THOMSON REUTERS ENDNOTE

[Thorbole, 5(1): January, 2016] **ISSN: 2277-9655**
(I2OR), Publication Impact Factor: 3.785

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

COMPARATIVE EVALUATIONS OF SURFACE ROUGHNESS AND CUTTING FORCES DURING HARD TURNING UNDER DRY AND COMPRESSED AIR COOLING MEDIUM

Suryakant Thorbole, R.N. Patil, Satish Chinchanikar

[1] M.Tech. Scholar Mechanical Engineering Department, Bharati Vidyapeeth Collage of Engineering, Pune, India

[2] Production Engineering Department, Bharati Vidyapeeth Collage of Engineering, Pune, India

[3] Mechanical Engineering Department, Vishwakarma Institute of Information Technology, Pune, India

ABSTRACT

In this present work, an experimental investigation through mathematical modelling was carried out to study the effects of different cooling mediums and cutting parameters on surface roughness and cutting forces, during the hardturning of hardened AISI 52100 steel (60±2) HRC. Experiments were performed using PCBN insert under dry and compressed air cooling medium. Experimental observations indicates that hard turning under compressed air cooled condition produced lower values of surface roughness and cutting forces. However, there is no significant effect of cutting speed on the surface roughness. Compressed air lubrication have proved to be more productive with better surface finish and reduced cutting forces. It has been observed that surface roughness gets affected mostly by feed and not by depth of cut. Cutting forces changing randomly as per change in cutting speed.

KEYWORDS: RSM, PCBN, Hard Turning, Cutting forces, Surface roughness

INTRODUCTION

In recent years, with continuous development in cutting tool materials and cutting tool technology, it has become possible to machine harder materials having hardness up to 65HRC. Now a day's machining of hard turning is an interesting subject in industry and research. Hardened steels are mostly utilized in automobile, die gear, bearing industries. Therefore advanced technologies required for machining of hardened steel with higher material removal rate (MRR). Hard turning is conducted on materials with hardness with the range of 45-65 using different types of cutting tools such as coated carbide inserts, CBN, coated CBN insert and PCBN[1].

Even though grinding is producing good surface finish research on hard turning indicates that, it minimises the machining time up to 65 times for conventional turning. From literature survey it is high speed, low feed and low depth of cut finishing process. In present study cutting speed, feed and depth of cut as indicated in the following table 1. PCBN inserts are more suitable for this type of operation, because of high hardness, wear resistance and chemical stability [1]

Table 1: machining process parameters used in experimentation

Parameters	**Levels**				
	-1.66	-1	0	+1	+1.66
Cutting speed (m/min)	100	125	150	175	200
Feed rate (mm/rev)	0.1	0.15	0.2	0.25	0.3
Depth of cut (mm)	0.1	0.2	0.3	0.4	0.5

Numerous mathematical models have been proposed by different researchers to analyze the influence of cutting conditions on surface roughness and cutting forces and to optimize machining parameters for turning of hardened steel. Effect of machining parameters on the cutting forces and surface roughness produced is studied by Gaurav Bartarya and S.K. Choudhary, [2]. They used CBN insert (make: seco, type TNGA160408 S01525) of chamfered edge geometry on EN31 bearing steel (60±2 HRC), also called as AISI52100 bearing steel. They found depth of cut is the most influential parameter affecting the three cutting forces followed by the feed rate.

Cutting forces are low at higher cutting speed when operated with higher feed rate and depth of cut. Cutting forces get affected mostly by depth of cut followed by feed. Surface roughness gets affected significantly at higher feed and depth of cut. These are the observations by Satish Chinchanikar, S.K.Choudhary, [1]. Satish Chinchanikar, A.V. Salve et al. [7] did the comparative evolutions of surface roughness during hard turning under dry and water based and vegetable oil based cutting fluid. They used PVD coated nanolaminated TiSiN-TiAlN carbide tool for hard turning of AISI 52100 steel (60-62 HRC). An experimental observation indicates that hard turning with cutting fluid not significantly improved the surface roughness in comparison with dry turning.

EXPERIMENTAL DETAILS

2.1 cutting inserts and experimental procedure

Turning test was performed on hardened AISI 52100 steel (60-62 HRC) which were carried out on a CNC lathe (model: simple turn-5075, Ace Micromatic, India and controller: Siemens-802C). Workpiece hardness was aintaine maintained uniform throughout the cross section with a maximum variation of ±2 HRC by a precisely controlled hardening and tempering process. The workpiece used has a diameter and length of 60mm and 600mm respectively. Experiments were performed using PCBN insert of seco tools company. All the insert have identical geometry designated by ISO as CNMG 20708(80º diamond shape with 0.8 mm nose radius) with plane wiper geometry. A right hand style tool holder designated by ISO as PCLNR 2525M12 was used for mounting the insert during experiments the work piece was held in a three jaw chuck and supported by a centre in a tailstock. Tool height its overhang and tool geometry were kept constant. Tool height and its overhang were set to the required level with the help of gauges. Before carrying out actual experiment some rough turning is carried out on the work piece in order to remove the oxidized layer and surface irregularities on the work piece surface. To measure the surface roughness of the machined work piece the surtronics DU surface roughness tester is used Taylor and Hobson make). The least count of this instrument is 0.1µm. it gives direct digital value of the Ra. Instrument was calibrated by using standard specimen provided by the manufacturer. For surface roughness measurement the instrument was held on the machined surface. The stylus of the traversing unit measures the value by traversing through a fixed sample length. Surface roughness was measured at four different points on the machined surface, and the average surface roughness value was noted.

2.2 cooling mediums

In this study, experiments were turning carried out under dry condition and with compressed air cutting fluid. Readily available compressed air (4 bar pressure) was used without any treatment. A continuous supply of compressed air from compressor was given through pipe in place of conventional oil based coolant.

2.3 cutting conditions

Experiments were planned using central composite rotatable design (CCRD) matrix varying the cutting speed, feed and depth of cut. ranges of parameters were decided on the basis of the tool manufacture's recommendation, literature review and machine capability. In this study twenty experiments were conducted for each cooling medium to develop a cutting force and surface roughness model. Coded levels and corresponding actual values of cutting parameters are given in following Table no 1.

MATHEMATICAL MODELS

3.1 Regression equations

Hard turning experiments were conducted by varying input parameters i.e. cutting speed, feed and depth of cut. Experiments were conducted in two different cooling environments, described as follows.1) Hard turning in dry cutting condition i.e. without coolant 2) Hard turning by using compressed air as a coolant. In each experiment forces were measured with the help of dynamometer and surface roughness was measured with the help of surface roughness measuring instrument. Values of the forces were directly noted from the dynamometer display. But for surface roughness was measured at three different points, on machined surface of the work piece and then average value was noted. RSM technique was used to analyse experimental results. Regression equations were developed for machining forces and surface roughness were developed based on experimental data. Stat- ease Design Expert® software was used to calculate the values of coefficients of equations. Equations developed for various forces and surface roughness for both cooling systems (Dry & compressed air) are given as follows [12].

Cutting force: Dry condition,

Cf=-27.23-0.5298*V+552.68*f+668.74*d (1)

Feed force: Dry condition,

Ff=447.95-3.56*V-545.66*f-635.429*d+11.66*V*f+3.87*V*d-2969.25*f*d+0.0000653*V^2-964.682*f^2+1518.33*d^2 (2)

Radial force: Dry condition,

Rf=276.74-6.03*V+2424.31*f+350.57*d-2.36*V*f-2.1*V*d-73*f*d+0.023*V^2-4149.73*f^2+679.31*d^2 (3)

Cutting force: compressed air condition,

Cf=-95.27-0.073*V+649.91*f+496.63*d (4)

Feed force: compressed air condition

Ff=223.3-2.12*V-659.67*f+77.62*d+0.31*f*d-1.55*V*d+582*f*d+0.007855*V^2+1482.86*f^2+457.59*d^2 (5)

Radial force: compressed air condition,

Rf=32.86-0.1471*V+465.97*f+343.35*d (6)

Now equations for surface roughness are given as below:

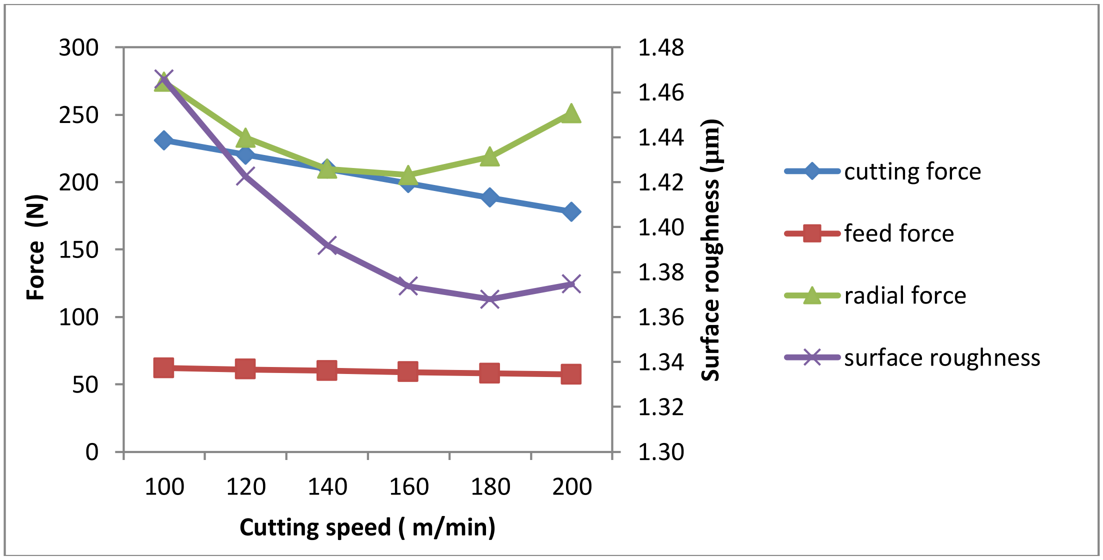
Surface roughness: Dry condition,

Ra=0.1519+0.001509*V+3.9363*f-1.2863*d-0.022*V*f-0.009*V*d+5*f*d+0.0000156*V^2+18.409*f^2+3.1022*d^2 (7)

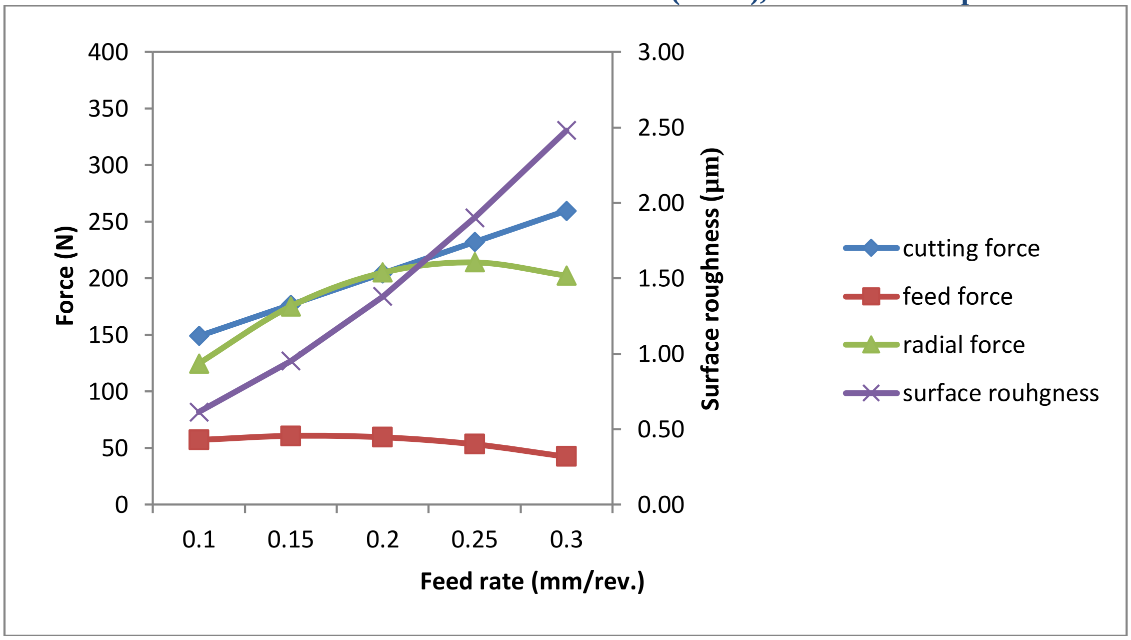
Surface roughness: compressed air condition,Ra=0.1404-0.00228*V+3.26*d-0.2284*d-0.044*V*f-0.017*V*d+11*f*d+0.0000551*V^2+27.27*f^2+1.44*d^2 (8)

RESULTS AND DISCUSSION

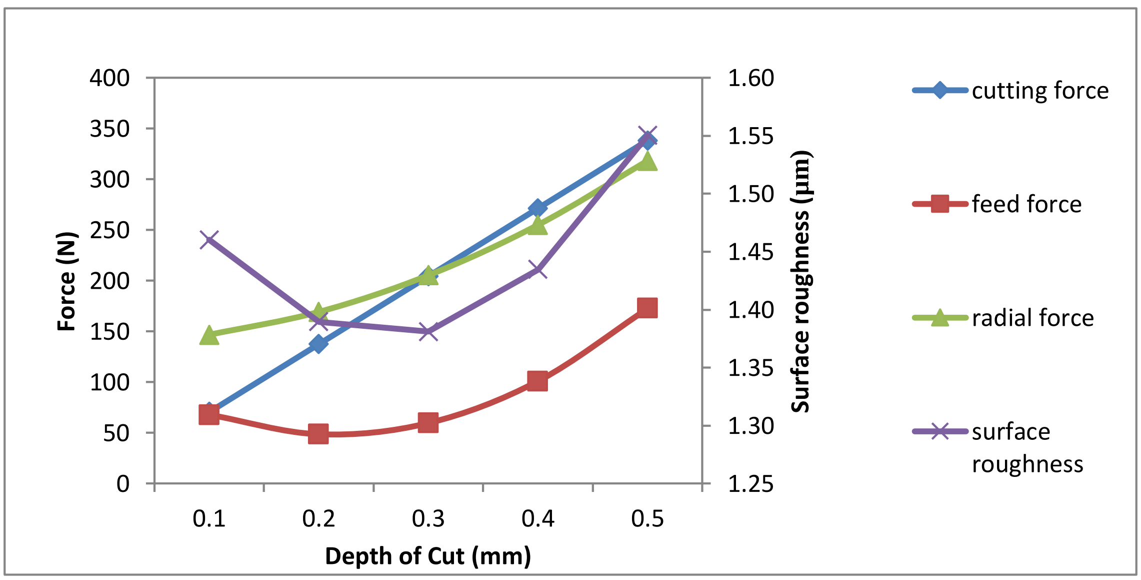
In this section, effect of different cooling mediums and cutting parameters on machining forces i.e. cutting force, feed force and radial force along with surface roughness, during hard turning of AISI 52100 steel with PCBN insert is discussed based on developed regression equations. Graphs showing the various responses are plotted by varying one of the input parameter and keeping another two parameters constant.



(a)



(b)



(c)

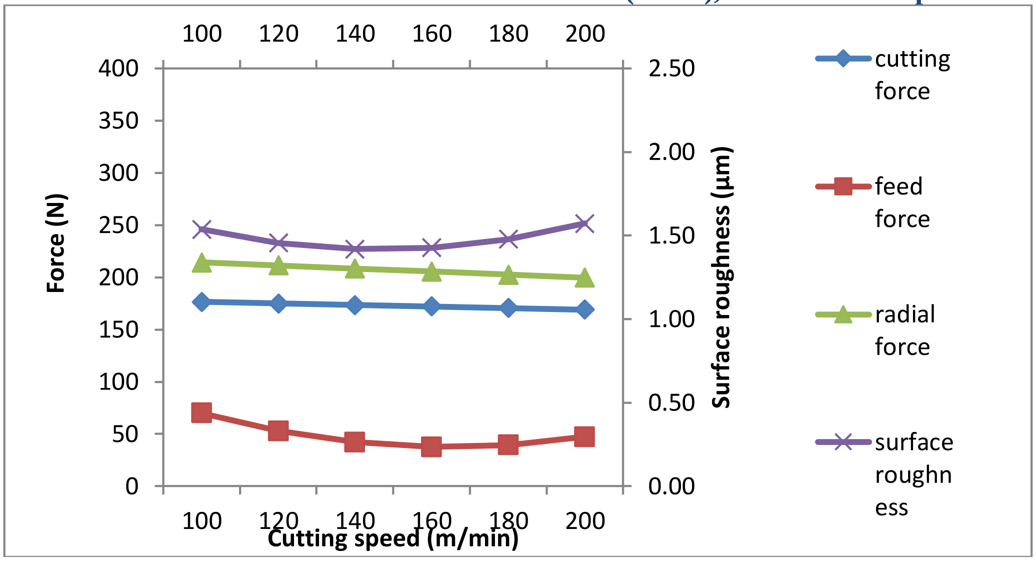
Fig 1: ***Effect of cutting parameters on cutting forces varying with (a)cutting speed, (b) feed and (c) depth of cut, in dry hard turning codition.***

Effect of cutting speed on various forces like cutting force, feed force and radial force along with surface roughness is illustrated in above figures 1(a), (b) and (c). Fig.1 (a) is plotted by using the centralized values of feed rate (0.2mm/rev) and depth of cut (0.3mm) and varying the cutting speed in the given domain, while hard turning the AISI 52100 steel in dry condition. Here it can be seen that cutting force increased with increase in the cutting speed, feed force remains constant, radial force initially decreased but increased afterwards and surface roughness decreased as increase in cutting speed. This is because of the fact that, shear plane energy and frictional energy increases with cutting speed, so the temperature at shear plane increases and material becomes softer and hence the required cutting force decreased. As the work piece material became soft, the feed force remains constant through out the turning process. After 150m/min the tool wear rate increased and tool geometry gets damaged, resulted in the increase of radial forces. Cutting speed in the range of 150m/min to 200m/min increases the interface tool- chip temperature, which softens work piece material to be cut. Due to this the shearing forces in shear zone remains controlled. Consequently it results in decrease in surface roughness [13].

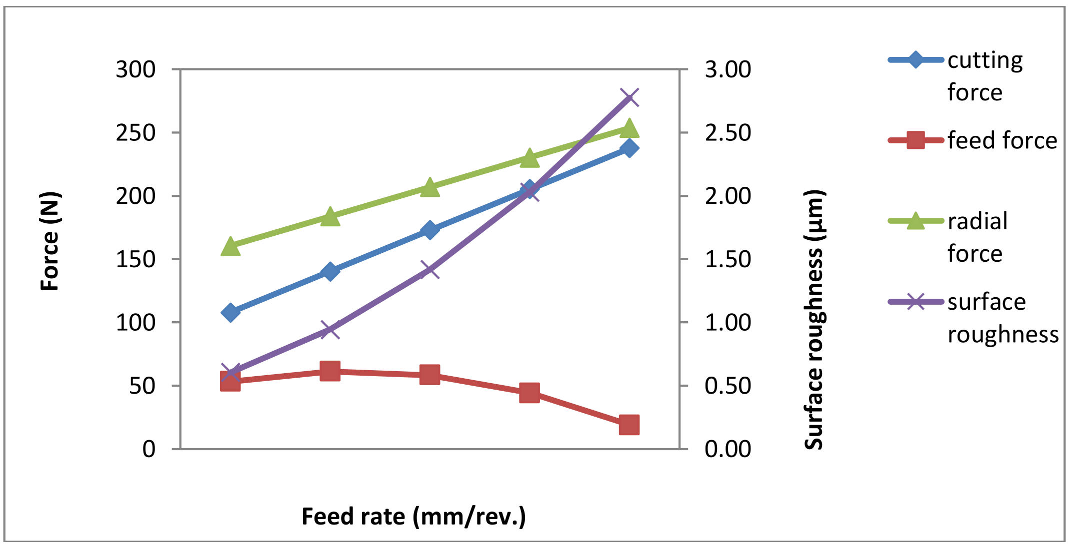
It can be seen that, the above figure. 1(b) is plotted by using cutting speed of 150m/min and depth of cut of 0.3mm, simultaneously varying the feed rate in the given domain. Here in this fig, it can be observed that, cutting force increased gradually with feed, Feed force remained constant; on the other hand radial force initially increased and gets decreased after 0.2mm/rev. The surface roughness found to be increased with increase in feed rate. This is because of the fact that, with the increase in the feed rate, the region of the sheared chip increases. Larger efforts for chip removal were required due to higher resistance to material rupture. The increase in the feed rate results in a larger volume of the cut material at the same time. It also induces dynamic effect on the cutting forces. In tool chip contact area and at tool chip interface there is always some normal stress. Due to all these reasons, the cutting force increased with feed.

Due to increased feed rate, shear strength was reduced in tool work piece interface area so less feed force required for feed operation. Therefore the feed force remains constant. At low feed rate the resistance of work piece material for rupture is larger as compared to higher feed rate due to low temperature and high hardness of material. But as the feed rate increased beyond 0.2 mm/rev, type of chip formed during cutting was changed from continuous to serrated type. It results in decreasing of the radial force. Increase in the feed results in producing feed marks on the turned surface of the work piece, resulting in the increase in the surface roughness value [13].

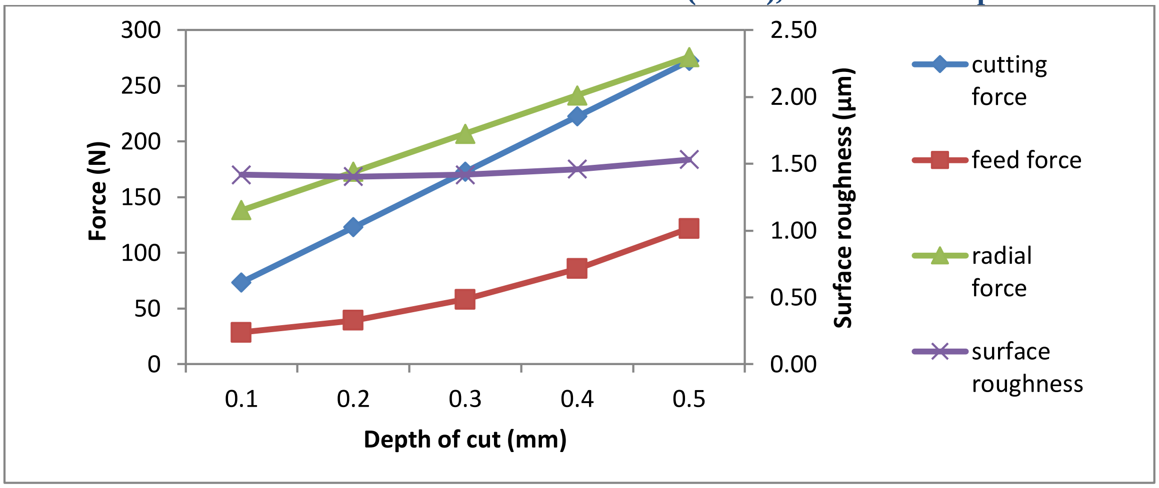
It can be seen that, the figure 1(c) plotted by using cutting speed of 150m/min and feed of 0.2mm/rev and simultaneously varying the depth of cut i given domain. Increase in depth of cut results in increased tool work contact length. It increases the machining forces. Consequently chip thickness becomes significant that causes the growth of the volume of deformed metal, and it requires larger cutting forces to cut the chip. So the cutting forces were increased with the increase in the feed rate. In large depth of cut the contact area between insert and work piece increases, increasing shear plane area. For this increased area larger forces are required. Therefore feed force and radial force increased with increase in depth of cut. Here it can be seen that all forces were increases with increase in the depth of cut. In above figure 1(c), it can be seen that the surface roughness increases initially and after 0.3mm of depth of cut, it starts to decrease. This is because, due to increased radial forces lateral vibrations are generated in the tool and hence increase in roughness value of the hard turned surface of the work piece[14].


100
120
140
160
180
200
400
350
300
250
200
150
100
50
0
2.50
2.00
1.50
1.00
0.50
0.00
Force (N)
Surface roughness (µm)
Cutting speed (m/min)
cutting force
feed force
radial force
surface roughn ess

(a)


300
250
200
150
100
50
0
3.00
2.50
2.00
1.50
1.00
0.50
0.00
Force (N)
Surface roughness (µm)
Feed rate (mm/rev.)
cutting force
feed force
radial force
surface roughness

(b)



(c)

Fig 2: ***Effect of cutting parameters on cutting forces varying with (a)cutting speed, (b) feed and (c) depth of cut, in compressed air ascooling medium condition.***

It can be seen that, in figure 2(a) due to the use of compressed air all cutting forces and surface roughness remained constant, in varying cutting speed condition. This is because the compressed air works as a good lubricant and reduces the temperature in cutting zone, so tool geometry remains protected without generating vibrations. So there is no vibrations, no increase in forces. In figure 2(b) cutting force and radial force increased but feed force increases up to 0.2mm/rev and after that it decreases. This is because of the fact that, increase in feed, increases the shear plane area of the chip which requires higher cutting forces. The compressed air used as a coolant to minimize the temperature. It removes the heat from the cutting zone, but the distribution of the temperature in the cutting zone is uneven. It is observed that, increased feed leads to produce feed marks on the turned surface resulting in the increase in the surface roughness value.It can be observed that, due to use of the compressed air the all machining forces i.e. cutting force, feed force and radial force increases. The reason for this is , due to compressed air the material removal rate is increased and the chip thickness is increased which requires more forces . .but the value of the surface roughness remains constant. There is no any significant change in the value of the surface roughness, with increase in the depth of cut. This is because due to compressed air and high depth of cut the chips formed are of thin and fragmented type, which do not affect adversely to the surface of the work piece [15].

CONCLUSIONS

The current research work was carried out to study the hard turning process of AISI52100 bearing steel under two different environments, namely as dry turning (without any coolant) and other is using compressed air as a coolant. The interrelated effects of process parameters (cutting speed, feed rate and depth of cut) were studied on the response variables like surface finish and cutting forces with the help of graphs.Effect of cutting parameters on surface roughness: There is no significant effect of the cutting speed on the surface roughness. Surface roughness is mostly influenced by feed rate. At lower value of feed rate we can get better value of surface roughness. There is no significance effect of the depth of cut on the surface roughness. Better surface finish can be obtained in hard turning by using compressed air as a coolant as compared with dry turning.

- Effect of cutting parameters on force components:
- Cutting force decreases as cutting speed increases and vice versa.
- Feed force decreases as increase in cutting speed and vice versa.
- Radial force increases with increase in cutting speed.
- Cutting force increases as increase in feed rate.
- Feed force changes randomly, when feed rate increases.
- Radial force also changes randomly, when feed rate increases.
- Cutting force, feed force and radial force increases as per increase in depth of cut.

Results shows that the hard turning performance of AISI 52100 bearing steel using PCBN insert on the application of compressed air is better than the dry hard turning.

REFERENCES

1. Hamdi Aouici, yllese, kamel chaoui, Mabrouki, rigal analysis of surface roughness and cutting force components in hard turning with CBN tool: prediction model and cutting conditions optimization, measurements 45 (2012) 344-353.
2. Gaurav bartaryaa, S.K, chaudhary, effect of cutting parameters on cutting force and surface roughness during finish hard turning of AISI 52100 grade steel, procedia CIRP 1 (2012) 651-656.
3. S.B. Hosseini, T.Beno,U.Klement, J. Kaminski, K. Ryttberg, Cutting parameters during hard turning-Measurements and effects on white layer formation in AISI 52100.
4. Amanda Lynne McKie, mechanical properties of CBN-Al composite materials dependence on grain size of CBN and binder content, Thesis for M.S. at university of the Witwatersrand, johanseberg octomber 2009,10-180.
5. T. Ozel, Y. Karpat, Asrivastava, hard turning with variable microgeometry PCBN tools, CIRP annals-Manufacturing technology 57(2008) 73-76.
6. Klocke, F. And Eisenblatter ,G. Dry cutting. Annals of CIRP 1997, 46(2), 519-526.
7. nun ming-liu Ko-ta chiang. Chen ming hung int j adv manuf technology(2013) 67; 1053-1066. Modelling and analyzing the effects of air cooled turning on machinability of Ti-6Al-4v titanium alloy using cold air gun system.
8. Suha K Shihab, Zahid A. Khan, Aas Mohammad, Arshad Noor Siddiqeed, RSM based study of cutting temperature during hard turning with multilayer coated carbide insert. Procedia material science 6 (2014) 1233-1242.
9. Catalogue and technical guide 2015: seco tool
10. B. C. Routara, A. K. Sahoo, A.K. Parida and P. C. Padhi,Response surface method and genetic algorithm used to optimize the cutting condition for surface roughness parameters in CNC turning. Procedia engineering 38 (2012) 1893-1904
11. minitab 17 softwar
12. Satish Chinchanikar, A.V. Salve, P. Netake, A. More, S. Kendre and R. Kumar, Comparative evalutions of surface roughness during hard turning under dry and with water based and vegetable oil based cutting fluids, procedia material science 5 (2014) 1966-1975.
13. A. Srithar, k. Palanikumar, B. Durgaprasad , experimental investigation and surface roughness analysis on hard turning of AISI D2 steel using coated carbide inserts.
14. R. Suresh, S. Basavrajappa, G.L.Samuel, predictive modling of cutting forces and tool wear in hard turning using response surface methodology. Procedia Engineering 38 (2012) 73-81.
15. Awadhesh pal, S.K.Choudhury, satish chinchanikar, machinability assessment through experimental investigation during hard and soft turning of hardened steel.procedia material science 6 (2014) 80-91.
16. M.M.A. Khanna, mithua, N.R, Dharb, Effects of minimum quantity lubrication on turning AISI 9310 alloy steel using vegetable oil based cutting fluid, journal of Materials processing technology 209 (2013) 1978-1988
17. Dhar, N.R., Ahmed, M.T. An experimental investigation on effect of minimum quantity lubrication in machining AISI 1040 steel. International journal of machine tools and manufacture 2007,47,748-753.
18. Varprasad.Bh, Srinivasa Rao.Ch, P.V. Vinay, effect of machining parameters on tool wear in hard turning of AISI D3 steel.Procedia engineering (2014) 338-345.
19. Bernhard Karpuschewskia , konard Schmidta, JuliaPrilukovab, jozef Be noc,IIdiko Ma nKovac,Nguyen Trong Hieud observed influence of tool edge preparation on performance of ceramic tool inserts when hard turning , Journal of materials Processing Technology 209(2013) 1978-1988.
20. S. Caruso, D. Umbrello, J.C. Outeiro, L. Filice, F. Micari. An experimental investigation of residual stresses in hard machining of AISI 52100 steel. Procedia Engineering 19 (2011) 67-72.