The Study of Factors Influencing to Surface Hardness of Hardened Carbon Steel - SCM 440 Grade in Hard turning

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ABSTRACT

The purpose of this research was to study factors influencing to surface hardness on hardened carbon steel in dry and wet turning conditions. Material used in experiment was steel grade: SCM440, and hardness of material before experiment between 50-55 HRC. Cutting tools was CBN (Cubic Boron Nitride).The experiment was done by using factorial design and factors were consisted of cutting speed at 150,200 and 250 m/min, feed rate at 0.08, 0.12 and 0.16mm/rev, and depth of cut at 0.2, 0.4, 0.6 mm, with cooling (Wet) and non-cooling (Dry) conditions. In wet turning the result revealed that the surface hardness after cutting was significantly increased at the level of .05. The interaction factors affected to surface hardness were cutting speed and depth of cut, which showed significantly at the level .05. In dry turning the result revealed that the surface hardness after cutting was significantly increased at the level of .05. The main factor affected to surface hardness was the feed rate, and interaction factors affected to surface hardness were cutting speed and depth of cut, which showed significantly at the level .05. Moreover, it was found that dry and wet turning conditions were not significantly different on surface hardness after turning at the level .05.

1. INTRODUCTION

Hard turning (HT) process has now become a viable method to machine automotive component made of ferrous alloys with hardness above 45 HRC. (Anupam Agrawal, et al 2015) On account of reduce lead time and production cost, HT eliminates some of the processing steps and procedures involved during classical machining process for hard ferrous alloy materials; indeed, 80% of the cycle time was saved when hard turning a pinion shaft (59-62 HRC).(W.B. Rashid et al 2014)

Most of energy in the cutting process is largely converted into heat. This heat is generated by plastic deformation and friction at the tool-chip and tool-workpiece interfaces. The generation of heat during machining increases the temperature in cutting zone. Increase in the temperature may affect the strength, hardness, wear resistance and life of the cutting tool, cause difficultly in controlling the accuracy due to dimensional changes in the part being machined and on the machined surface integrity and cause thermal damage to the workpiece and affect its properties and service life. The temperature in the cutting zone is affected by the cutting parameters: the cutting speed, the speed rate, and the depth of cut. It also depends on the properties of the workpiece material, as well as on the physical properties of the tool. (Suha K. Dhihab et al. 2014)

Due to the heat generated during machining of some hardened alloy steels, secondary hardening can occur which causes more machining difficulties. (M.A.El Hakim et al. 2015)

In the present study; the influence of the cutting parameter (cutting speed, feed rate, depth of cut, and coolant) to surface hardness of hardened carbon steel (SCM440) on cutting temperature during turning.

2. EXPERIMENT

2.1 Materials and method

The material chosen for study was SCM 440 Steel. The chemical composition as shown in Table 1.The austenitic transformation temperature was 845 ºC and water and oil quenched. For the hardness of the studied martensitic and bainitic microstructures were 50 - 55 HRC. The experiment was conducted with three controllable 3-level factors and 2 conditions are shown in Table 2.

Table 1. Chemical composition of SCM440 alloy steel

C	Si	Mn	Cr	Mo	S
0.38-0.43	0.15-0.35	0.6-0.9	0.9-1.2	0.15-0.3	≤0.035

Table 2. Experiment factors and their levels

Factors	Unit	Level-1	Level-2	Level-3
Cutting speed	m/min	150	200	250
Feed rate	mm/rev	0.08	0.12	0.16
Depth of Cut	mm	0.2	0.4	0.6
Coolant		No	Yes	

Cutting tool for experiment must have the highest hardness as well as best possible features of toughness and thermal conductivity. (J.C.Camargo et al., 2014). CBN tool was chosen for study because these tools are recommended for machining at high speed, which involve elevated temperatures and materials hardness (> 55 HRC). The tools were provided in the form of inserts with geometry NP-TNGA160404GA3 (manufactured by Mitsubishi) grade BC8020 of CBN in combination with a highly wear resistant TiAIN coating Layer, Which increased cutting edge strength and high crater wear resistant, results in longer tool life and improved machining efficiency under heavy duty or interrupting cutting.

Machine tool, the hard turning experiment was performed on CNC turning YAMAZAKI MAZAK Quick turn NEXUS-150II.The technical characteristics are shown in Table 3.

Table 3. The technical characteristics of Machine tool.

Model	Quick TURN NEXUS-150II	Main spindle(30min,rating) : 5000 rpm, 15KW(20HP)
CD	(300,500)	
Chuck size	18”	
Travel(X/Z)	190/315,545mm	

3. Results and discussion

3.1 Comparative surface hardness between pre and post turning in 2 conditions.

In wet condition Fig.1 shown surface hardness between pre and post wet turning. Analysis by T-test mean difference (p-value = 0.00< 0.05) the result revealed that the surface hardness after cutting was significantly increased at the level of .05. And Fig.2 Shown microstructure of edge workpiece (No. 53) after turning that shown heat affects to surface workpiece on the average of depth at 193 µm. and deformation to martensitic microstructure was increased.

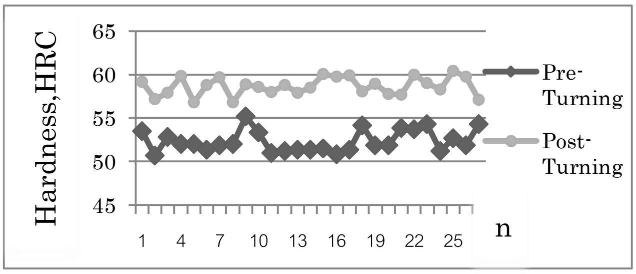

Fig.1 Hardness of surface workpiece, in wet turning

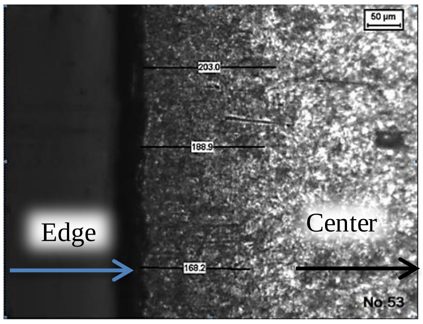

Fig.2 Microstructure of edge workpiece in wet condition.

In dry condition Fig.3 shown surface hardness pre with post dry turning. Analysis with T-test mean difference (p-value = 0.00< 0.05) the result revealed that the surface hardness after cutting was significantly increased at the level of .05. And Fig.4 Shown microstructure of edge workpiece (No.50) after turning that shown heat affects to surface workpiece on the average of depth at 201 µm and deformation to martensitic microstructure was increased.

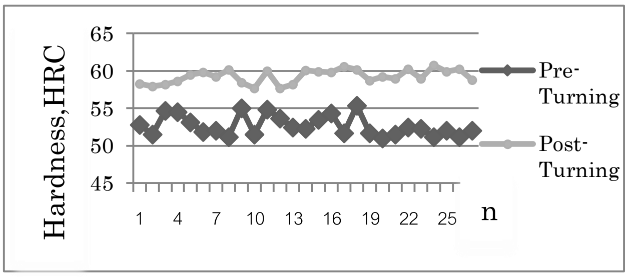

Fig.3 Hardness of surface workpiece, in dry turning

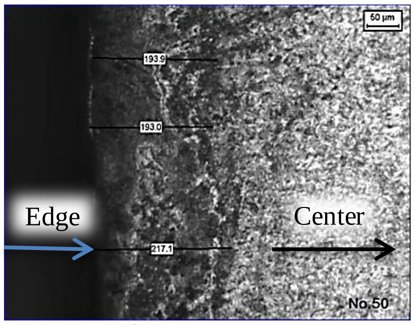

Fig.4 Microstructure of edge workpiece in dry condition.

3.2 Analysis factors influencing to surface hardness in 2 conditions. The result of analysis from difference of surface hardness pre and post turning.

In wet condition, the interaction factors affected to surface hardness were cutting speed and depth of cut, (A*B) P-Value < 0.05 which shown in Table 4.

Table 4. Analysis (ANOVA) the difference of hardness.

Source	DF	Seq.SS	AdjSS	AdjMS	F	P
Depth of cut(A)	2	2.410	2.410	1.205	0.96	0.424
Cutting speed(B)	2	9.715	9.715	4.858	3.86	0.067
Feed (C)	2	7.550	7.550	3.775	3.00	0.107
A*B	4	35.443	35.443	8.861	7.04	**0.010**
A*C	4	1.594	1.594	0.399	0.32	0.859
B*C	4	6.878	6.878	1.720	1.37	0.327
Error	8	10.063	10.063	1.258		
Total	26	73.654				

S= 1.12385 R-Sq = 87.00% R-Sq(adj) = 59.74%

Fig.5 showed interactions of cutting speed and depth of cut, when used at lower cutting speed(150 m/min) and depth of cut (0.2 mm) were affected to surface hardness of SCM440 less increased, when used more cutting speed and depth of cut were affected to surface hardness of SCM440 more increased.

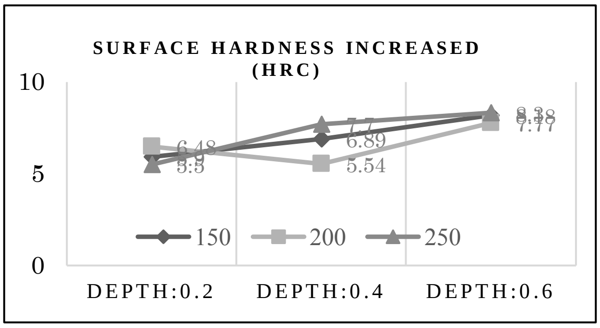

Fig.5 Interactions of cutting speed and depth of cut

In dry condition, the main factor affect to surface hardness was feed rate, P-Value < 0.05. And the interaction factors affected to surface hardness were cutting speed and depth of cut, (A*B) P-Value < 0.05 which shown in Table 5.

Table 5. Analysis (ANOVA) the difference of hardness.

Source	DF	Seq.SS	AdjSS	AdjMS	F	P
Depth of cut(A)	2	11.056	11.056	5.528	4.38	0.062
Cutting speed(B)	2	5.865	5.865	2.932	2.32	0.160
Feed (C)	2	20.736	20.736	10.368	8.21	**0.012**
A*B	4	23.709	23.709	5.927	4.69	**0.030**
A*C	4	4.780	4.780	1.195	0.95	0.485
B*C	4	1.458	1.458	0.364	0.29	0.877
Error	8	10.104	10.104	1.263		
Total	26	77.709				

Fig.6 showed the main effect of feed rate when used at lower feed rate (0.08mm/rev) was effect to surface hardness of SCM440 less increased, but when used at more feed rate was effect to surface hardness of SCM440 more increased. And Fig.7 showed interactions of cutting speed and depth of cut, when used at lower cutting speed(150 m/min) and depth of cut (0.2 mm) were affected to surface hardness of SCM440 less increased, when used at more cutting speed and depth of cut were affected to surface hardness of SCM440 more increased.

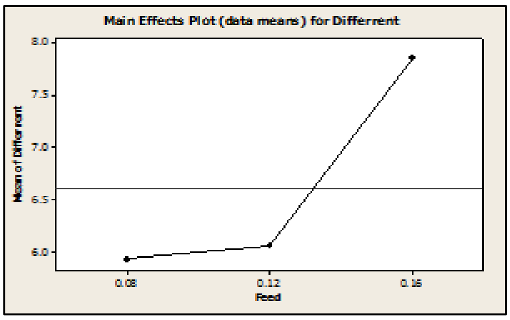

Fig.6 The feed rate effect to surface hardness of SCM440

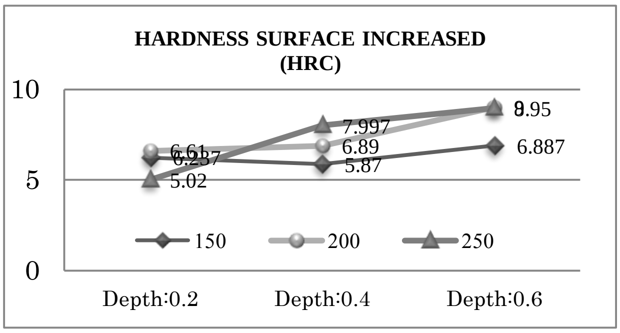

Fig.7 Interactions of cutting speed and depth of cut

Comparative difference of 2 conditions

the difference of 2 conditions wet cutting and dry cutting were analysis by T-test mean difference (p-value = 0.474 > 0.05) the result revealed that the surface hardness after turning in 2 conditions was not difference at the level of .05. Shown in Table 6

Table 6 Paired T for Wet cutting – Dry cutting

95% CI for mean difference (-1.142, 0.545)

	N	Mean	StDev	SEMean
Wet Cutting	27	6.316	1.683	0.323
Dry Cutting	27	6.614	1.728	0.332
Difference	27	-0.298	2.134	0.410

T-Test of mean difference =0(vs not =0): T-Value=-0.73

P-value = 0.474

CONCLUSION

In this study, the cutting tool temperatures and workpiece surface cooling rate of 2 conditions were determined secondary hardening occurred during hard turning of SCM440 steel.

In during hard turning, the cutting edge temperatures can occur both below and above the austenitic phase transformation temperature,A_{c1} (845 ºC).And obtained the surface cooling rate during hard turning at $10^4$and 10^5ºC/s for cutting speed between 30 and 260 m/min (S.B. Hosseini et al, 2014). It was affected to the microstructure of edge workpiece deformation to martensitic microstructure was increased which shown in Fig.2and4, and effected to surface hardness increased. For comparable surface hardness the cooling rate either cooling or non-cooling were result in significantly not difference.

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NOMENCLATURE

A : Depth of cut (mm)
B : Cutting speed (m/min)
C : Feed rate (mm/rev)
Wet cutting : Use Cooling during cutting
Dry turning : Not use Cooling during cutting
HT : Hard turning

Subscripts

rev : Revolve
mech : Mechanical

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