Original Article

A Novel Detection of surface roughness for AA 6063 using AlTiN coated HSS tool in comparison with Uncoated tool using surface roughness tester

K. L. Mohan Raja[1], R. Venkatesh[2]

[1]Research Scholar, Department of Mechanical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu. India. Pincode: 602105.
[2]Project Guide, Department of Mechanical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu. India. Pincode: 602105.

Abstract

Aim: The motive of this study is to detect the surface roughness of AA 6063 samples using the AlTiN coated HSS drill and Uncoated drill machined in the (Super Jobber) Novel CNC drilling center. The surface roughness formed on the drilled surface was tested in a surface roughness tester. **Materials and Methods:** The AA 6063 with a diameter of 25 mm and length of 20 mm was used for this research. The experiments were conducted for two groups namely the samples are drilled using AlTiN coated HSS drill (intervention group) and the samples are drilled using an Uncoated drill (control group). The surface roughness test for machined samples was performed according to ASTM standards in the (SJ410-Mitutoyo) surface roughness tester. The sample count calculated by G-POWER software was 80% and a total of 20 samples per group was derived. **Results:** According to this study, the obtained Surface roughness for AA 6063 samples machined using AlTiN coated drill was 1.1336 µm and the samples machined using an Uncoated drill were 1.9502 µm. By considering the one-way ANOVA test in SPSS software, the significance value was $p= 0.025$ ($p <0.050$) indicating the tool efficiency while drilling. **Conclusion:** Within the limitations of this research, the samples drilled with AlTiN coated HSS drill has lower surface roughness than samples drilled with an Uncoated drill.

Keywords: Novel CNC drilling, AA 6063, AlTiN coated HSS drill, Uncoated drill, Surface Roughness, one-way ANOVA, SPSS software, ASTM standard.

DOI: 10.47750/pnr.2022.13.S04.064

INTRODUCTION

The manufacturing industries are constantly tested for accomplishing higher productivity and good quality to remain competitive. The ideal shape, size, and complete ferrous and non-ferrous materials are routinely delivered through drilling the performed spaces with the assistance of cutting tools (Sui, Kountanya, and Guo 2016). Drilling is a significant and broadly utilized machining measure in designing ventures. Surface quality is a significant presentation trademark to assess the efficiency of machine devices just as machined surfaces (Al-Janan and Liu 2016). A good quality drilling surface can prompt improvement in fatigue strength, corrosion resistance, assembly tolerance, wear rate, coefficient of friction, cleanability, thermal resistance, aesthetics, etc. At the same time, the cutting temperature increases with expansion in the process boundaries (Jancewicz and Szymanowski 2018). This is inconvenient to both the instrument and the tool as it causes dimensional imprecision by thermal deformation, damages the tool's sharpness, and causes vibration (Kalamkar and Monkova 2020).

Based on the past 5 years of research literature, research articles related to Metal Matrix Composites were found to be around 900 papers in Google Scholar and around 1150 papers in ScienceDirect. The effective qualities of AISI 304 during Novel CNC drilling factors using a 10mm HSS twist drill for optimizing the surface roughness (Khule, Naravade, and Shelke 2020). The Taguchi method for optimizing the drilling boundaries in EN31 uses PVD-coated and uncoated drills to determine its surface roughness and material removal rate (Mukhopadhyay et al. 2019). Drilling parameters of AA 2024 using Taguchi L18 orthogonal array using 16mm carbide drill for identifying its surface roughness (L. Li et al. 2020). Optimizing the surface roughness in Al 6061 in end milling using various drills by varying its machining parameters (Kumar et al. 2018). CNC milling operation for determining the surface roughness for 40 Cr steel using CVD coated drill (Son 2020). Effect of cutting parameters for AA 1100 for determining the surface roughness and burr formation in the micro-milling machine (Kiswanto, Zariatin, and Ko 2014), motivated the performance improvement of Aluminum Alloy, it is the best study and related to this research.

Our team has extensive knowledge and research experience that has translate into high quality publications(Bhansali et al. 2021; Jayanth et al. 2021; Sudhakar, Ravel, and Perumal 2021; Sathiyamoorthi et al. 2021; Deepanraj et al. 2021; Raju et al. 2021; Arun Prakash et al. 2020; Kamath et al. 2020; Shanmugam et al. 2021; Rajasekaran et al. 2020; Adhinarayanan et al. 2020; Rajesh et al. 2020; Aurtherson et al. 2021). Articles related to the influence of AA 6063 samples drilled with AlTiN coated HSS drill in comparison to Uncoated drill for identifying surface roughness were not found. In this research, the effect of drilling parameters on surface roughness for the AlTiN coated HSS drill and Uncoated drill was studied.

Materials And Methods

The preparation of samples and Novel CNC drilling of the samples as per design were carried out at Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Chennai, utilizing the facilities in the Department of Mechanical engineering. In this research, the AA 6063 was used as the base metal. The experimental setup was carried out in (Super Jobber) Novel CNC drilling center using an AlTiN coated HSS drill and an Uncoated drill. The experimental setup of the Novel CNC drilling center was shown in Fig. 1. Using a value of 80 percent in the G power calculator, the obtained sample count was 20 per group, the standard deviation is 0.4139 and the mean value is 1.54 (Jaeggi et al. 2022). A total of two groups were used for this research (control group and intervention group).

For machining samples in the control group, an AA 6063 rod of 25 mm diameter is parted to the length of 20mm. Care should be taken while drilling to avoid poor surface quality while drilling. An Uncoated drill of 8mm diameter was used for drilling the samples by varying the speed and feed rate in the Novel CNC drilling center. The Uncoated drill was shown in Fig. 2. A total of 20 samples were drilled. Fig. 3 shows the drilled samples of the Uncoated drill.

The samples in the intervention group were drilled similarly to that of the control group, but an AlTiN coated HSS drill of 8mm diameter was used. The AlTiN drill was shown in Fig. 4. A total of 20 samples were drilled using this tool. Fig. 5, shows the drilled samples of the AlTiN coated HSS drill.

The surface roughness of the samples was obtained using an (SJ410-Mitutoyo) surface roughness tester. The surface roughness tester was shown in Fig. 6. The tests were conducted on 40 samples as per ASTM standards.

The data was collected by mounting the sample on the surface roughness tester and the needle was made to detect the surface of the sample. Then the measured surface roughness (μm) data was noted.

Statistical analysis

The IBM SPSS software V26 programming bundle was utilized in this research for statistical analysis. The samples were tested by comparing the control group and intervention group. The independent variables were speed (rpm) and feed rate (mm/rev) and the dependent variables were the values of surface roughness (L. H. Li et al. 2018)). The one-way ANOVA method was used for statistical tests.

Results

The surface roughness of samples machined using AlTiN coated HSS drill (intervention group) has lower surface roughness than samples machined using an Uncoated drill (control group). Table 1 shows the surface roughness values for the control group and intervention group. Table 2 shows the descriptives for AlTiN coated HSS and Uncoated drill, including the standard deviation. The obtained mean value for AlTiN was 1.1336 μm and for uncoated 1.9502 μm. Table 3 shows the results obtained from the One-way ANOVA (Analysis of Variance). The statistical significance value of $p = 0.025$ ($p < 0.050$) was obtained. Fig. 7 shows the graph plotted using the mean surface roughness of AlTiN coated and Uncoated samples. It shows the Mean Error bars of 95% Confidence Interval mean and the Error bars of ± 1 standard deviation has been obtained from the graph. From the result, the mean values of the two groups were different.

Discussion

The lower surface roughness was obtained when the samples were drilled using the AlTiN coated HSS drill. From the descriptive statistical analysis results (Table 2), it was found that the mean surface roughness of the intervention and control groups is 1.1336 μm and 1.9502 μm. The one-way ANOVA test shows a significant value of 0.025 for 40 samples (Table 3).

The AlTiN coated drills were manufactured under PVD (physical vapor deposition) method, have higher efficiency, and also have faster material removal rate. Due to the aluminum coating, it is resistant to wear and has less friction when compared to uncoated drills (Barshilia 2014). The mechanism and working procedure of CNC machines has been discussed by (Smid 2010). The surface roughness for AA 6063 was done using the Uncoated twist drill that produced the Ra = 1.53 μm to 3.63 μm (Zhang et al. 2013). By varying the cutting speed from 2200 to 2800 rpm at the angles of 90^0 and 135^0 respectively (Shekar 2019). The obtained surface roughness value is Ra = 2.07 μm. The surface roughness was expressed as the non-uniform structures of materials resulting from various machining operations. In quantifying surface roughness, the average was represented with the (Ra) symbol, which is commonly used (Bennett 2007). Theoretically, Ra is the arithmetic average value of departure of the profile from the mean line throughout the sampling length. It is also important for controlling machining performance (Burakowski and Wierzchon 1998).

Machining aluminum is one of the tough jobs because of its soft nature. During machining, the Built-in Edges (BUE) were formed the machining such materials and it represents an unfavorable impact on the surface nature of the material is the limitation of this study. The surface roughness can be improved by varying and optimizing the materials. The surface finish in the aluminum alloy has been studied and can be developed in the future.

Conclusion

Within the limitations of this study, the detection of Surface roughness during Novel CNC drilling of AA6063 samples machined using AlTiN coated drill produced the value of 1.1336 μm and the samples machined using an Uncoated drill produced 1.9502 μm. According to the ANOVA test, the mean significance value for samples machined using AlTiN coated and Uncoated drill is p= 0.025 (p <0.050). This study concludes that the AA6063 samples machined using AlTiN coated drill have produced less Surface roughness than the Uncoated drill.

DECLARATIONS:

Conflict of Interests

The authors of this paper declare no conflict of interest

Authors Contribution

Author GV was involved in the data collection, data analysis, and manuscript writing. Author BR was involved in conceptualization, data validation, and critical review of the manuscript.

Acknowledgment

The authors would like to express their gratitude towards Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (Formerly known as Saveetha University) for providing the necessary infrastructure to carry out this research work successfully

Funding:

We thank our financial sponsors for financial support that enabled us to complete this study.

1. Veekay Process Pvt. Ltd…
2. Saveetha School of Engineering.
3. Saveetha Institute of Medical and Technical Sciences.
4. Saveetha University.

References

1. Adhinarayanan, Rajesh, Aravindh Ramakrishnan, Gopal Kaliyaperumal, Melvinvíctor De Poures, Rajesh Kumar Babu, and Damodharan Dillikannan. 2020. “Comparative Analysis on the Effect of 1-Decanol and Di-N-Butyl Ether as Additive with diesel/LDPE Blends in Compression Ignition Engine.” *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, June, 1–18.
2. Al-Janan, Dony Hidayat, and Tung-Kuan Liu. 2016. “Path Optimization of CNC PCB Drilling Using Hybrid Taguchi Genetic Algorithm.” *Kybernetes*. https://doi.org/10.1108/k-03-2015-0069.
3. Arun Prakash, V. R., J. Francis Xavier, G. Ramesh, T. Maridurai, K. Siva Kumar, and R. Blessing Sam Raj. 2020. “Mechanical, Thermal and Fatigue Behaviour of Surface-Treated Novel Caryota Urens Fibre–reinforced Epoxy Composite.” *Biomass Conversion and Biorefinery*, August. https://doi.org/10.1007/s13399-020-00938-0.
4. Aurtherson, P. Babu, Bhanu Teja Nalla, Karthikeyan Srinivasan, Kulmani Mehar, and Yuvarajan Devarajan. 2021. “Biofuel Production from Novel Prunus Domestica Kernel Oil: Process Optimization Technique.” *Biomass Conversion and Biorefinery*, May. https://doi.org/10.1007/s13399-021-01551-5.
5. Barshilia, Harish C. 2014. “Growth, Characterization and Performance Evaluation of Ti/AlTiN/AlTiON/AlTiO High Temperature Spectrally Selective Coatings for Solar Thermal Power Applications.” *Solar Energy Materials and Solar Cells*. https://doi.org/10.1016/j.solmat.2014.07.037.
6. Bennett, Jean M. 2007. “Characterization of Surface Roughness.” *Nanostructure Science and Technology*. https://doi.org/10.1007/978-0-387-35659-4_1.
7. Bhansali, Karan J., Kamlesh R. Balinge, Subodh U. Raut, Shubham A. Deshmukh, M. Senthil Kumar, C. Ramesh Kumar, and Pundlik R. Bhagat. 2021. “Visible Light Assisted Sulfonic Acid-Functionalized Porphyrin Comprising Benzimidazolium Moiety for

Photocatalytic Transesterification of Castor Oil." *Fuel* 304 (November): 121490.
8. Burakowski, Tadeusz, and Tadeusz Wierzchon. 1998. *Surface Engineering of Metals: Principles, Equipment, Technologies*. CRC Press.
9. Deepanraj, B., N. Senthilkumar, D. Mala, and A. Sathiamourthy. 2021. "Cashew Nut Shell Liquid as Alternate Fuel for CI Engine—optimization Approach for Performance Improvement." *Biomass Conversion and Biorefinery*, February. https://doi.org/10.1007/s13399-021-01312-4.
10. Jaeggi, Marco, Sharon Gyr, Monika Astasov-Frauenhoffer, Nicola U. Zitzmann, Jens Fischer, and Nadja Rohr. 2022. "Influence of Different Zirconia Surface Treatments on Biofilm Formation in Vitro and in Situ." *Clinical Oral Implants Research*, February. https://doi.org/10.1111/clr.13902.
11. Jancewicz, Kacper, and Mariusz Szymanowski. 2018. "The Relevance of Surface Roughness Data Qualities in Diagnostic Modeling of Wind Velocity in Complex Terrain: A Case Study from the Śnieżnik Massif (SW Poland)." *Geoinformatics and Atmospheric Science*. https://doi.org/10.1007/978-3-319-66092-9_7.
12. Jayanth, Bellappu Venkat, Melvin Victor Depoures, Gopal Kaliyaperumal, Damodharan Dillikannan, Dilipsingh Jawahar, Kumaran Palani, and Ganesha Prasad Meravanigee Shivappa. 2021. "A Comprehensive Study on the Effects of Multiple Injection Strategies and Exhaust Gas Recirculation on Diesel Engine Characteristics That Utilize Waste High Density Polyethylene Oil." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, June, 1–18.
13. Kalamkar, Vilas R., and Katarina Monkova. 2020. *Advances in Mechanical Engineering: Select Proceedings of ICAME 2020*. Springer Nature.
14. Kamath, Manjunath, Subha Krishna Rao, Jaison, Sridhar, Kasthuri, Gopinath, Sivaperumal, and Shantanu Patil. 2020. "Melatonin Delivery from PCL Scaffold Enhances Glycosaminoglycans Deposition in Human Chondrocytes – Bioactive Scaffold Model for Cartilage Regeneration." *Process Biochemistry* 99 (December): 36–47.
15. Khule, Tushar, Rahul Naravade, and Sagar Shelke. 2020. "Surface Grinding Parameters Optimization of Austenitic Stainless Steel (AISI 304)." *International Journal of Scientific Research in Science, Engineering and Technology*. https://doi.org/10.32628/ijsrset207337.
16. Kiswanto, G., D. L. Zariatin, and T. J. Ko. 2014. "The Effect of Spindle Speed, Feed-Rate and Machining Time to the Surface Roughness and Burr Formation of Aluminum Alloy 1100 in Micro-Milling Operation." *Journal of Manufacturing Processes*. https://doi.org/10.1016/j.jmapro.2014.05.003.
17. Kumar, A. Sravan, A. Sravan Kumar, Sankha Deb, and S. Paul. 2018. "A Study on Micro-Milling of Aluminium 6061 and Copper With Respect to Cutting Forces, Surface Roughness and Burr Formation." *Volume 4: Processes*. https://doi.org/10.1115/msec2018-6570.
18. Li, Leijun, Dilip Kumar Pratihar, Suman Chakrabarty, and Purna Chandra Mishra. 2020. *Advances in Materials and Manufacturing Engineering: Proceedings of ICAMME 2019*. Springer Nature.
19. Li, L. H., N. H. Yu, C. Y. Chan, and W. B. Lee. 2018. "Al6061 Surface Roughness and Optical Reflectance When Machined by Single Point Diamond Turning at a Low Feed Rate." *PloS One* 13 (4): e0195083.
20. Mukhopadhyay, Arkadeb, Tapan Kumar Barman, Prasanta Sahoo, and J. Paulo Davim. 2019. "Modeling and Optimization of Fractal Dimension in Wire Electrical Discharge Machining of EN 31 Steel Using the ANN-GA Approach." *Materials* 12 (3). https://doi.org/10.3390/ma12030454.
21. Rajasekaran, S., D. Damodharan, K. Gopal, B. Rajesh Kumar, and Melvin Victor De Poures. 2020. "Collective Influence of 1-Decanol Addition, Injection Pressure and EGR on Diesel Engine Characteristics Fueled with diesel/LDPE Oil Blends." *Fuel* 277 (October): 118166.
22. Rajesh, A., K. Gopal, De Poures Melvin Victor, B. Rajesh Kumar, A. P. Sathiyagnanam, and D. Damodharan. 2020. "Effect of Anisole Addition to Waste Cooking Oil Methyl Ester on Combustion, Emission and Performance Characteristics of a DI Diesel Engine without Any Modifications." *Fuel* 278 (October): 118315.
23. Raju, P., K. Raja, K. Lingadurai, T. Maridurai, and S. C. Prasanna. 2021. "Glass/Caryota Urens Hybridized Fibre-Reinforced nanoclay/SiC Toughened Epoxy Hybrid Composite: Mechanical, Drop Load Impact, Hydrophobicity and Fatigue Behaviour." *Biomass Conversion and Biorefinery*, March. https://doi.org/10.1007/s13399-021-01427-8.
24. Sathiyamoorthi, Ramalingam, Gomathinayakam Sankaranarayanan, Dinesh Babu Munuswamy, and Yuvarajan Devarajan. 2021. "Experimental Study of Spray Analysis for Palmarosa Biodiesel-diesel Blends in a Constant Volume Chamber." *Environmental Progress & Sustainable Energy* 40 (6). https://doi.org/10.1002/ep.13696.
25. Shanmugam, Rajasekaran, Damodharan Dillikannan, Gopal Kaliyaperumal, Melvin Victor De Poures, and Rajesh Kumar Babu. 2021. "A Comprehensive Study on the Effects of 1-Decanol, Compression Ratio and Exhaust Gas Recirculation on Diesel Engine Characteristics Powered with Low Density Polyethylene Oil." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 43 (23): 3064–81.
26. Shekar, Ch. 2019. "Machining of Inconel -718 by EDM Using Taguchi Method for Optimization of Material Removal Rate & Surface Roughness." *International Journal for Research in Applied Science and Engineering Technology*. https://doi.org/10.22214/ijraset.2019.10064.
27. Smid, Peter. 2010. *CNC Control Setup for Milling and Turning: Mastering CNC Control Systems*. Industrial Press Inc.
28. Son, Nguyen Hong. 2020. "A Survey on the Effects of Cutting Parameters on Surface Roughness When Milling 40Cr Steel Using End Mill Cutter." *European Journal of Engineering Research and Science*. https://doi.org/10.24018/ejers.2020.5.1.1704.
29. Sudhakar, M. P., Merlyn Ravel, and K. Perumal. 2021. "Pretreatment and Process Optimization of Bioethanol Production from Spent Biomass of Ganoderma Lucidum Using Saccharomyces Cerevisiae." *Fuel* 306 (December): 121680.
30. Sui, Jianbo, Raja Kountanya, and Changsheng Guo. 2016. "Development of a Mechanistic Force Model for CNC Drilling Process Simulation." *Procedia Manufacturing*. https://doi.org/10.1016/j.promfg.2016.08.064.
31. Zhang, Wei, M. L. Zheng, M. M. Cheng, and W. T. Wang. 2013. "Experiment Research of Cutter Edge and Cutting Parameters Influence on Machined Surface Roughness for High Speed Milling Hardened Steel." *Advanced Materials Research*. https://doi.org/10.4028/www.scientific.net/amr.670.70.

TABLES AND FIGURES

Table 1. The experimental values of Surface Roughness for samples drilled using AlTiN coated HSS drill and Uncoated drill.

S. NO	SURFACE ROUGHNESS OF UNCOATED DRILL (µm)	SURFACE ROUGHNESS OF AlTiN COATED HSS DRILL (µm)
1	1.925	1.123
2	1.932	1.112
3	1.954	1.157
4	1.965	1.140
5	1.969	1.151
6	1.962	1.131
7	1.948	1.126
8	1.935	1.138
9	1.924	1.134
10	1.931	1.145
11	1.927	1.117
12	1.963	1.169

13	1.977	1.154
14	1.998	1.132
15	1.937	1.129
16	1.918	1.119
17	1.953	1.143
18	1.954	1.109
19	1.942	1.113
20	1.989	1.129

Table 2. Descriptive table represents the mean and standard deviation for AlTiN coated HSS drill and Uncoated drill.

Descriptives								
Surface roughness								
	N	**Mean**	**Std. Deviation**	**Std. Error**	**95% Confidence Interval for Mean**		**Minimum**	**Maximum**
					Lower Bound	**Upper Bound**		
Uncoated drill	20	1.9502	.02235	.00500	1.9397	1.9606	1.92	2.00
AlTiN Coated HSS drill	20	1.1336	.01623	.00363	1.1260	1.1411	1.11	1.17
Total	40	1.5419	.41395	.06545	1.4095	1.6742	1.11	2.00

Table 3. One-way ANOVA test represents the significance value for AlTiN coated HSS and Uncoated drills. It is observed that on performing One-Way ANOVA, there is a statistical significant difference for surface roughness ($p= 0.25$, $p<0.05$).

ANOVA					
SURFACE ROUGHNESS					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.668	1	6.668	17476.293	.025
Within Groups	.014	38	.002		
Total	6.683	39			

Fig. 1. Super Jobber Novel CNC drilling center.

Fig. 2. 8mm Uncoated drill

Fig. 3. 8mm AlTiN coated HSS drill.

Fig. 4. Samples drilled using Uncoated drill.

Fig. 5. Samples drilled using AlTiN coated HSS drill.

Fig. 6. Mitutoyo Surface Roughness Tester.

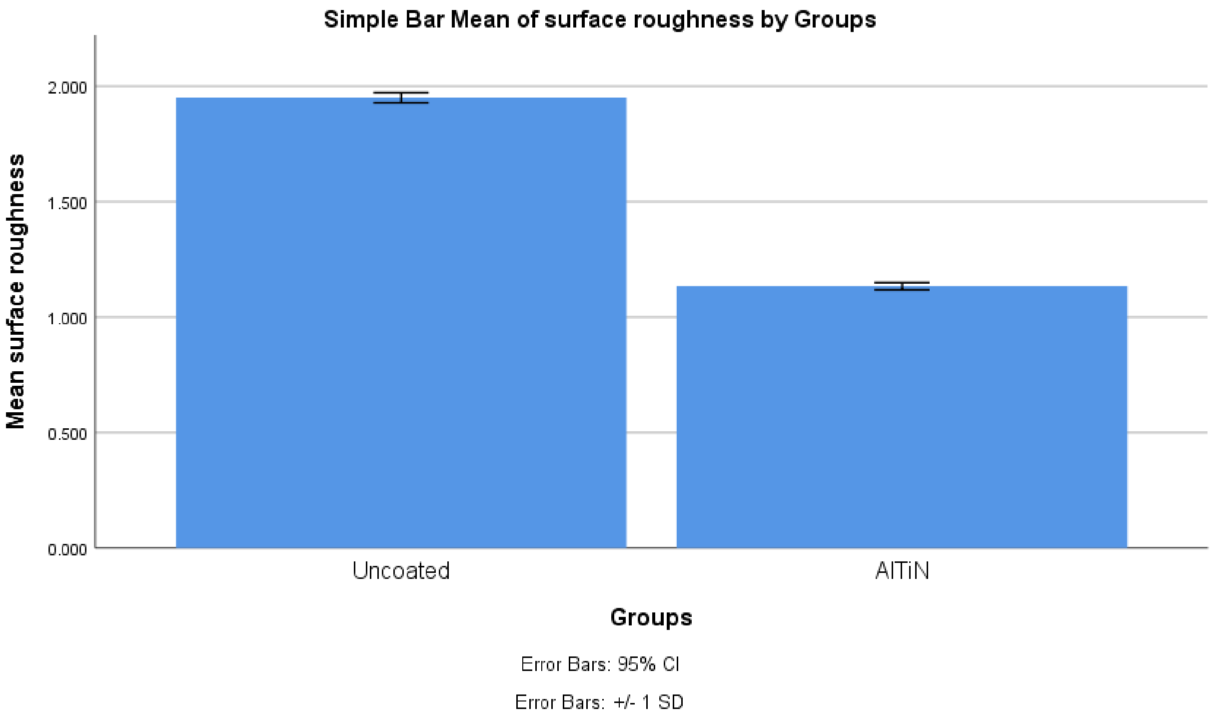

Fig. 7. Bar chart showing the comparison of mean values of Surface roughness between samples machined using AlTiN coated drill and Uncoated drill. The mean of samples machined using AlTiN coated drill is not significantly different from the samples machined using an Uncoated drill. X-axis: Mean Surface roughness of AA 6063 samples machined with AlTiN coated drill vs Uncoated drill. Y-axis: Mean values of groups ± 1 SD and error bars of 95% CI.