeds (v_c), feed rates (f) and depth of cut (a_p) were chosen within the specified intervals recommended by the cutting tool manufacturer and arranged in three levels in Table 2.

Table 2: Machining parameters and their levels for hard turning of bore hole dia.59.6H7

Level	Cutting Speed (m/min.)	Feed rate (mm/rev.)	Depth of cut (mm)
1	110	0.05	0.08
2	130	0.07	0.10
3	150	0.09	0.12