To minimize tool wear, new CNC drilling of stainless steel was performed with a comparison of the performance of TiN-coated drill bits and drill bits without a coating.

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ABSTRACT

Aim: In this experimental research, the performance of Titanium Nitride (TiN) coated drill bit and uncoated drill bit is compared during CNC drilling of SS316L stainless steel and a detailed analysis is made over the tool wear obtained by these materials. **Materials and Methods:** The experimental group was TiN coated drill bit and the control group was uncoated drill bit. SS316L stainless steel was used as a workpiece material in this experiment. By using drilling factors such as cutting speed, rate of feed and types of tool, 20 samples per group were required for machining both groups with 95% g power. **Result:** Based on the experiment of TiN coated drill bit with the uncoated drill bit, the mean t value of TiN was 0.8824 mm and the mean value of uncoated was0.7431 mm. The significance value obtained between the experimental group and control group is 0.018which is lower than the desired value 0.05 ($P<0.05$). **Conclusion:** Within the limits of this study, TiN coated drill bit provides superior tool wear than the uncoated drill bit during the CNC drilling process of stainless steel.

KEYWORDS: CNC drilling, Novel tool coating, SS316L Stainless Steel, Tool wear, Uncoated HSS drill bit, TiN coated HSS Drill bit.

INTRODUCTION

Drilling is a basic conventional machining process in which the drill bit is used to remove the material from the workpiece, when the fourth industrial revolution is reshaping the global landscape like never before, products must be produced in large quantities where the quality of the product must be higher as well. That is where the implication of CNC machining occurs (Tamizharasan et al. 2019). Drilling is the process of cutting holes in a solid material using a rotating cutting tool.When we need a circular hole in a workpiece of any size there, we can use a drilling operation, by a drilling operation you can form any size of holes in a workpiece. Although a lathe can be used for drilling, a drill machine is more ideal for drilling holes in a workpiece. Lower productivity was the main concern in industries forty to fifty years ago. It was also difficult to deliver the items with high dimensional precision and excellent surface finish. (Xiao, Song, and Zhao 2020) CNC machines have been developed

over time to achieve great dimensional accuracy and superior surface finish. TiN drill bit and uncoated drill bit were evaluated for tool wear improvement. The stainless steel used in this review was SS316L. This steel is used to make modern edges, screw drivers, aviation parts, and petrochemical applications because it has a higher solidity to weight ratio (Kelsen and Johnson, n.d.). Drilling is one of the most important metal cutting operations among traditional machining methods, accounting for 33% of all metal cutting operations. By subtracting the unworn size after machining from the clearance face size before machining, the size of the tool wear was estimated.The study of experimental and statistical analysis was made over using different types of coated nitride to improve the tool wear. It is found that the various cutting parameters will directly affect the tool wear of the workpiece during the tool wear process.

There are several researches conducted in the area of minimizing tool wear using CNC machining centers. Nearly 3255 similar articles published in Google Scholar and 1851 in Science Direct. In this study, TiN coated drill bits are used to drill 316 stainless steel, and the outcomes are compared to uncoated HSS drill bits. Tool wear analysis during stainless steel milling (Amaro, Ferreira, and Simes 2018), influence of tool wear in stainless steel turning (Saketi, Stby, and Olsson 2016), method of tool wear coating (Pyatykh, Savilov, and Timofeev 2021), study of tool wear in stainless steel designation of tool wear (Dyl 2021), wear of stainless steel (Perez, Tanaka, and Jibiki 2013). Relationship between tool wear and thermal coatings is the best-suited study among all those research papers carried out by (Amaro, Ferreira, and Simes 2018).(Bhavikatti et al. 2021; Karobari et al. 2021; Shanmugam et al. 2021; Sawant et al. 2021; Muthukrishnan 2021; Preethi et al. 2021; Karthigadevi et al. 2021; Bhanu Teja et al. 2021; Veerasimman et al. 2021; Baskar et al. 2021)

From all the above mentioned research works, it is understood that TiN drill bit is a capable cutting tool. But by using this insert not many research works have been conducted in the field of improving tool wear. In this work, evaluation of TiN drill during dry CNC machining of SS316L Stainless steel is a novel thing. Hence this experimental research aims to evaluate the performance of TiN drill with uncoated drill during machining of SS316L Stainless steelAs a result, the goal of this study is to compare the performance of TiN coated drill bits with uncoated drill bits in order to obtain lower tool wear and boost productivity.

MATERIALS AND METHODS

The sample specimen that was involved in this study was SS316L stainless steel. In this experiment, there were two groups: an experimental group and a control group. The TiN coated drill bit and uncoated drill bit were used as cutting tools. The CNC machining facility at Saveetha Industries, Saveetha School of Engineering (SSE), Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai, was used to do all of the innovative drilling in this project. One set of 20 samples for TiN coated drill bit and another set of 20 samples for uncoated drill bit were used during novel CNC drilling (Jalali and Kolarik 199). The sample size was calculated with 95 % g power using a clinical online sample size calculator. The mean value and standard deviation consideration for this work were

0.8824 mm and 0.28822 mm respectively during the CNC drilling process.

Tool wear is a popular and important making method. The workpiece material used in this experimental investigation was SS316L stainless steel. Because of its high hardness, toughness, exceptional resistance to oxidation, yield strength, and outstanding ductility, SS316L stainless steel was chosen for this experiment. SS316L stainless steel cylindrical rod (50 mm length and 20 mm diameter) was cut into required pieces to the dimension of 50mm length and 20mm diameter for conducting this experiment. For innovative drilling, steel cylindrical rods were cut into appropriate sample pieces with a length of 50 mm and a diameter of 20 mm. Mehta Metals in Chennai supplied these samples. Chemical composition of SS316L Stainless Steel is shown in Table 1.

As an experimental group, a TiN coated drill bit was employed. The fast preparations, abbreviated as HSS, are a subcategory of hardware prepares that are known for their ability to machine and cut materials at rapid speeds (high hot hardness). It's not surprising that it's used in power-saw cutting blades and boring instruments. In comparison to more seasoned high-carbon steel instruments, high velocity steel can withstand higher temperatures without blowing its top (hardness). A correct solidifying reaction should be offered in heat treatment to achieve fantastic cutting execution from HSS.The properties of TiN as shown in Table 4 and the experimental group as shown in Fig. 1.

As a control group, an uncoated HSS drill bit was employed. This drill bit is mainly used to machine non-ferrous materials, bearing balls and nozzles. The specification of the insert Uncoated - Specification- Titanium nitride uncoated drilling, Negative relief angle, Fixing hole diameter -20 mm, Drill depth of hole 30 mm. The chemical composition of the Uncoated drill bit is shown in Table 2 and the control group as shown in Fig. 2.

The CNC drilling machine used for this experiment was CNC YCM EV1020A machining center. For the drilling process, a workpiece measuring 50 mm in length and 20 mm in diameter was clamped. The TiN coated drill bit and uncoated drill bit were used to drill the samples. Saveetha Industries, Saveetha School of Engineering (SSE), Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai was used to carry out the drilling process and surface roughness measurement.The specifications of CNC drilling machines are; Maximum drill diameter - 20 mm, Maximum drill diameter of hole - 30mm, Maximum length - 50 mm. Maximum spindle speed - 2500 rpm. The input parameters used were cutting speed, rate of feed and type of tool (Abas et al. 2020). The drilled specimens were positioned on a tool weartester to measure tool wear. The specification of this tool wear tester. Measuring range X-axis - 20mm (1inch); Measured profiles - roughness; graph analysis, diameter of length - 50 mm; Z1-axis (detector unit) - 860 mm.

STATISTICAL ANALYSIS

The mean, standard error, and standard deviation were calculated using the SPSS statistical package. The statistical programme SPSS v.26 was used to calculate the mean, standard error, and standard deviation. As a significant threshold, the probability value $P < 0.05$

was used. To obtain a 95% confidence level, 40 samples were collected for analysis. An independent sample T-test was used to assess the importance of the TiN coated drill bit over the uncoated drill bit.

RESULT

Material composition of SS316 stainless steel and Coated drill tool Chemical Composition is shown in Table 1 and 2 respectively. The properties of TiN coated drill bit shown in Table 3. The TW of specimens machined with TiN and uncoated Drill bits was measured and tabulated after the drilling process was completed. The measured tool wear values are shown in Table 4. To obtain the tool wear values, both the experimental and control groups used conventional input factors such as cutting speed, rate of feed, and types of tool and the obtained tool wear values are shown in Table 5. The TiN Drill bit has a standard deviation of 0.28822 and a mean value of 0.8824 mm , according to the group statistical analysis (Table 6). Table 7 presents the results of the Independent Sample T-test and The significant value of $P = 0.018 (P < 0.05)$. Fig. 1 and Fig. 2 show the TiN drill bit and the HSS drill bit respectively. Fig. 3 and Fig. 4 show the drill bit configuration and the tool setup respectively. Fig. 5 depicts a CNC machining center which is used to carry out the drilling process. The tool wear value difference between the experimental group of0.8824mm and the control group of 0.7431 mm is shown in the bar graph (Fig. 6). The TiN drill bit has a higher mean accuracy and standard deviation than the uncoated HSS drill bit.

DISCUSSION

The mean Tool wear(TW) for TiN drill bits was 0.8824 mm with a standard deviation of 0.28822 mm, which was much lower than the mean TW for HSS drill bits, which was 1.06250 mm with a standard deviation of 0.7431, as shown in Table 6. The significance of this comparative study was $P = 0.010$ ($P < 0.05$), as shown in Table 7, and the analysis was carried out with a 95% percent confidence level, as shown in Table 5. As shown in Fig. 6, a clustered bar graph was utilised to compare the mean TW of uncoated HSS drill bits and TiN drill bits. When comparing TiN drill bits to HSS drill bits, the graph shows that TiN drill bits have the lowest TW. The authors stated that better surface finish is attained by TiN coated because it has better physical qualities such as better hardness and rigidity than the uncoated drill bit (Chakraborty et al. 2015).

The selection of independent input parameters of this experiment is in line with the findings of the above authors. The researchers used three important cutting parameters namely, cutting speed, feed rate and depth of cut, which have been considered during the machining of TiN (Saeidi et al. 2019). The TW was lowered in a dry machining environment using optimized machining parameters in the work. The results of this investigation differed from those of that study because more coolant was used in this trial to reduce burr formation and input parameters were kept constant (Smulders and Kosian, 2016). This may be because that experiment might have been conducted with different input parameters and working conditions. The temperature caused due to dry machining of the workpiece is really high, which may lead

to deformation of the workpiece (Zuilhof, 2016) .

The machining parameters play an essential part in the innovative drilling process and have an impact on the drill bit performance. This demonstrates that coated drill bits are more durable than uncoated drill bits.The coating has a strong heat and oxidation resistance. This allows for faster cutting speeds and, as a result, faster work processes. TiN coating can provide up to 10 times the service life of uncoated tools, depending on the application. However even if the tool wear is evident, under careful observation, it was seen that the tool coating was not completely eroded in any part of the tool. Also, there was no significant change in the tool performance relative to the tool coating wear. Hence it can be concluded that the tool wear, even if inconsistent, was not significantly affecting the tool wear in this study.

CONCLUSION

In the Machining of, the SS316L stainless steel example material was drilled with an HSS drill instrument and a TiN coated drill device in a Vertical Machining Center CNC. A self-contained example t-test in SPSS programming was used to calculate tool wear for both instruments. The TiN coated apparatus has a mean value instrument wear (0.8824 mm), which is a substantial improvement from the HSS drill's mean value TW (0.7431 mm). Tool wear is higher in uncoated HSS bores than in TiN-coated boring machines, according to research. The machining was done on a CNC machine with no coolant and variable axle speed and feed rates in dry conditions.

DECLARATIONS

Conflict of interest

The authors of this paper declare no conflict of interest.

Authors Contribution

Author MST was involved in data collection, data analysis, and manuscript writing. Author CT was involved in conceptualization, data validation, and critical review of manuscript.

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TABLES & FIGURES

Table 1. Chemical composition of SS316L Stainless Steel

Elements	Fe	C	Cr	Mn	Si	P
Wt%	<0.15%	12.0-14.0%	<1.0%	<1.0%	<0.04%	>0.3%

Table 2. Chemical composition of HSS Uncoated Drill bit

Elements	C	W	Mo	Cr	V	Si	Mn	S	P
Wt%	0.70-0.80%	17.5-19.0%	0.30%	3.80-4.40%	1.00-1.40%	0.20-0.40%	0.10-0.40%	0.030%	0.030%

Table 3. Chemical composition of TiN Coated Drill bit

Elements	Ti	Al	N
Wt%	27.02	26.86	46.12

Table 4. The Properties of TiN coated drill bit

S.no	Properties	
1	Density	5.4 gm/cm
2	Electrical resistivity (microhm-cm)	bulk 10-30; PVD 30-100; CVD 200-10,000
3	Thermal conductivity	bulk: 0.19 W/cm K
4	Thermal diffusivity	0.68 cm
5	Coefficient of thermal expansion	9.3 ppm/K [recall Si is 2.3 ppm/K]
6	Coefficient of elasticity	251 GPa [Si is about 100 GPa]
7	Melting point	melting point

Table 5. Tabulated TW values for TiN coated and uncoated which was measured with TW-tool wear tester.

S.No	TOOL WEAR (mm)	
	TiN Coated Drill Bit	**HSS Uncoated Drill Bit**
1	0.7531	0.4475
2	0.1892	0.6324
3	0.9751	0.7239
4	0.8124	0.8532
5	0.7641	0.7961
6	1.0665	0.6527
7	0.9961	0.7513
8	1.1121	0.5618
9	1.2891	0.6112
10	0.9682	0.6982
11	0.8741	0.8691
12	1.1841	0.6823
13	1.3442	0.9486
14	0.8136	1.2065
15	1.0762	0.6083
16	0.5194	0.7664
17	0.0534	0.6349
18	0.5936	0.8121
19	0.8257	0.7144

20	0.4475	0.6823

Table 6. Coated (Mean - 0.8824 and standard deviation - 0.28822) for the selected samples. The standard error mean value for TiN is 0.06445 and uncoated is 0.03505.

Group	N	Mean	Std. Deviation	Std. Error Mean
TiN Coated	20	0.8824	0.28822	0.06445
Uncoated HSS	20	0.7431	0.15675	0.03505

Table 7. Tabulation for independent sample T-test. The outcome of the independent sample T test shows a significant difference between the control group and experimental group.The significance value p = 0.018 (P < 0.05), t value is 1.899 and 1.899 and the df is 38 and 29.335**.**

		F	Sig.	t	df
TOOL WEAR	**Equal variances assumed**	6.088	0.018	1.899	38
	Equal variances not assumed			1.899	29.335

Fig 1: TiN Coated Drill Bit Specifications:- Maximum Size: 5.5 mm, Material type: High speed steel, Bit diameter: 10 mm, Tensile strength: 100-400 Mpa, Hardness: 80 HRC

Fig 2: HSS Uncoated Drill Bit. Specifications:- Maximum Size: 0.5-60 mm, Material type: High speed steel, Bit diameter: 10 mm, Tensile strength: 100-400 Mpa, Hardness: 45-80 HRC

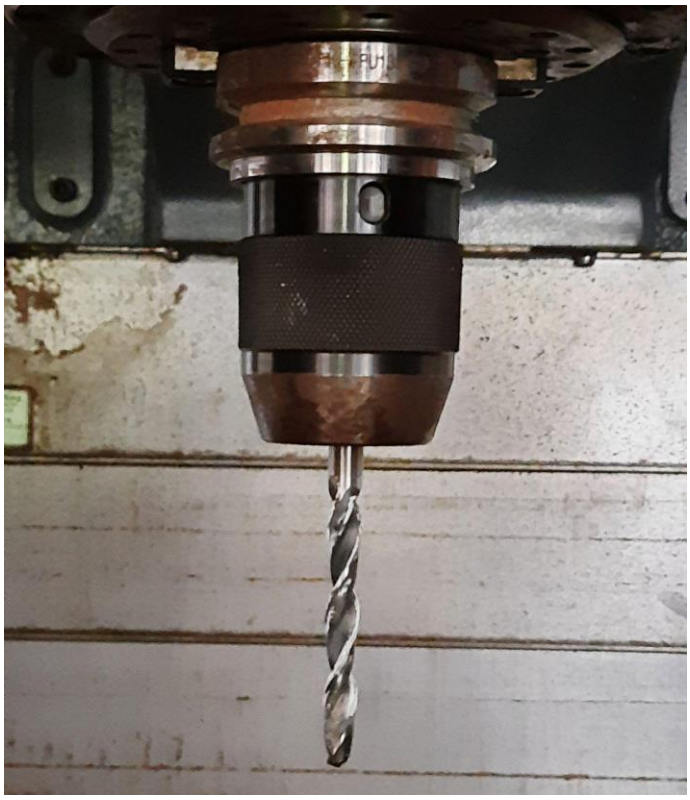

Fig 3: Drill Bit Setup

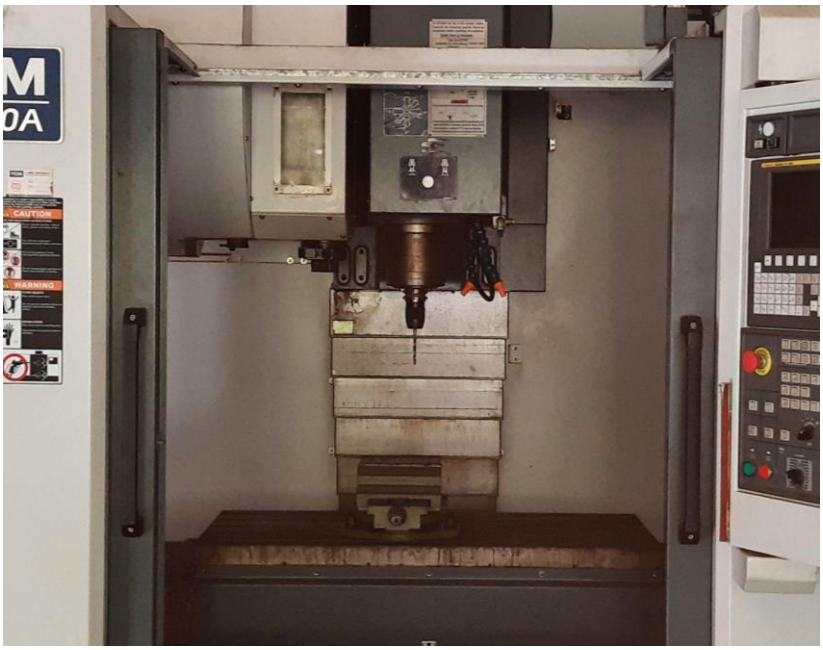

Fig 4: Tool Setup For Machining

Fig 5:CNC MACHINING - YCM EV1020A. Specifications:- Spindle Speed: 45~10,000rpm; Spindle Power (opt.): 5.5/7.5kW (7.5/11kW) & 7.4/10HP (10/14.8HP); Spindle Taper: BT40; X-axis Travel: 1,020mm 40.2"; Y-axis Travel: 520mm 20.5"; Z-axis Travel: 540mm 21.3"; Distance Between Spindle Nose & Table Top: 140mm~680mm 5.5"~26.8"; Rapid Feed Rate: 36/36/24 m/min, 1,417/1,417/945 ipm; Cutting Feed Rate: 1~10,000mm/min, 0.04~394 ipm.

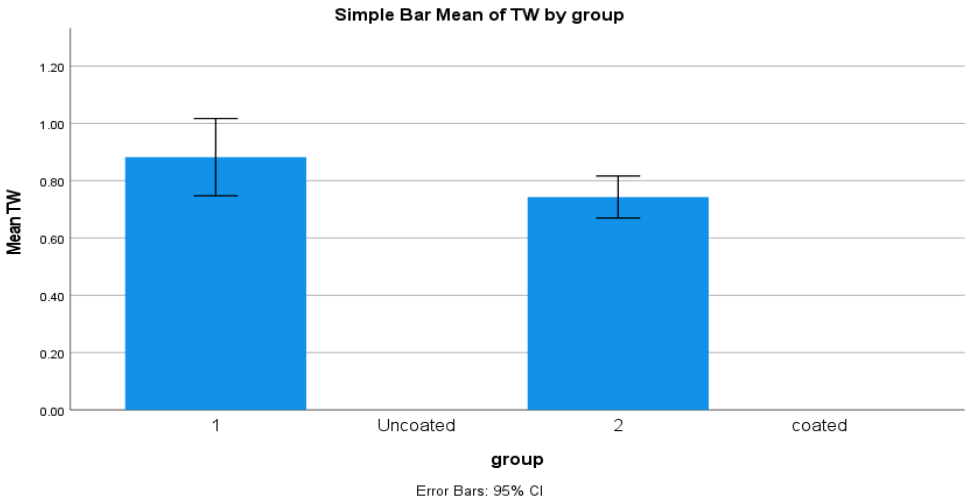

Fig 6: Comparison of coated and Uncoated Drill Bit in terms of mean Tool wear. The mean Tool wear of TiN Coated is low compared to uncoated HSS drill and the standard deviation of TiN Coated is less than uncoated HSS drill. X -Axis : TiN Coated vs uncoated HSS drill. Y Axis : Mean accuracy of detection + 1 SD