International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Determination of Surface Roughness Throughout CNC Turning of ASTM 316 Steel Expending Taguchi Method

Shweta Siktta Swain, N. K. Kund

***Abstract**: Plan of experiment involving Taguchi method got developed and executed to gauge impact of various machining variables (V, F and D) on surface roughness throughout CNC turning of ASTM 316 steel using coated carbide insert. Research findings through different mathematical analyses provided the effective guideline for choosing appropriate machine settings to realize surface roughness within the recommended range during stated turning operation. Ideal machining situations got determined to minimize the surface roughness (here surface roughness factors R_a with R_z) in turning of the same. Feed remains observed as paramount momentous variable for workpiece surface roughness. Furthermore, cutting speed remains observed as subsequent paramount momentous variable for workpiece surface roughness. Additionally, depth of cut remains observed as least paramount momentous variable for workpiece surface roughness, R_z only, however, depth of cut got absolutely insignificant impression on R_a. Present investigation clearly reveals that multicoated carbide inserts performed splendidly at optimal machining variables combination of V = 150 m/min, F = 0.10 mm/rev with D = 0.4 mm. Calculated ideal limit of sample surface unevenness, R_a and R_z are $0.16\ \mu m \leq R_a \leq 0.52\ \mu m$ and $1.4\ \mu m \leq R_z \leq 3.1\ \mu m$, respectively. Moreover, surface roughness, R_a is also within stipulated precarious limit of 1.5 µm (i.e. $R_a < 1.5\ \mu m$) for turning with coated carbide inserts.*

***Index Terms**: Surface Roughness, CNC Turning, ASTM 316 Steel, Taguchi Method, Machining Variables, Workpiece.*

I. INTRODUCTION

Metal cutting remains as the supreme significant practice for removal of undesirable material in manufacturing of any kind of modules. It is a machining practice where finished surface of preferred shape and size gets produced through detachment of superfluous materials stratums in shape of chips using wedge like device termed as cutting tool. Metal cutting practice remains influenced through relative motion between workpiece and cutting tool.

Manuscript published on November 30, 2019.
* Correspondence Author
Shweta Siktta Swain*, Department of Production Engineering, Veer Surendra Sai University of Technology (VSSUT) Burla (A Government Technical University).
Dr. N. K. Kund, Associate Professor in the Department of Production Engineering, VSSUT Burla (A Government Technical University).

Metal cutting remains as forming practice occurring in cutting structural modules through supply power generating determined fracture of stratum actuality detached. Here, fracture happens because of collective/net stress encompassing bending stress.

Key objective of machining practices (representative cases as demonstrated in figures 1-3) stand to transform workpiece for getting segment of desired geometry and surface quality using cutting tool through supreme concert throughout its epoch.

In machining practices, the major concern of customer requirements is surface roughness quality. Surface roughness remains primarily an outcome of process parameters like tool parameters/tool geometry (edge geometry, rake angle, nose radius, etc.) and machining variables/cutting conditions (V, F, D, etc.). Numerical or experimental evaluations on materials processing remain extant in collected works [1-7]. Computational and experimental researches stand also described [8-44].

Current research remains as examining the effect of machining variables on surface roughness throughout dry turning of ASTM 316 steel with multicoated carbide tool. Study includes determination of best levels of machining parameters for getting ideal the surface roughness parameters (R_a with R_z) using Taguchi method. In addition, machining variables (i.e. V, F and D) got correlated with performance outcomes (R_a with R_z).

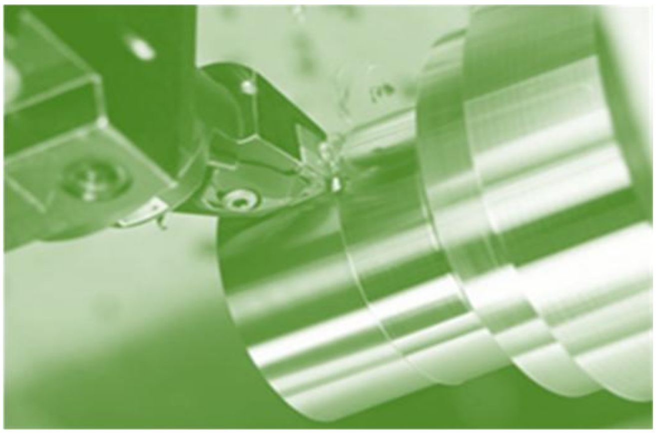

Figure 1. CNC turning practice

II. EXPERIMENTAL DETAILS

A. Sample Preparation from Work Materials

ASTM 316 steel sample bars of 90 mm length and 50 mm diameter got heated up to appropriate austenitizing temperature of 918 ºC and kept at that temperature for about 25 minutes to realize desired modifications in crystalline structure. Subsequently, oil quenching of stated sample. Then, tempering by reheating the stated sample up to a pre-calculated temperature of 398 ºC (just below lower critical temperature limit) for about 1.5 hours. Thereafter, air cooling for removing residual stresses aimed at structural homogenization.

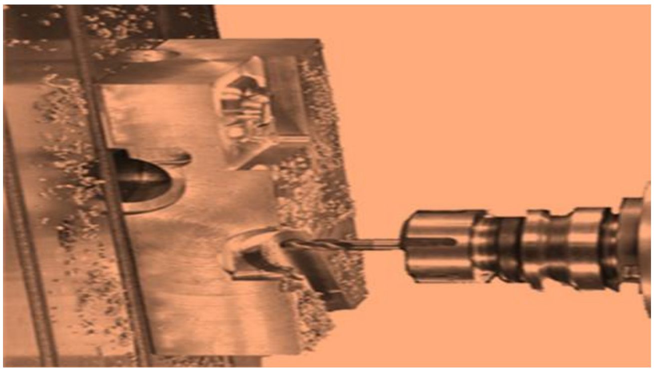

Figure 2. CNC milling practice

Figure 3. CNC grinding practice

B. Cutting Inserts

Multicoated inserts fixed on tool holder got utilized in present practice. Cutting geometry of the same is as stated: clearance angle = 5º, rake angle = −5º, cutting edge inclination = −5º, major cutting edge angle = 92º besides nose radius = 0.7 mm. Overall cases, both back rake and side rake are equal to −6º. All inserts intended for current experimentations got same geometry (with negative rake angle).

III. EXPERIMENTAL PROCEDURES

Experimentations got performed for examining influence of V, F and D on surface unevenness (R_a or R_z). For that Taguchi method is used through above stated parameters at three different levels mentioned in Table 1. CNC turning (with speed limit 3000 rpm and power limit 15 kW) operations got performed for generating investigational data in dry situation. Initially, thin layer from workpiece sample surface got removed and then a hole got drilled on sample face for providing support at tailstock as shown in figure 4.

Surface roughness (R_a or R_z) of turned surface got measured expending a surface roughness tester. Critical surface roughness $R_a < 1.5$ µm is adopted for surface finish in present CNC turning.

Table 1. Machining variables with levels.

Machining Variables	Levels		
	1	2	3
D (mm)	0.3	0.4	0.5
F (mm/rev)	0.1	0.15	0.2
V (m/min)	90	120	150

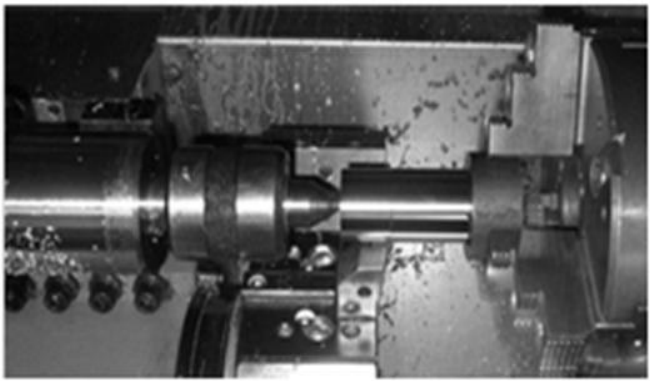

Figure 4. Photograph of cutting region

IV. RESULTS AND DISCUSSIONS

A. Demonstration of Experimental Results for Various Machining Process Parameters

The plan of experiment concerning Taguchi method remains developed and executed for evaluating effect of various machining variables like V, F and D on surface roughness throughout CNC turning of ASTM 316 steel using coated carbide insert. Twenty seven trials summarizes the experimental outcomes/observations aimed at surface roughness parameters. Lowest/least magnitudes/levels of surface roughness measures (R_a = 0.4 µm with R_z = 1.8 µm) got observed at F = 0.1 mm/rev, V = 150 m/min with D = 0.4 mm. Highest/uppermost magnitudes/levels of surface roughness measures (R_a = 2.4 µm with R_z = 9.8 µm) got enumerated at F = 0.2 mm/rev, V = 90 m/min with D = 0.4 mm.

B. Prediction of Optimal Design

Main effects plots (as demonstrated in figures 5 and 6) for momentous surface parameters (R_a and R_z) got developed and utilized for evaluating average surface roughness through ideal design situations. Useful levels of momentous surface parameters (R_a and R_z) got established for providing lesser magnitude of roughness. Feed level-1 with cutting speed level-3 (F_1V_3) usually provides smaller roughness magnitudes.

However, practice of evaluating average value rests on additivity existence pertaining to factorial influences meant for accuracy predictions. As no dependency lays between two key parameters the values can remain added for getting lesser roughness magnitude.

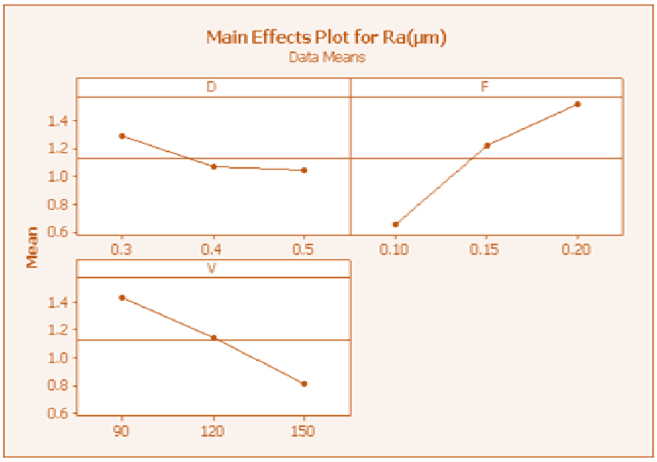

Figure 5. Main effects plot of R_a

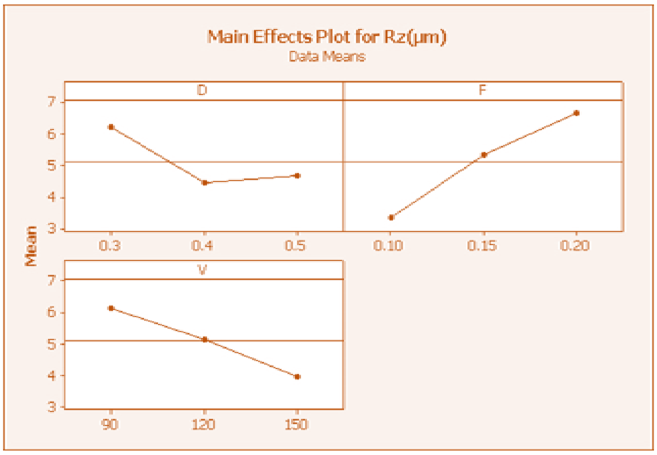

Figure 6. Main effects plot of R_z

While surface roughness (R_a) remains considered an estimated average stands at F_1V_3 level (i.e. while the two best momentous parameters stay at their superior level). Ultimately, estimated average R_a limit/range with peak confidence level is $0.16\ \mu m \leq R_a \leq 0.52\ \mu m$. Likewise, while surface unevenness (R_z) remains apprehensive, appraised average stands at F_1V_3 level. Lastly, estimated average R_z limit/range with peak confidence level is $1.4\ \mu m \leq R_z \leq 3.1\ \mu m$.

V. CONCLUSION

Taguchi method accompanied by design, development and execution of experiment is used to evaluate the influence of different machining variables (V, F and D) on surface unevenness throughout CNC turning of ASTM 316 steel using carbide insert. Research findings through different mathematical analyses provided the effective guideline for choosing appropriate machine settings to realize surface roughness within the stipulated limit during stated turning operation. Ideal machining situations got determined to minimize the surface roughness (R_a and R_z) in turning of the same. Feed remains observed as paramount momentous variable for workpiece surface roughness. Furthermore, cutting speed remains observed as subsequent paramount momentous variable for workpiece surface roughness. Additionally, depth of cut remains observed as least paramount momentous variable for workpiece R_z only, but, D got absolutely negligible impact on R_a. Current research evidently divulges that multicoated carbide inserts performed marvelously at optimum machining variables combination of V = 150 m/min, F = 0.10 mm/rev with D = 0.4 mm. The determined ultimate range of R_a with R_z are $0.16\ \mu m \leq R_a \leq 0.52\ \mu m$ and $1.4\ \mu m \leq R_z \leq 3.1\ \mu m$, respectively. Besides, R_a is below recommended safety limit 1.5 µm (i.e. $R_a < 1.5\ \mu m$) for turning using coated carbide inserts.

ACKNOWLEDGMENT

The authors gratefully acknowledge the vital supports and means from VSSUT Burla for performing this research work. The authors also wish to thank the reviewers and journal editors for their constructive and critical comments for improving the text.

REFERENCES

1. N. K. Kund, P. Dutta, 2010, Numerical simulation of solidification of liquid aluminium alloy flowing on cooling slope, Trans. Nonferrous Met. Soc. China, Vol. 20, pp. s898-s905.
2. N. K. Kund, P. Dutta, 2012, Scaling analysis of solidification of liquid aluminium alloy flowing on cooling slope, Trans. Indian Institute of Metals, Vol. 65, pp. 587-594.
3. N. K. Kund, 2014, Influence of melt pouring temperature and plate inclination on solidification and microstructure of A356 aluminum alloy produced using oblique plate, Trans. Nonferrous Met. Soc. China, Vol. 24, pp. 3465−3476.
4. N. K. Kund, 2015, Influence of plate length and plate cooling rate on solidification and microstructure of A356 alloy produced by oblique plate, Trans. Nonferrous Met. Soc. China, Vol. 25, pp. 61−71.
5. N. K. Kund, P. Dutta, 2015. Numerical study of solidification of A356 aluminum alloy flowing on an oblique plate with experimental validation, J Taiwan Inst. Chem. Ers., Vol. 51, pp. 159−170.
6. N. K. Kund, P. Dutta, 2016, Numerical study of influence of oblique plate length and cooling rate on solidification and macrosegregation of A356 aluminum alloy melt with experimental comparison, J. Alloys Compd., Vol. 678, pp. 343−354.
7. N. K. Kund, 2018, Effect of tilted plate vibration on solidification and microstructural and mechanical properties of semisolid cast and heat-treated A356 Al alloy, Int. J. Adv. Manufacturing Technol., Vol. 97, pp. 1617−1626.
8. N. K. Kund, 2019, EMS route designed for SSM processing, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 382−384.
9. N. K. Kund, 2019, Cooling slope practice for SSF technology, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 410−413.
10. N. K. Kund, 2019, Comparative ways and means for production of nondendritic microstructures, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 534−537.
11. N. K. Kund, 2019, Simulation of electronics cooling deploying water-zinc oxide nanofluid, International Journal of Recent Technology and Engineering, Vol. 7, pp. 1076−1078.
12. N. K. Kund, 2019, Numerical studies on fuel cell cooling introducing water-copper nanofluid, International Journal of Recent Technology and Engineering, Vol. 7, pp. 1079−1081.
13. N. K. Kund, 2019, Computational modeling of fuel cell expending water-zinc oxide nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 424−426.

14. N. K. Kund, 2019, Investigations on modeling and simulation of electronics cooling exhausting water-aluminum nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 660−663.
15. N. K. Kund, 2019, Numerical study on effect of nozzle size for jet impingement cooling with water-Al_2O_3 nanofluid, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 736−739.
16. N. K. Kund, 2019, Experimental investigations on impacts of nozzle diameter on heat transfer behaviors with water jet impingement, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 745−748.
17. N. K. Kund, 2019, Comparative CFD studies on jet impingement cooling using water and water-Al_2O_3 nanofluid as coolants, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 545−548.
18. N. K. Kund, 2019, Experimental studies on effects of jet Reynolds number on thermal performances with striking water jets, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2195−2198.
19. N. K. Kund, D. Singh, 2019, CFD studies on heat transfer and solidification progress of A356 al alloy matrix and Al_2O_3 nanoparticles melt for engineering usages, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2043−2046.
20. N. K. Kund, S. Patra, 2019, Simulation of thermal and solidification evolution of molten aluminum alloy and SiC nanoparticles for engineering practices, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2047−2050.
21. N. K. Kund, 2019, Numerical modeling on heat dissipation from electronics through water-titanium carbide nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1772−1775.
22. N. K. Kund, 2019, CFD modeling on influence of impinging spout strength for device cooling with water-Al_2O_3 nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1776−1779.
23. N. K. Kund, 2019, Computational modeling on fuel cell cooling with water based copper oxide nanofluid, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1967−1970.
24. N. K. Kund, 2019, Modeling and simulation on IC cooling using water centered SiO_2, TiC and MgO nanofluids, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1971−1975.
25. N. K. Kund, 2019, CFD simulation on IC thermal cooling through water involved TiO_2, AlN and CuO nanofluids, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1976−1980.
26. N. K. Kund, 2019, CFD simulation with modeling on fuel cell thermal management using water based SiO_2, TIC and SIC nanofluids, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 1291−1295.
27. N. K. Kund, 2019, CFD modeling on thermal management of IC using water based Fe, Cu and Al nanofluids, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 1666−1670.
28. N. K. Kund, 2019, Numerical simulation and modeling on thermal cooling of fuel cell using water based Al_2O_3, SiC and CuO nanofluids, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 2047−2051.
29. N. K. Kund, 2019, Computational modeling and simulation on thermal management of fuel cell with water based ZnO, TiC and AlN nanofluids, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 2052−2056.
30. N. K. Kund, 2019, Numerical modeling and simulation on fuel cell thermal cooling with water based TiO_2, AlN and CuO nanofluids, International Journal of Engineering and Advanced Technology, Vol. 8, pp. 2272−2276.
31. N. K. Kund, 2019, Computational modeling on thermal control of electronics using water-silicon carbide nanofluid, International Journal of Recent Technology and Engineering, Vol. 8, pp. 644−647.
32. N. K. Kund, 2019, Numerical simulation on influence of nozzle to plate distance for spout impact cooling with water-Al_2O_3 nanofluid, International Journal of Recent Technology and Engineering, Vol. 8, pp. 1290−1293.
33. N. K. Kund, 2019, Numerical modeling on fuel cell cooling using water based aluminum nitride nanofluid, International Journal of Recent Technology and Engineering, Vol. 8, pp. 1294−1297.
34. N. K. Kund, 2019, Numerical simulation on IC cooling with water based TiN, TiC and SiC nanofluids, International Journal of Recent Technology and Engineering, Vol. 8, pp. 1351−1355.
35. N. K. Kund, 2019, Computational simulation on IC cooling using water based ZnO, AlN and Al_2O_3 nanofluids, International Journal of Recent Technology and Engineering, Vol. 8, pp. 2280−2283.
36. Pabak Mohapatra, N.K. Kund, 2019, Experimental and numerical examinations of temperature distributions along SSF pin fins cast through semisolid materials processing, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 500−503.
37. Pabak Mohapatra, N.K. Kund, 2019, Numerical research on thermal variations along SSF pin fins shaped with SSM processing, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 504−507.
38. N.K. Kund, 2019, Experimental work on influences of Reynolds number on cooling behaviors with water jet impingement, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1867−1870.
39. N.K. Kund, 2019, Experimental research on effects of nozzle size intended for water jet impingement cooling, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1871−1874.
40. N.K. Kund, 2019, Experimental exploration on influences of nozzle to plate spacing on cooling performances using impinging water jets, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1989−1992.
41. N.K. Kund, 2019, Experimental examination on impacts of jet inclination on cooling performances using striking water jets, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 1993−1996.
42. N.K. Kund, 2019, Forced convection experimentation designed for cooling behaviors encompassing water jet impingement, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2222−2225.
43. S.K. Sahu, N.K. Kund, 2019, Microstructural characterization and evaluation of sliding wear of Hastelloy C276 under different loading conditions, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 2841−2845.
44. S.K. Sahu, N.K. Kund, 2019, Hardness along with electrochemical corrosion performance examination of Hastelloy C276, International Journal of Innovative Technology and Exploring Engineering, Vol. 8, pp. 3251−3254.

AUTHORS PROFILE

Shweta Siktta Swain obtained her B.Tech. in Mechanical Engineering from Biju Patnaik University of Technology Rourkela. Right now, she is pursuing her M.Tech. in Manufacturing System Engineering (MSE) Specialization in the Department of Production Engineering, Veer Surendra Sai University of Technology (VSSUT) Burla (A Government Technical University).

Dr. N. K. Kund obtained both M.Tech. & Ph.D. in Mechanical Engineering from IISc Bangalore. He has also obtained B.Tech.(Hons) in Mechanical Engineering from IGIT Sarang, Utkal University Bhubaneswar. He has published several research papers in international journals and also guided many research scholars, besides, wide teaching and research experience. He is presently working as Associate Professor in the Department of Production Engineering, VSSUT Burla (A Government Technical University).