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Effect of cutting conditions on surface roughness and cutting forces in hard turning of AISI 4340 steel

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ABSTRACT

In the present work, the comparison study for surface roughness and main cutting force is studded between Dry, Wet lubricant and solid lubricant condition during the turning the AISI 4340 steel, hardness 60 HRC with CBN insert. Water-based lubricant used as a wet lubricant and boric acid in powder form is used as a solid lubricant. The objective of this study is to know about optimum machining parameters and best conditions with dry or solid lubricants for hard turning operation and it is also important to find the research gap through different studies. The results indicated that there is a significant effect on surface roughness (Ra) and main cutting force (Fc) when cutting under different conditions (Dry, Wet and Solid condition) with different cutting parameters. It has been found that with solid lubricants surface roughness value decreased as compared to dry hard turning. The proper selection of lubricants in the solid state along with cutting conditions and tool angles is essential for achieving the overall improvement in the hard turning process. With the use of lubricants in the solid form, hard turning may become a viable alternative to dry and wet hard turning process.

Keywords— *Hard turning, Cutting conditions, Surface roughness, Response surface methodology*

1. INTRODUCTION

Hard turning is a process in which hard material which has a hardness above 45 HRC is machined with the help of single point geometrical tools [1]. To reduce the cost, improve quality and minimize setup times in order to remain competitive is a challenge to the manufacturer of those components and manufacturer of goods. Grinding is a process which is used in industries but it involves expensive machinery and lengthy setup times, high manufacturing time, costly equipment's. In hard turning material removal rate is high that is why it is a fast process as compare to grinding hard turning process. The other advantages of precision hard turning over grinding include fewer production costs, high flexibility and enriched workpiece quality [2].

Hard turning is generally a replacement of grinding which is mostly used in automotive industries. As compared to the grinding process turning process for hard steel is preferred. The main factor takes towards the use of hard turning in place of grinding has been the development of various cubic boron nitride (CBN) cutting tool insert, PCBN, Ceramic insert, coated carbide, etc. which is capable of machining the high strength materials with a properly defined cutting edge. Ceramic tools are less hard then CBN tools in both low and high temperatures. High thermal conductivity and low thermal expansion coefficient are also important properties of CBN which are used in hardened steel turning. High CBN (around 90%), and lower CBN content (around 60%) are two different grades of CBN tools with a ceramic phase added to the material, usually titanium nitride. High CBN content tools are generally recommended for the turning operation of hardened steels with interrupted surfaces because these tools exhibit higher toughness than tools with an added ceramic phase (low CBN content tool). Therefore, the high CBN content of these tools makes them harder than those with a lower amount of CBN. The CBN grade in which part of the CBN content is replaced by a ceramic phase loses in hardness and toughness, but gains in chemical stability. This is important for the finish operations of continuous surfaces, where a high temperature is reached, and diffusive wear must be avoided (Sandvik, 1994). Usually, these tools have a chamfer on the cutting edge to strengthen it and protect it against chipping and breakage [22].

2. LITERATURE

Singh and Rao [1] discussed surface finish, and it was found that it varies when the cutting parameters vary. Statistical analysis of the experiment processed using ANOVA (analysis of variance). Surface roughness increases with the increase of feed rate and depth of cut and decreases with the increase of cutting speed. Diniz and Macaroni [2] used AISI 1045 steel bars with an average hardness 96 HRB along with the vegetable oil as cutting fluid with 6% water concentration. Cutting fluid used at different flow rates, (91 and 111 min^{-1}) and pressure 0.04 Mpa. Due to the lubricant application on the tool, the tool life improves as compared to dry cutting and also reduce the temperature formed during turning. In this [3] they used graphite and molybdenum disulphide in powder form having 2 µm average particle sizes as solid lubricants. The solid lubricant was supplied from 0.5 gm/min to 15 gm/min through the designed apparatus. It was found that the molybdenum di-sulphide shows the better result as compared to graphite. Surface roughness value decreased 8% to 10% when graphite is used and 13% to 15% decreased due to molybdenum disulphide. Cutting forces were reduced when lubricants were applied from 1gm/min. to 2gm/min flow rate.

Krishna et al. [4] studied the tool wear and surface roughness when solid lubricants were applied and compare with dry and wet machining. Graphite and boric. Kang He and Xu (2014) developed modelling technique for predicting surface roughness with the use of new HMM-SVM (hidden Markov model and least squares support vector machine) model based on Bayesian in hard turning. AISI 4340 steel and AISI D2 steel are used as the workpiece materials with an average surface hardness value of 50, 55 and 60 HRC respectively. According to the GB/T1031-2009 standard, the range Ra 0.2 to Ra 0.4 is denoted as accuracy grade [Ra 0.4], Ra 0.4 to Ra 0.8 as accuracy grade [Ra 0.8], and Ra 0.8 to Ra 1.6 as accuracy grade [Ra 1.6]. It is found that HMM-SVM estimates the surface roughness with the highest accuracy as compared with MR and LSSVM. According to MR 6 was misjudgment found and according to HMM-SVM with probability comparison, 4 misjudgments were found. HMM-SVM model reduces the risk of accuracy grade misjudgment of surface roughness and improves prediction accuracy. The mean absolute error for HMM-SVM, LSSVM and MR are 0.0504, 0.0969 and 0.1635 respectively.

Beatricea et al. (2014) discussed the surface roughness in terms of cutting parameters with the use of cutting fluid through the ANN model (artificial neural network) in hard turning. cutting fluid parameters used, the pressure at injector is 100 bar, rate of cutting fluid application 8ml/min. , composition of cutting fluid - 20% oil in water and frequency - 500 pulses/min. in the present investigation, the surface roughness (RA) was considered as a performance parameter. When the feed rate was 0.05 and the cutting velocity was 115, the experimental result was 1.45 µm and according to ANN prediction 1.35 µm, the % error was 6.89. In model analysis, the coefficient of determination is used as a measure to consider how better the prediction. In this study, the coefficient of determination was found is 0.95962 for 3-7-7-1 configuration and standard error of 0.0950. According to the ANN model, the accuracy is possible with a smaller number of turning data.

Shihab et al. (2014) AISI 52100 hardened alloy steel was used as a work material to investigate the effect of cutting parameters (cutting speed, feed and depth of cut) on the cutting temperature in hard turning with the use of RSM (response surface methodology) and multilayer-coated carbide insert. RSM (response surface methodology) is used for data collection and analysis. Tool chip thermocouple is used to measure the cutting temperature. Results show that, the optimized value of cutting temperature from 566.593 ºC - 592.028 ºC at particular parameters. Cutting speed and feed rate are the major parameters for increasing the cutting temperature.

A. Pal et al. (2014) studied the effects of cutting parameters on cutting forces, chip-tool interface temperature and surface roughness during the hard turning and soft turning. During this study effects of cutting parameters on cutting forces (axial force Fx, a radial force Fy and a tangential force Fz) are observed when the depth of cut is 0.3 mm and feed value is 0.113 mm/rev. at three different levels of hardness. The cutting forces decrease with the increase of cutting speed and increases with the increase of depth of cut and feed rate. Radial force magnitude is 15-20% higher than tangential force and 102-112% higher than axial force during experiments. Surface roughness increases with the increase of feed and depth of cut and decreases with the increase of cutting speed.

Bordin et al. (2014) investigated the effects of process parameters on surface integrity with longitudinal turning (hard turning) under dry conditions. The CoCrMo alloy with PVD coated TiAIN carbide tool was used for the study. The effects of cutting speed and feed rate on surface integrity were evaluated in terms of surface topography, surface roughness, residual stresses, microhardness measurements. The feed rate plays a major role in surface roughness. For smoother surface, low feed rate is required. When cutting speed is 60 m/min. then the uniform surface profiles resulted. XRD analysis showed that high compressive stress resulted on the surface for all the cutting conditions and a small reduction of stress level observed at depth of 50µm. Surface hardening increases with the increase of cutting parameters.

P. Paul et al. (2014) studied the tool wear with the use of magnetorheological fluid with the minimal fluid application. AISI 4340 steel was used as work material with is used in automobile, aircraft engine, gear shafts etc. Magnetorheological (MR) fluids belongs to a class of controllable fluids which consist of fluid impregnated with ferromagnetic particles. The viscosity of fluid increases as the strength of magnetic field increases. It was found that the tool wear is reduced due to magnetorheological fluid with 75 µm size Ferro particles. Cutting forces also reduced up to 22.3% and 44.4 % improvement in surface finish.

S.B. Hosseini et al. (2015) discussed the white layers concept during hard turning through formation mechanisms and studied the mechanically induced white layers (M-WL) and thermally induced white layers (T-WL). Chromium-containing high carbon steel of grade AISI 52100 (DIN100Cr6) work material used. Water-based containing 5% oil, applied to rake face with the pressure of 5 bars. In this study, the formation mechanism of white layers induced at 30m/min compared with WLs generated at 110m/min and 260m/min. The difference is observed due to the absence of FCC- austenite reflections. White layers formed at 30m/min with BCC- ferrite and orthorhombic. The average grain size of WLs is 10 nm and submicron grain up to 200nm it was noticed that the grain size increases with the increase of cutting speed from 30m/min.to 260m/min.

Ventura et al. (2015) 16MnCrS5 steel having hardness 60 ± 2 HRC and length 200mm turned without cutting fluid. In this study, the influence of cutting edge geometry of high content CBN insert in interrupted hard turning was investigated. Tool performance with different edge geometries was discussed. The contact length between cutting edge and workpiece chip was minimum when the sharp cutting edge is considered due to this, bluntness increases with the increase of contact length and an increase of forces were observed. The lower increase for first three geometrics (sharp, chamfer and K = 2.0), and higher increased values can be seen for the last two (K = 1.0 and K = 0.5) due to the vibrations related to the higher force components.

Revel et al. (2016), used AISI 52100 bearing steel rings thermally treated to an average hardness of 61±1 HRC to study the surface roughness and residual stresses. The full factorial experimental design was performed to analyze the effect of cutting parameters. Surface roughness strongly affected by feed rate and it was found that when feed rate decreases surface roughness decreases and with the increase in cutting speed the surface finish increases.

3. EXPERIMENTAL

This chapter includes the material and methodology employed for the hard turning process of selected material. The experimental procedures and experimental data generated during the turning of AISI 4340 steel with cutting conditions (dry, wet lubricant, and solid lubricant condition) discussed in details in this chapter. The selection of input parameters with their working range, cutting conditions, and details of instruments used in the experimental process presented in this part of the thesis. Machining variables such as cutting force and surface roughness are influenced to a large extent by cutting parameters such as cutting speed, feed and depth of cut as well as fixed geometric parameters such as approaching angle, rake angle and nose radius with different cutting conditions (dry condition, wet condition and solid lubricant condition). In order to minimize the machining time and hence the cost of machining in an industrial Environment, there is a need for optimization of cutting parameters and cutting conditions.

In this study, the AISI 4340 Steel with hardness 60 HRC is used for experimental work. There were three cutting parameters cutting speed, feed and depth of cut used with three cutting conditions dry condition, wet lubricant condition and solid lubricant condition. Design of experiments is based upon central composite designed by RSM methodology. In total twenty numbers of experiments have been conducted with one centre experiment for each of the selected condition. Analysis of the machining variables under different cutting conditions has been carried out for material. Further, a comparison of the various selected condition has been carried out with regard to machining variables by varying one or more than one cutting parameter at a time. Final results were analyzed by using analysis of variance (ANOVA).

4. HEAT TREATMENT PROCESS

The material is heated up to 830º C Temperature and quenched in an oil tank. After quenching process tempering process done to maintain the hardness 60 HRC. Tempering is done to avoid the cracks or stresses in material formed during the heating process

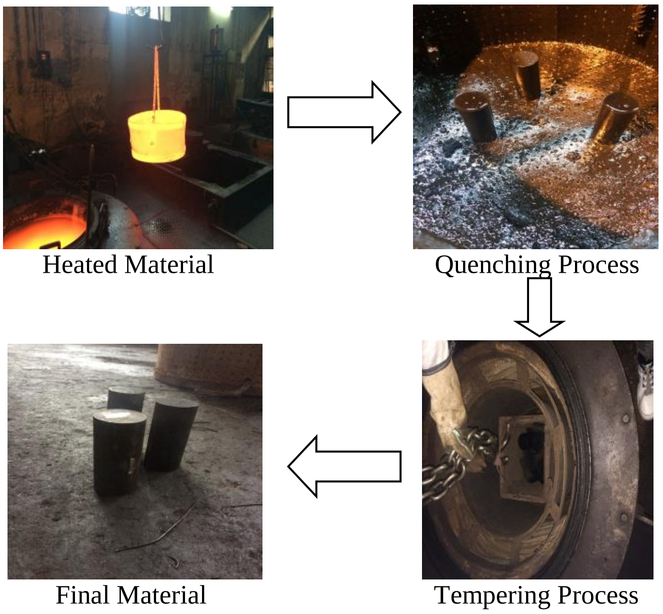

Fig. 1: Hardening process

4.1 Cutting tool: Cutting insert used for this experimental work was CBN insert with specification CCMT0908. It is selected according to the machine specification and tool holder. To machine work material of 60 HRC; CBN insert is recommended because of its high hardness properties, wear resistance and thermal stability. Tool specification is given in table 1.

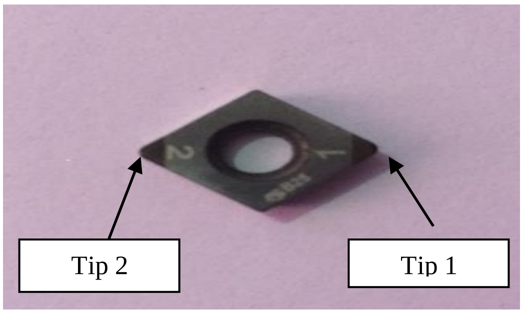

Fig. 2: Cutting insert

Table 1: Cutting tool details

Insert type	CBN (cubic born nitride)
Insert Shape	Rhombic
Insert specification	CCMT09
Nose radius	0.8 mm

5. SURFACE ROUGHNESS ANALYSIS

The experiments were carried out according to the cutting conditions and cutting parameters. To specify the experiments Face-Centered Central Composite Design (FC-CCD) was used in Design Expert software (Version 8.0.).Analysis of variance (ANOVA) was employed to find out the most significant input parameters, and their interactions, in terms of their significant effect on different cutting parameters and cutting condition. To check the cutting parameter and cutting conditions performance, sequential F-test, lack of fit test and other adequacy measures were used. The effects of selected cutting parameters such as cutting speed, feed and depth of cut with the dry cutting condition, wet lubricant cutting condition and solid lubricant cutting condition have been discussed. Table 2 presents the experimental design matrix and collected data for surface roughness (Ra) with different conditions.

5.1 Comparison Plot for Surface Roughness with all Cutting Conditions

Table 2: Experimental design matrix and results of surface roughness

S no.	Cutting Speed	Feed	D.O.C	Ra, Dry Condition	Ra, Wet Lubricant	Ra, Solid Lubricant
1	100.00	0.12	0.10	0.45	0.51	0.41
2	150.00	0.04	0.10	0.18	0.19	0.19
3*	125.00	0.08	0.20	0.39	0.47	0.33
4*	125.00	0.08	0.20	0.39	0.46	0.33
5	150.00	0.12	0.30	0.71	0.78	0.66
6*	125.00	0.08	0.20	0.39	0.47	0.33
7	125.00	0.04	0.20	0.32	0.38	0.28
8	100.00	0.04	0.10	0.22	0.25	0.21
9	100.00	0.04	0.30	0.57	0.66	0.5
10	100.00	0.12	0.30	0.88	1.1	0.68
11	150.00	0.12	0.10	0.35	0.44	0.28
12	125.00	0.08	0.30	0.58	0.66	0.52
13	125.00	0.12	0.20	0.62	0.71	0.55
14*	125.00	0.08	0.20	0.39	0.47	0.33
15*	125.00	0.08	0.20	0.39	0.47	0.33
16	150.00	0.08	0.20	0.37	0.44	0.32
17	125.00	0.08	0.10	0.25	0.3	0.22

18	150.00	0.04	0.30	0.49	0.56	0.44
19*	125.00	0.08	0.20	0.39	0.47	0.33
20	100.00	0.08	0.20	0.44	0.52	0.38

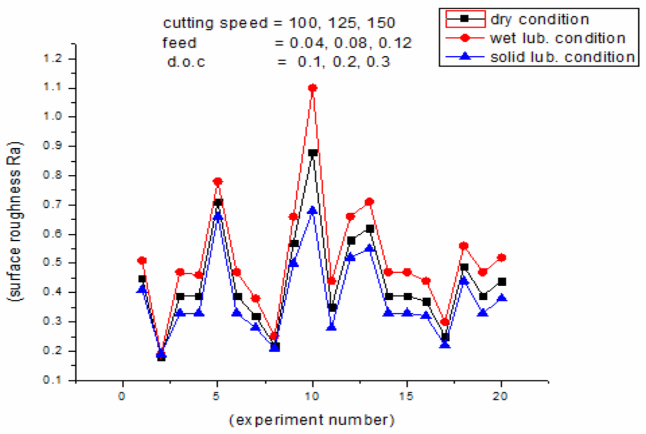

Fig. 3: Comparison plot of Surface roughness (Ra) with all Cutting condition

The results of the solid lubricant in hard turning of AISI 4340 steel with CBN insert are better as compared to the other two conditions (wet lubricant condition and dry condition). The values of surface roughness (Ra) decreases in solid lubricant condition as compared to wet lubricant condition and dry condition because with the use of solid lubricant, the frictional force between workpiece and insert reduced as compared to dry condition and wet lubricant condition. Due to this, material removes smoothly in solid lubricant condition. In dry turning the friction between work material and insert is high as compared to solid lubricant condition and in wet lubricant condition, surface roughness is increasing due to the increase of hardness during turning.

6. CONCLUSION

In this study, machining variables such as cutting forces and surface roughness were measured during turning of AISI 4340 Steel with CBN (Cubic Boron Nitride) insert under different cutting conditions. The maximum value of surface roughness in dry condition is 0.88 µm when the cutting speed is 100 mm/s, feed 0.12 mm/rev. and the depth of cut is 0.3 mm. The maximum value of surface roughness in wet lubricant condition is 1.1 µm, at a same cutting speed, feed and depth of cut which are used in the dry condition. The maximum value of surface roughness in solid lubricant condition is 0.68 µm, at same cutting parameters which are used in both dry condition and wet lubricant condition. According to these values solid lubricant conditions are best suited for turning of AISI 4340 steel as compared to wet and dry conditions in all the process parameters.

7. REFERENCES

[1] Srithara, K. Palani Kumar, B. Durgaprasad, “Experimental Investigation and Surface roughness Analysis on Hard turning of AISI D2 Steel using Coated Carbide Insert”, Procedia Engineering 97 (2014) 72 – 77.

[2] W. Grzesik, Krzysztof Zak, Piotr Kiszka, “Comparison of surface textures generated in hard turning and grinding operations”, Procedia CIRP 13 (2014) 84 – 89.

[3] Varaprasad, S Rao., P.V. Vinay, “Effect of Machining Parameters on Tool Wear in Hard Turning of AISI D3 Steel”, Procedia Engineering 97 (2014) 338 – 345.

[4] Tao Chen, Suyan Li, Bangxin Han, Guangjun Liu, “Study on cutting force and surface micro-topography of hard turning of GCr15 steel”, International Journal of Advance Manufacturing Technology (2014) 72:1639–1645.

[5] H-J Hu, W-J Huang, “Studies on wears of the ultrafine-grained ceramic tool and common ceramic tool during hard turning using Archard wear model”, International Journal of Advance Manufacturing Technology (2013) 69:31–39.

[6] Roland Meyer, Jens Köhler, Berend Denkena, “Influence of the tool corner radius on the tool wear and process forces during hard turning”, International Journal of Advance Manufacturing Technology (2012) 58:933–940.

[7] Jinming M. Zhou, Stefan Hognas, Jan-Eric Stahl, “Improving waviness of bore in precision hard turning by pressurized coolant”, International Journal of Advance Manufacturing Technology (2010) 49:469–474.

[8] Singh Dilbag, P. V. Rao, “Performance improvement of hard turning with solid lubricants”, International Journal of Advance Manufacturing Technology (2008) 38:529–535.

[9] G. Mamalis, J. Kundrák, A. Markopoulos, D. E. Manolakos, “On the finite element modelling of high speed hard Turning”, International Journal of Advance Manufacturing Technology (2008) 38:441–446.

[10] Singh Dilbag, P. V. Rao, “A surface roughness prediction model for hard turning process”, International Journal of Advance Manufacturing Technology (2007) 32: 1115–1124.

[11] Yong Huang, Steven Y. Liang, “Modelling of CBN tool crater wear in finish hard turning”, International Journal of Advance Manufacturing Technology (2004) 24: 632–639.

[12] Kang He, Qingsong Xu and Mining Jia, “Modeling and Predicting Surface Roughness in Hard Turning Using a Bayesian Inference-Based HMM-SVM Model”, 1545-5955 © 2014 IEE

[13] Anuja Beatricea, E. Kirubakaranb, P. Ranjit Jeba Thangaiahc, K. Leo Dev Winsd, “Surface Roughness Prediction using Artificial Neural Network in Hard Turning of AISI H13 Steel with Minimal Cutting Fluid Application”, Procedia Engineering 97 (2014) 205 – 211.

[14] Suha K. Shihab, Zahid A. Khan, A. Mohammad, A. Noor Siddiqueed, ”RSM Based Study of Cutting Temperature during Hard Turning with Multilayer Coated Carbide Insert”, Procedia Materials Science 6 (2014) 1233 – 1242.

[15] A Pal, S.K. Choudhury, S Chinchanikar, “Machinability Assessment through Experimental Investigation during Hard and Soft Turning of Hardened Steel”, Procedia Materials Science 6 (2014) 80 – 91.

[16] Philippe Revel, Nabil Jouini, Guillaume Thoquenne, Fabien Lefebvre, “High precision hard turning of AISI 52100 bearing steel”, Precision Engineering (2015).

[17] Bordin, S. Bruschi, A. Ghiotti,” The effect of cutting speed and feed rate on the surface integrity in the dry turning of CoCrMo alloy”, Procedia CIRP 13 (2014) 219 – 224.

[18] S.B. Hosseini, U. Klement, Y. Yao and K. Ryttberg, “Formation mechanisms of white layers induced by hard turning of AISI 52100 steel”, Acta Materialia 89 (2015) 258–267.

[19] C.E.H. Ventura, J. Köhler, B. Denkena, “Influence of cutting edge geometry on tool wear performance in interrupted hard turning”, Journal of Manufacturing Processes 19 (2015) 129–134.

[20] P. Vamsi Krishna, D. Nageswara Rao, “Performance evaluation of solid lubricants in terms of machining

[21] Parameters in turning”, an international journal of machine tools and manufacture 48 (2008) 1131-1137.

[22] P. Sam Paul, A.S. Varadarajan, S. Mohanasundaram, ”Effect of magnetorheological fluid on tool wear during hard turning with the minimal fluid application”, archives of civil and Mechanical engineering (2014).

[23] Anselmo Eduardo Diniz, Ricardo Micaroni , "Influence of the direction and flow rate of the cutting fluid on tool life in turning process of AISI 1045 steel" international journal of machine tools and manufacture 47 (2007)247-254.

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