Comparative Assessment on Cutting Performances of Multi Coated Carbide Insert in Dry and Spray Impingement Cooling Environments

R. Kumar¹, R. K. Das¹, A. K. Sahoo¹, P. C. Mishra¹, M. Ukamanal¹
¹School of Mechanical Engineering, Kalinga Institute of Industrial Technology
Deemed to be University, Bhubaneswar-24, Odisha India
E-mail: ramanujkumar22@gmail.com

ABSTRACT. In recent years, environmental conscious lubricating system is highly popular for hard turning applications due to lots of limitation and complexity noticed in wet and dry cutting environments. Present work focused on performance analysis of multilayer coated carbide tool on heat treated AISI D2 steel (55 ± 1 HRC) in dry as well as in spray impingement cooling surroundings. Chip-tool interface cutting temperature (T), average surface roughness (Ra) and chip morphology have been considered as the performance measuring parameters. Machining performance under spray cooling environment is improved compare to dry. Cutting temperature at chip-tool interface increases with rise in cutting speed and depth of cut whereas surface roughness increases with cutting feed. Continuous and discontinuous chips with saw tooth have been observed in both cutting environments.

1. Introduction

Manufacturing industries around the world are now emphasizing on lowering the cost solution with better quality product to maintain their product in competitive era. Since few years lots of invention has been carried to developed new cutting tools for replacing conventional grinders for machining of hard metals. Costly Ceramic, CBN, PCBN are highly accepted tools for hard turning under dry condition but improved coating technology developed various low cost multi-coated carbide tool for hard turning [1]. Higher cutting temperature thus rapid tool wear creates a major issues related to cutting with coated carbide tool. However there is needed to use some advanced cooling technique to control the cutting temperature in hard cutting. Plenty of works using different kinds of lubrication methods have been reported by various researchers to lowering the heat in hard turning of metallic piece. Minimum quantity lubrication [1, 2], spray impingement cooling [3, 4], high pressure cooling etc. methods have been implemented in turning of high hardness steel which is reported by various researchers.

The comparative performance analysis in machining of high chromium high carbon D2 steel revealed that the performance characteristics under near dry machining are far better than dry [2]. The performance evaluation between spray and dry cooling on turning of heat treated AISI 1015 steel using carbide insert has been carried and improved results was found in spray cooling environment [3]. Taguchi L₁₆ based experimental investigation on AA 7075/SiC metal matrix test-piece under dry and spray cooling surrounding was carried and comparative assessment revealed that the machining under spraying surrounding was more advantageous to dry [4]. Surface quality under MQL was noticed to be better relative to wet and dry cutting due to convection as well as evaporation mechanism of heat transfer in
In machining under minimum quantity of oil cooling the surface quality was found to be better than wet cutting [6]. Analysis of surface quality in finish turning of heat-treated EN 24T using carbide insert was carried in dry as well as in high pressure cooling surrounding. High pressure coolant provided effective cooling and lubrication with reduced friction thus improved surface quality compare to dry [7]. The influence of approach angle and turning parameters on cutting forces and tool-tip temperature were investigated under dry and MQL condition. The cutting ability under MQL was seemed to be higher than dry in terms of tool-tip temperature and machining forces [8].

According to literatures studied, very few works have been found on application of eco-friendly spray impingement cooling in hard turning with multicoated carbide insert. However, there is need more study on effects of spray cooling in hard turning. Keeping this view, the present work emphasizes on study of machining performances in turning of heat-treated AISI D2 grade steel using multicoated carbide in environment conscious spray cooling and compared with dry cutting performances.

2. Implementation details

AISI D2 tool steel of hardness 55±1 HRC has been taken as workpiece with initial diameter 48 mm and machining length is 200 mm. The machining has been carried on high speed HMT NH22 precision lathe of power capacity 11KW. WIDIA made CVD applied multilayered (TiCN/TiN/Al2O3) coated carbide tool of ISO designation CNMG 120408 have been used. The cutting insert is fitted in tool holder which is designated as PCLNR 2525 M12. The experiments have been carried in dry and spray impingement cooling surroundings and the performance characteristics has been compared. The spray cooling parameters say air pressure (1.5 bar) and water pressure (1 bar) has been consider constant in each experiment [3]. The schematic view for entire spraying set-up with machine tool is displayed in Figure 1 and the measuring instruments for temperature, surface roughness and chip morphology have been displayed in Figures 2a-c respectively.

**Figure 1.** Schematic view of turning setup in spray cooling condition
3. Result and Discussions

In the present work, the turning of heat treated AISI D2 steel has been carried in dry and spray impingement cooling environments using multilayer coated carbide tool. The relative performance between dry and spray cooling has been studied using cutting temperature, surface roughness and chip morphology.

3.1. Analysis of cutting temperature

From the test results, higher magnitudes of temperature at tool-chip interface have been observed in case of dry cutting compare to spray cooling as shown in Figures 3a-d and Figures 3e-h respectively. At smallest depth of cut 0.1 mm, temperature rises with increasing speed and feed whereas the temperature found in dry cutting is much higher than spray assisted machining as shown in Figure 4. In case of spray environment the cutting fluid easily penetrate into cutting zone as well as chip can easily remove from tool-chip interface which results in decrease the friction between chip-tool as well reduce the cutting zone temperature. Similar finding was also reported by Kumar et al. [5]. Maximum temperature generated in spray cooling is nearly about 200°C (Figure 3h) which is very less than the temperature developed in dry condition at same parameters (Figure 3d). However it can be said that the spray cooling method has excellent capability to lowering the heat at cutting zone. Lower amount of heat can decelerate the abrasion phenomena, chipping thus lowering the tool wear growth. In both cutting surroundings, highest temperature has been observed at highest speed and highest depth of cut cutting condition due to higher magnitude of cutting speed very minute amount of time is available to decapitate the heat from cutting zone. Cutting speed and depth of cut have traced to be more influencing machining factor for cutting temperature. Shihab et al. also found that all the three turning variables were significant for chip-tool interface cutting temperature and out of three cutting speed was highly dominated [10].

Figure 2. (a) measurement of cutting temperature (b) measurement of surface roughness (c) optical image capturing of chip

The online measurement of temperature (T) using Fluke Ti-32 thermal camera (Figure 2a) is employed at chip-tool interface during cutting operation and the SmartView 3.11 software is used to visualize the temperature on computer screen. After one complete cut the, the surface roughness of turned surface has been measured at different five spot using Taylor Hobson (Surtronic 25) instrument (Figure 2b) and the average value of five readings has been taken as arithmetic average surface roughness (Ra). After each cut the chips have been collected and their images have been captured using optical microscope (Olympus STM6, Japan) with 30x magnification of SC30 camera (Figure 2c).
Figure 3. Thermal images (a-d) dry condition (e-h) spray impingement cooling condition
Figure 4. Influence of cutting speed and feed on temperature

3.2. Analysis of surface roughness

In all test runs the surface roughness produced in spray cooling condition are lower than the dry condition. For both cutting surroundings the average roughness is found to be lower than recommended limit of 1.6 micron. In both cutting conditions, the surface quality decreases with improving feed at entire range of depth of cut and cutting speed.

Figure 5. Influence of cutting speed and feed on average surface roughness
Figure 5 indicates that for both cutting situations, the surface roughness gets decline with improving speed and feed at lowest depth of cut 0.1 mm whereas better quality of surface observed in spray condition with respect to dry cutting. In both cutting environment, as speed increases from 63 to 140 m/min and cutting feed increases from 0.08 to 0.16 mm/rev the surface roughness improves whereas as speed changes from 140 to 182 m/min and cutting feed decreases from 0.16 to 0.08 mm/rev surface quality improves. However it has been justified that the surface quality is highly dominated by feed. Similar findings have been reported by Sahu et al. [3]. In both condition best quality of surface have been observed at turning factors $v = 108$ m/min, $f = 0.08$ mm/rev, $d = 0.1$ mm whereas worst quality surface produced at $v = 140$ m/min, $f = 0.16$ mm/rev, $d = 0.2$. However it can be said that at higher parametric condition the poor quality of finished surface produce.

3.3. Effects of cutting temperature on surface roughness

As the result obtained under spray condition shows lower ranges of temperature compare to dry cutting which indicates lower frictional value at chip tool interface however better quality surface has been reported compare to dry cutting. In both cutting conditions, higher magnitude of average surface roughness has been observed at larger values of cutting temperatures. At lowest depth of cut, better surface quality reported due to lower magnitudes of cutting temperature whereas at highest depth of cut poor surface quality has been noticed due to higher cutting temperature.

3.4. Chip morphology

In dry cutting spiral c and ε shaped discontinuous chips produced at higher cutting feed condition. Majority of test runs helical shaped continuous chips (Figure 6a & Figure 6c) are produced. Continuous chips are produced because of quasi-stationary deformation in shear zone.

![Figure 6. Images of chip produced in hard turning (a-b) $v = 63$ m/min, $f = 0.08$ mm/rev, $d = 0.2$ mm (c-d) $v = 182$ m/min, $f = 0.08$ mm/rev, $d = 0.3$ mm](image)

Similar results were mentioned by Mhamdi et al. [9]. The colour of chips produced is either metallic (Figure 6a & Figure 6c) or partial blue. Saw tooth profile at the edge of chips have been notice in all test runs (Figure 6a & Figure 6c). Similar types of chip morphology have been observed in machining of 4340 steel by Sahoo and Sahoo [11]. In spray cooling condition the shape of chips produced is either helical (Figure 6b) or spiral c or ε shape (Figure 6d). At higher ranges of feed spiral c and ε shaped discontinuous chips are noticed. At lower feed and highest speed combination spiral c and ε shape chip produced as shown in Figure. 6d. The colour of chips have been identified as metallic, partial blue and burnt blue. Partial blue and burnt blue colours are identified at higher cutting speeds. Saw tooth profile has been seen in each test runs. Saw tooth chips for less brittle materials are produced due to periodic propagation of cracks due to high speed and feed. Similar observation has been reported by Saw and Vyas [12].
4. Conclusions

A comparative cutting performances analysis of multi coated tool under dry and spray cooling on hard turning of AISI D2 steel has been carried and some major findings are presented below.

Overall machining performance under spray impingement cooling has been relatively better than dry surrounding. Higher temperature has been observed in case of dry cutting which denotes higher intensity of friction at chip-tool compare to spray cooling. Speed and depth of cut can be claimed as dominating cutting factors for cutting temperature. Better quality of surface observed in spray assisted cutting compared to dry. In both cutting conditions, cutting feed seemed to be highest influencing factor for surface roughness and at lowest depth of cut, better surface quality whereas at highest depth of cut poor surface quality has been noticed. Continuous and discontinuous with saw tooth chips have been produced in both cutting environments. Saw tooth chips have been produced due to cyclic fracture of metal in cutting.

Acknowledgements

The authors express their gratitude and thank to Kalinga Institute of Industrial Technology Deemed to be University Bhubaneswar, Odisha for providing the experimental facility to execute the research work.

References

[1] Chinchanikar S and Choudhury S K 2015 Int. J. Mach. Tools Manuf. 89 95–109
[2] Sharma J and Sidhu B S 2014 J. Clean. Prod. 66 619–623
[3] Sahu S K, Mishra P C, Orra K and Sahoo A K 2014 Proc. Inst. Mech. Eng.B-J Eng. Manuf. 229(2) 251-265
[4] Mishra P C, Das D K, Ukamanal M, Routara B C and Sahoo A K 2015 Int. J. Ind. Eng. Comput. 6 445–456
[5] Kumar S, Singh D and Kalsi N S 2017 Materials Today: Proceedings 4 3627–3635
[6] Diniz A E, Ferreira J R and Filho F T 2003 Int. J. Mach. Tools Manuf. 43 317–326
[7] Mia M and Dhar N R 2016 Measurement 92 464–474
[8] Saini A, Dhiman S, Sharma R and Setia S 2014 J. Mech. Sci. Technol. 28(6) 2307–2318
[9] Mhamdi M B, Salem S B, Boujelbene M and Bayraktar E 2013 J. Mech. Sci. Technol. 27(11) 3451–3461
[10] Shihab S K, Khan Z A, Mohammad A and Siddiqueed A N 2014 Procedia Mater. Sci. 6 1233–1242
[11] Sahoo A K and Sahoo B 2012 Measurement 45 2153–2165
[12] Shaw M C and Vyas A 1998 CIRP Ann.-Manuf. Technol. 47(1)77–82