Journal of Basic and Applied Engineering Research
p-ISSN: 2350-0077; e-ISSN: 2350-0255; Volume 3, Issue 2; January-March, 2016, pp. 127-131

http://www.krishisanskriti.org/Publication.html

Investigation of Tool Wear and Surface Finish of Carbide Coated Inserts under Dry and MQL Conditions

Isha Srivastava

DIT, University, Dehradun
E-mail: Isha0603@gmail.com

Abstract—*In this experimental study, the experiments were performed in different carbide inserts i.e PVD-A (TiAlN+TiN), PVD-B (TiCN+TiN), CVD-A (TiCN+Al_2O_3+TiN.0315), CVD-B (TiCN+Al_2O_3+TiN) to evaluate the performance of coated inserts under Dry and MQL condition during end milling of EN–31 hardened die steel of 43±1 HRC. A fabricated MQL setup was used in this experimental study with flow rate 15-17 ml/hr and the pressure 6-7 bar. The experiments were performed under fixed cutting parameters i.e. depth of cut (3 mm), feed rate (12 mm/min), cutting speed (200 m/min). Effect of these parameters was evaluated on the cutting force, surface roughness and tool wear. The experiments were performed in three repeated trials of 4.5 min each to measure the progressive tool wear. Results show that in MQL machining, less cutting force and tool wear, as well as the good surface finish was achieved as compared to the dry machining. PVD B inserts experienced catastrophic failure after 13.5 minutes which shows PVD B was not suitable for given set of parameter. PVD A provides less cutting force as well as tool wear and also generate good surface finish among all four inserts. CVD A achieves the good result as compared to CVD-B inserts due to 0.0315% more TiN coating present in CVD A.*

Keywords*: Cutting forces; Cutting parameters; Dry machining; MQL machining; PVD-coated inserts; Surface roughness; Tool wear.*

1. INTRODUCTION

Cutting fluids are extensively used in metal cutting operations to do lubrication, cooling, and the flushing away of chips from the cutting zone. But it has also the adverse effect on the environment due to the sewage of the lubrication into the river or dump in a ground. This lubrication machining also effects the health of the human being such as asthma, pyrosis, dermatitis as well as fungal infection. So MQL machining is preferred over flood machining in metal cutting operation which has many advantages. It always effective in every cutting speed either it is low or high. In MQL, it is the mixture of less quantity of coolant with the large quantity of air to make aerosol which also helps to reduce the cost of lubrication. This aerosol mixture is injected directly on the cutting zone. It easily reaches to the cutting zone at high spindle speed due to its high pressure during cutting. As the aerosol mixture injected to the cutting zone, coolant is vaporized due to the high cutting temperature and the air remain in the atmosphere which reduce the disposal problem of the lubrication or as well as no health issue arises while machining under MQL condition [1]. In last decade, extensive research has been performed on dry and MQL condition of machining. MQL machining increased tool life as cutting speed increases and also help to reduce the tool wear and increase the tool life [2,3]. MQL machining provides good surface finish as the spindle speed increased whereas another machining, decreased the surface of the machined surface as the cutting speed increased [4,7]. In MQL, the less cutting force was achieved. Hence, it was proved that MQL (with cooling air) was a good substitute for other old-fashioned techniques [5,7]. Tian et al. [6] performed the experiment to measure the influence of cutting speed on cutting force and tool wear and concluded that the resultant cutting forces first decreases, but after some time, it increases with the cutting speed. Wang et al. [8] evaluated the wear performance of uncoated tool inserts and PVD coated tool inserts in face milling (up or down milling) Inconel 182 under different lubrication conditions and concludes that PVD coated tool inserts have longer tool life compared to uncoated ones in all lubrication conditions. In this investigation, the EN-31 material is used for the experiment due to its high resisting nature against the wear. Tool wear is directly affecting the tool life of the tool which affects the productivity. This experimental study motivated on the role of cutting fluid in the milling of EN–31. The experiments were performed in two stages: one with the dry condition and the other with the MQL condition and experiments were stopped either occur catastrophic failure or after 13.5 mm machining. At that moment the results of the experimental study were compared in terms of the cutting force, surface roughness and tool wear under different cutting condition. In this investigation, the EN-31 material is used for the experiment due to its high resisting nature against the wear. Tool wear is directly affecting the tool life of the tool which affects the productivity. The aim of this study is to investigate the performance of MQL machining over the dry machining and measure the cutting forces, surface finish and tool wear under fixed cutting speed, depth of cut and feed rate. For this experimental study, fabricated MQL setup was used with a flow rate of 15-17 ml/hr at 6-7 bar pressure.

2. EXPERIMENT PROCEDURE

2.1 Methods and Methodology

The experiment was performed on the 3 axes vertical CNC machine. Maximum power of the machine is 3.7 KW. EN–31 hardened die steel workpiece of 110x65x18 mm was used. In this experiment, Sandvik coromant R390-020A20-11L carbide tool holder of 20 mm diameter and Birla Kennametal Hydrogrip adaptor BT40-SHYD20-095M whose runout is 0-2 microns was used. PVD (TiAlN+TiN), (TiCN+TiN), and CVD ($TiCN+Al_2O_3+TiN$. 0315), ($TiCN+Al_2O_3+TiN$) were used for this experiment. Carbide tool has the capacity to loaded two inserts in a single row.

2.2 MQL setup

A fabricated MQL setup was installed for the experimental study. In this fabricated MQL setup, coolant was stored in the storage tank and release the coolant in a droplet. This coolant droplet is dissolved in a high pressure air and make aerosol. Now this aerosol mixture is directly injected on the interface of the tool-workpiece to reduce the cutting forces as well as cutting temperature which is generated on the cutting zone. Flow diagram of fabricated MQL setup is shown in Fig. 1. The flow rate of the MQL is 15–17 ml/hr at 6-7 bar pressure.

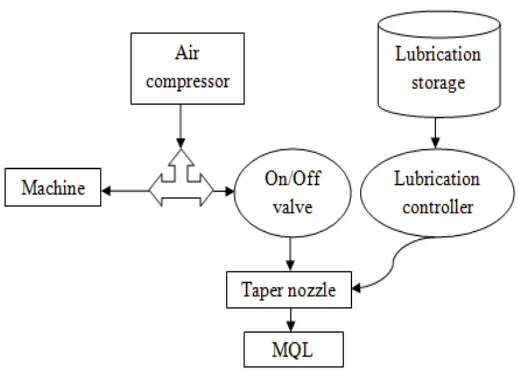
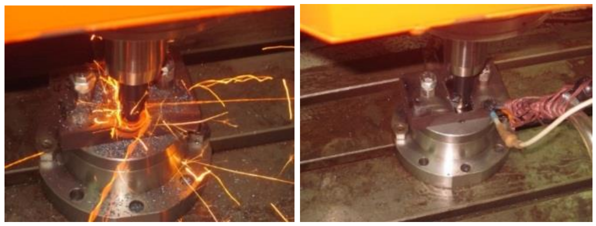


Fig. 1: Flow diagram of minimum quantity lubrication.

2.3 Experimental Setup

The experiments were performed in two machining condition at three repeated pass of 4.5 min to measure the cutting force, surface finish as well as progressive tool wear after every cut, to know the cutting ability of these different insert under this cutting parameter. Cutting forces were measured during the cutting operation performed on the workpiece. Kistler Dynamometer 5070A was connected with desktop and record the cutting force during cutting operation in dry lubrication as well as MQL (minimum quantity lubrication) machining. Workpiece mounted on the dynamometer to measure the cutting force as shown in Fig. 2.



(a) Dry cutting **(b) MQL cutting**

Fig. 2: Shows the cutting forces on dry and MQL condition.

Movement of tool in x, y, z direction during cutting operation and represent the flank wear on tool flank surface is shown in Fig. 3. Surface roughness tester was used to measure the surface finish. Before start measuring the surface roughness machine should be calibrated. A measuring microscope was used to measure the tool wear of the carbide coated tool.

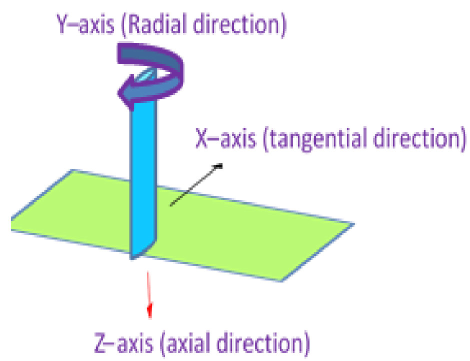


Fig. 3: Movement of tool in x, y, z direction.

3. RESULTS AND DISCUSSION

3.1 Effect of machining condition on Cutting force

The experiment was performed in a three repeated trial of 3 mm depth of cut in every work piece for analysis the maximum radial forces which are acted on the work piece during the cutting. The experiments were conducted in MQL (minimum quantity lubrication) and dry lubrication and compare the performance of the PVD and CVD insert in these two machining conditions. The results shows that in PVD-coated inserts, less radial forces are generated as compared to the CVD inserts due to the thin coating as shown in Fig. 4. The examinations were first done with the two PVD inserts and measures the max radial forces. A similar operation was done with the two CVD inserts. In this study, cutting length of the workpiece was 55 mm and measure the max radial forces in the interval of every 4.5 min till 13.5 min or when the catastrophic failure occurs. PVD A (TiCN+TiN) coated insert experienced the catastrophic failure in dry machining after 9 min machining due to the thin coating (3 micron) which is yet tougher and normally smoother whereas CVD coating is thick (9-12 micron) and highly wear resistant. In MQL machining, less radial forces generated as compared to the dry machining [2,5]. PVD tool A provides good result among all the carbide inserts in both dry as well as MQL. PVD tool A reduces 5-10% of the cutting forces in MQL machining whereas PVD tool B reduces 20-25% cutting forces in MQL condition. CVD tool A generates 35-40% less cutting force and CVD tool B also reduces 15-20% cutting forces in MQL condition as compared to the dry condition.

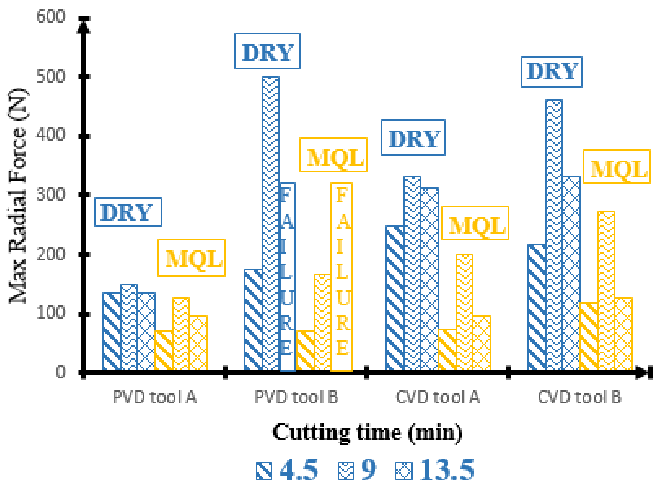


Fig. 4: Cutting force result of the inserts after 13.5 min under fixed conditions (Vc=200 m/min, f=12 mm/min, doc=3mm).

3.2 Effect of machining condition on Tool Wear

Tool wear was measured on different CVD and PVD inserts at the constant feed rate of 12 mm/min, depth of cut of 3 mm, and cutting speed of 200 m/min as shown in Fig. 5. Once performing the cutting operation under the dry and MQL condition, then measured the tool wear by measuring microscope after every trial to measure the progressive tool wear of all the different inserts as shown in Fig. 6. Tool wear was increased as the cutting time increases [9]. In MQL machining, less tool wear occurs as compared to the dry condition. Hence, it helps to increase the tool life [10,11]. PVD tool experience less tool wear during the MQL machining as compared to the CVD inserts. In CVD inserts, no breakage and failure occur during the machining because it has thick coating and highly wear resistant whereas in PVD inserts, it experiences the breakage or catastrophic failure during operation because it has thin coating which help to reduce the tool wear but unfortunately, it breaks as PVD tool A experience the catastrophic failure after 9 min machining. CVD tool A provide the best results as compared to the CVD tool B. PVD tools A gives good result as compared to the PVD tool B and PVD tool A gives the best result among all the PVD and CVD inserts as shown in Fig. 5. PVD tool A reduces 30% of the tool wear in MQL machining whereas PVD tool B reduces 40% tool wear in MQL condition. CVD tool A generates 10% less tool wear and CVD tool B also reduces 25% tool wear in MQL condition as compared to the dry condition.

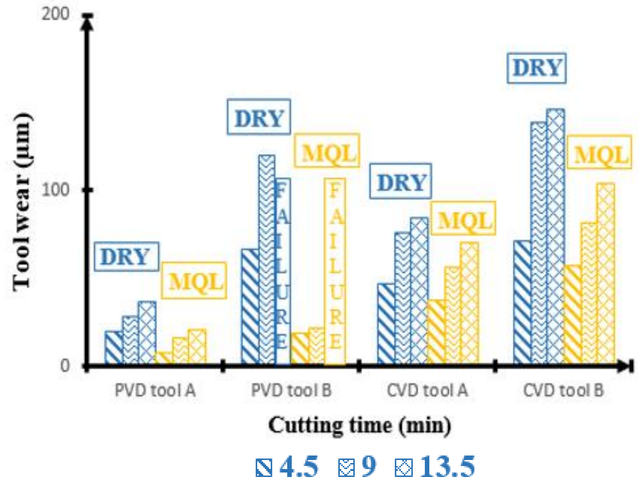
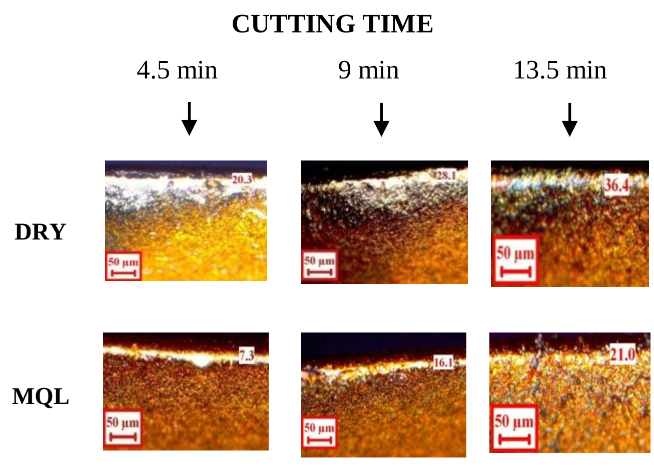
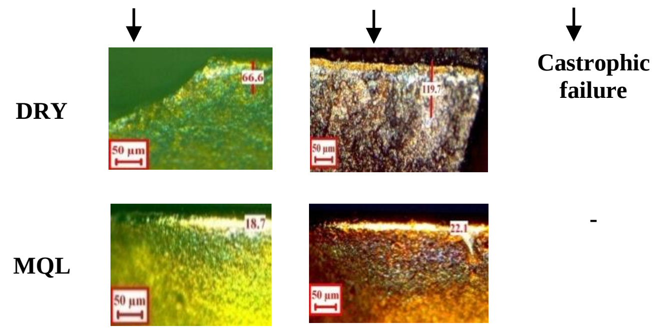


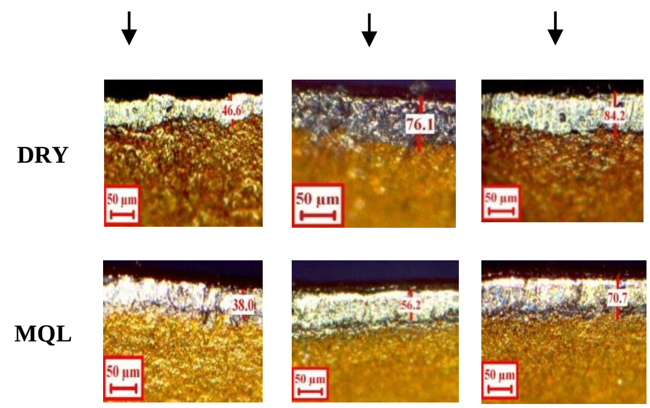
Fig. 5: Tool wear result of the inserts after 13.5 min under fixed conditions (Vc=200 m/min, f=12 mm/min, doc=3mm).



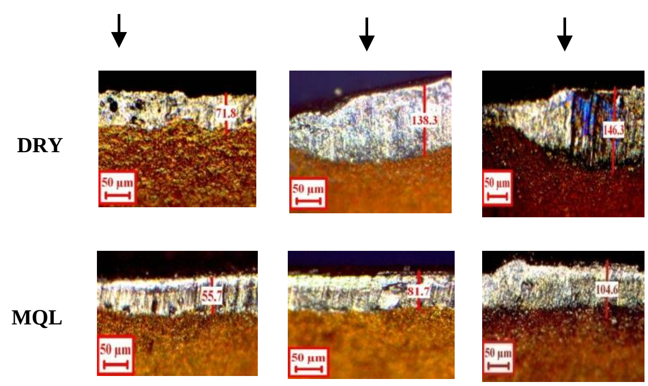
(a): PVD tool A



(b): PVD tool B



(c): CVD tool A

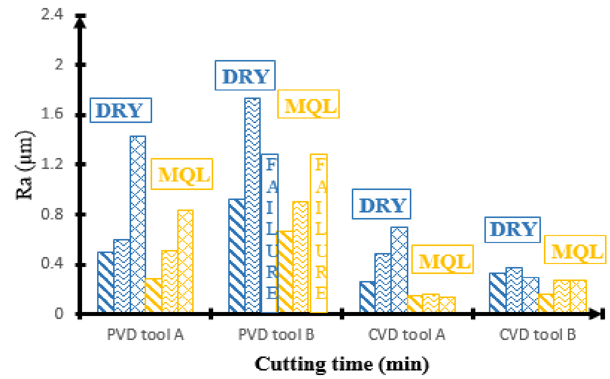


(d): CVD tool B

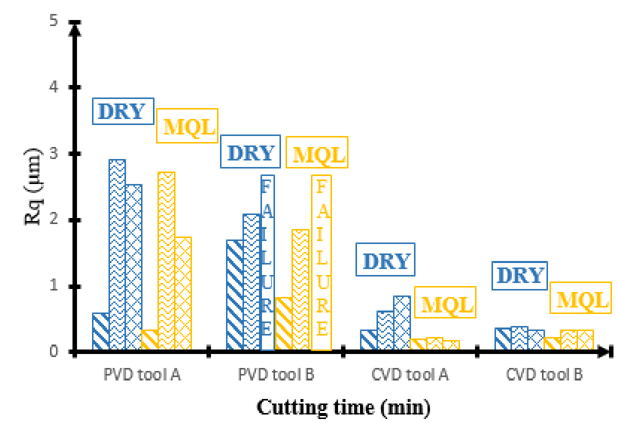
Fig. 6: Microscopic structure of the flank wear (a) PVD tool A (b) PVD tool B (c) CVD tool A (d) CVD tool B.

3.3 Effect of machining condition on Surface Roughness

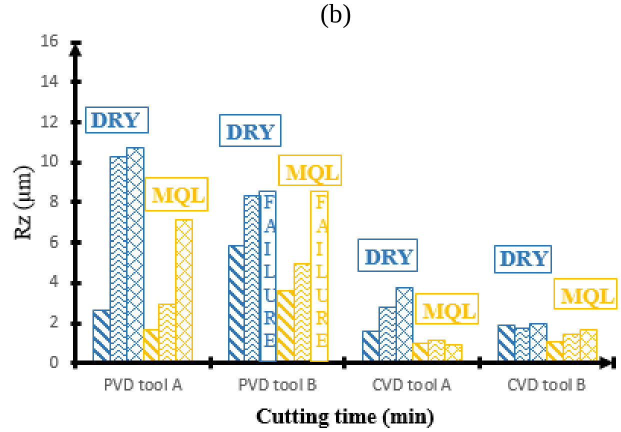
After cutting operation, measure the surface roughness (Ra, Rq, Rz) of the machine parts after every trial to see the effect of cutting time on the machined surface. It was observed after measuring the surface roughness of every trial that in MQL machining, good surface finish was achieved as compared to the dry machining [1,4,9] as shown in Fig. 7. And among all four different coated carbide inserts CVD tool provides a good surface finish as compared to the PVD tool because it has a thick layer coating which has an ability to wear resistance and also effective in a high heat condition. CVD tool A has a 0.0315% more TiN coating which offer outstanding and increase the resistance of the built-up-edge and ability to work on the gummy material. CVD tool A provides a good surface finish as compared to the CVD tool B in MQL condition.



(a)



(b)



(c)

4.5 9 13.5

Fig. 7: Surface roughness value of the inserts after 13.5 min under fixed conditions (Vc=200 m/min, f=12 mm/min, doc=3mm) (a) Ra (b) Rq (c) Rz

PVD tool A provide a good surface finish in MQL condition as compared to the PVD tool B because PVD tool A has TiAlN coating which is stable as well as harder and also more effective in high temperature than TiCN coating which is in PVD tool B.

4. CONCLUSIONS

This experiment motivates the advantages of MQL machining over dry machining condition. In this investigation, runs are performed to observe the effect of cutting parameter on the cutting forces, surface roughness and tool wear. The experiment was stopped after 13.5 min of cutting or if the wear reached to 0.313 mm. During the experiment, it is noticed that all different inserts achieve less cutting force, tool wear and good surface finish in MQL machining as compared to dry machining. MQL machining reduces 20-45% cutting zone temperatures as compared to dry machining. MQL machining also provides outstanding results in the field of the surface roughness as compared to the dry. PVD B experience the catastrophic failure in dry condition after 9 min due to its thin coating thickness. This coating was not suitable for given set of parameter PVD A provides good results among all the inserts. Its coating thickness is 4 µm, which was suitable for given set of parameter and able to reduce the tool wear and cutting force as well as also increase the quality of the machined surface. Coating thickness plays an important role to increase the efficiency of the cutting tool. CVD A has 4 µm whereas CVD B has 9 µm. CVD inserts have thick coating thickness as compared to the PVD inserts, so it was able to work under all condition but it generates more cutting force, tool wear and surface roughness as compared to the PVD inserts.

5. ACKNOWLEDGEMENTS

This work was supported in part by a grant from the Thapar University, Patiala, Punjab.

REFERENCES

[1] B. Ozcelik, E. Kuram, and B. T. Simsek, "Comparison of Dry and Wet End Milling of AISI 316 Stainless Steel," *Mater. Manuf. Process.*, vol. 26, no. 8, 2011, pp. 1041–1049.

[2] J. Sun, Y. S. Wong, M. Rahman, Z. G. Wang, K. S. Neo, C. H. Tan, and H. Onozuka, "Effects of Coolant Supply Methods and Cutting Conditions on Tool Life in End Milling Titanium Alloy," *Mach. Sci. Technol.*, vol. 10, no. 3, 2006, pp. 355–370.

[3] A. Braghini Junior, A. E. Diniz, and F. T. Filho, "Tool wear and tool life in end milling of 15-5 PH stainless steel under different cooling and lubrication conditions," *Int. J. Adv. Manuf. Technol.*, vol. 43, no. 7–8, 2009, pp. 756–764.

[4] N. Tosun and M. Huseyinoglu, "Effect of MQL on Surface Roughness in Milling of AA7075-T6," *Mater. Manuf. Process.*, vol. 25, no. 8, 2010, pp. 793–798.

[5] S. M. Yuan, L. T. Yan, W. D. Liu, and Q. Liu, "Effects of cooling air temperature on cryogenic machining of Ti-6Al-4V alloy," *J. Mater. Process. Technol.*, vol. 211, no. 3, 2011, pp. 356–362.

[6] X. Tian, J. Zhao, J. Zhao, Z. Gong, and Y. Dong, "Effect of cutting speed on cutting forces and wear mechanisms in high-speed face milling of Inconel 718 with Sialon ceramic tools," *Int. J. Adv. Manuf. Technol.*, vol. 69, no. 9–12, 2013, pp. 2669–2678.

[7] B. Boswell and M. N. Islam, "The challenge of adopting minimal quantities of lubrication for end milling aluminium," *Lect. Notes Electr. Eng.*, vol. 229 LNEE, 2013, pp. 713–724.

[8] Z. Wang and X. Wang, "The principle and application of cutting-point virtual tool radius compensation for ellipsoidal outer contour finishing using a ball end mill," *Int. J. Adv. Manuf. Technol.*, vol. 71, no. 9–12, 2014, pp. 1527–1537.

[9] S. Gaikwad, P. G. Student, V. D. P. Associate, and S. B. P. Assistant, "Exprimental and statistical analysis of pvd and cvd coated cutting tools based on tool wear in end milling of en 8," vol. 1, no. 9, 2014, pp. 2013–2015.

[10] A. M. El-Tamimi and T. M. El-Hossainy, "Investigating the Tool Life, Cutting Force Components, and Surface Roughness of AISI 302 Stainless Steel Material Under Oblique Machining," *Mater. Manuf. Process.*, vol. 23, no. 4, 2008, pp. 427–438.

[11] C.-D. Wang, M. Chen, Q.-L. An, M. Wang, and Y.-H. Zhu, "Tool wear performance in face milling Inconel 182 using minimum quantity lubrication with different nozzle positions," *Int. J. Precis. Eng. Manuf.*, vol. 15, no. 3, 2014, pp. 557 – 565.