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Effects of Cutting Parameters on Tool Wear and Chip Shape when Dry Turning 6060 Aluminium Alloy Using Different Carbide Tool Geometries

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Abstract

This study presents an experimental investigation of tool wear and chip shape after turning 6060 aluminium alloy using wiper and conventional cutting tools under dry cutting conditions. The influence of parameters such as cutting speed, feed rate, depth of cut, and tool type on tool wear and chip shape were examined. A Taguchi L_9 orthogonal array was employed to optimise the cutting parameter, and the effect of each parameter on tool wear was determined using analysis of means (ANOM) and analysis of variance (ANOVA). It was found that a combination of a cutting speed of 1000 rpm, feed rate at 0.1 mm/rev, and depth of cut of 0.5 mm achieved minimal tool wear when dry turning 6060 aluminium alloy using wiper tools. Also, the ANOVA indicated that the main factor contributing to lower tool wear was cutting speed followed by feed rate, with percentage contribution ratios (PCRs) of 54.75% and 37.67% respectively. This confirms that the relationship between cutting speed and tool wear is proportional. Additionally, the ANOVA results demonstrated that the depth of cut, and tool type had little impact on tool wear. Although the wiper and conventional tools are made of similar material with different nose geometries, the wiper insert showed limited abrasion at the higher cutting speed compared to the conventional one. All turning tests produced long irregular continuous curled chips at the beginning of the cutting process, which then changed from the curled to a string-like shape wrapped around the insert tip and the machined part at the end of the turning process. Meanwhile, all the cutting parameters were found to have only a minor impact on chip shape when dry turning 6060 aluminium alloy.

Keywords: Dry turning, 6060 aluminium alloy, wiper and conventional coated carbide tools, tool wear, chip shape.

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تأثيرعوامل التشغيل الميكانيكي على تآكل آداة القطع وشكل الرقاقة عند عملية الخراطة الجافة لسبيكة الألومنيوم 6060 باستخدام آدوات قطع كربيدية مختلفة الأبعاد

صلاح الغرياني [*1] ، الطاهر ضو [2]

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الملخص

تقدم هذه الورقة دراسة معملية عن مدى تأكل أداة قطع المعادن وشكل الرقاقة أثناء الخراطة (CNC Machining) لسبيكة الألومنيوم 6060 بإستخدام آداة القطع التقليدية (Conventional cutting tools) وآداة القطع الماسحة (Wiper cutting tools) في ظل ظروف القطع الجاف. تهدف الورقة بشكل أساسي لدراسة مدى تأثير مدخلات عملية الخراطة والتي تشمل سرعة القطع ومعدل التغذية وعمق القطع ونوع آداة القطع على مخرجات العملية والمتمثلة في شدة تآكل آداة القطع (Tool wear) وشكل الرقاقة (Chip shape). تم تطبيق منهجية تاقوتشتي (Taguchi L_9) لتنفيذ الجانب العملي من هذه الدراسة، مع إستخدام البرنامج الإحصائي Minitab 20 لتحليل البيانات بواسطة (ANOVA). أظهرت النتائج أن الظروف المثلى لتحقيق أقل قيمة لمتوسط تآكل أداة القطع (Tool Wear) هي عند سرعة القطع 1000 لفة في الدقيقة، ومعدل التغذية 0.1 مم/دورة، وعمق القطع 0.5 مم، عند إستخدام آداة القطع (Wiper cutting tools). أشارت النتائج كذلك الى أن العامل الرئيسي الذي ساهم في تقليل تآكل آداة القطع هو سرعة القطع يليها معدل التغذية، بنسبة مساهمة مئوية تبلغ 54.75% و37.67% على التوالي. وهذا يؤكد العلاقة الطردية بين سرعة القطع وتآكل آداة القطع. بالإضافة إلى ذلك، أظهرالبحث أن عمق القطع Depth of cut ونوع آداة القطع Tool type كان لهما تأثير ضئيل على تآكل آداة القطع. رغم أن جميع أدوات القطع المستخدمة في هذه الدراسة مصنوعة من نفس المادة مع أختلاف في شكل حافة القطع Tool geometries إلا أن آداة القطع الماسحة (Wiper cutting tools) أظهرت تآكلًا محدودًا عند سرعة القطع القصوى مقارنة بآداة القطع التقليدية (Conventional cutting tools). أنتجت جميع إختبارات الخراطة رقائق ملتفة طويلة غير منتظمة ومستمرة في بداية عملية القطع، وتتغير بعد ذلك من شكل مجعد إلى شكل يشبه الخيط تلتف حول آداة القطع والمشغولة في نهاية الإختبار. وفي الوقت نفسه، وجد أن جميع جميع مدخلات العملية (السرعة ، معدل التغذية، وعمق القطع، ونوع آداة القطع وشكل حافة القطع) لهم تأثير طفيف على شكل الرقاقة الناتجة من عملية الخراطة لسبائك الألومنيوم 6060 تحت ظروف القطع الجاف.

الكلمات الدلالية: القطع الجاف، سبيكة الألومنيوم 6060، آداة القطع الكربيدية التقليدية، آداة القطع الكربيدية الماسحة، تأكل آداة القطع، شكل الرقاقة الناتجة من عملية الخراطة.

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1. Introduction

Aluminium alloys are well-known alloys for their superior mechanical and physical properties. 6060 aluminium alloy is an alloy in the wrought aluminium-magnesium-silicon family. It is considered to be a medium-strength alloy, with tensile strength up to 374 N/mm^2, and has a relatively low density of 2.70 g/cm^3 which makes it an attractive material for applications where weight is a concern [1]. The key properties and advantages of aluminium alloys of light weight, corrosion resistance, strength-to-weight ratio, formability, weldability, recyclability, high electrical and thermal conductivity, and cost-effectiveness make them essential materials in a wide range of industries, including construction, transportation, packaging, and electronics, among others [2]. The versatility and performance of aluminium alloys continue to drive their increasing adoption and importance in modern engineering and manufacturing [3]. Aluminium alloys generally have the highest degree of machinability compared to other lightweight metals such as magnesium and titanium alloys [4]. However, their high ductility and low tensile strength can be responsible for problems of adhesion, built-up edge formation, and a degraded surface finish. Thus, suitable cutting fluids and tools are recommended for the successful machining of aluminium alloys [5]. At the same time, high wear rates of cutting tools have been observed in aluminium-silicon alloys with high silicon content [6, 7]. Cutting tool technology has advanced significantly in the modern machining industry, and novel cutting tool designs and materials have been produced to fulfil the needs of machining applications [8]. Carbide tools are commonly used in machining aluminium alloys due to the relatively low cutting temperature required compared to machining of steel and refractory materials such as nickel- and titanium-based alloys. Generally, the wear that occurs on carbide tools is flank wear and is mainly determined by cutting speed [9]. Cutting tool geometry, including the angles involved, nose radius, and thickness, directly influences factors such as surface finish, tool wear, tool life, cutting forces, chip form, and overall productivity in machining operations [10]. Compared to conventional cutting tools, wiper tools are designed to have a multi-radius geometry to provide improved surface finish and extend tool life by removing imperfections left behind by conventional cutting inserts. The primary functionality of wiper cutting tools is to create a smoother surface on the workpiece with less tool wear, eliminating the need for additional finishing operations [11, 12]. Several experimental studies have compared the cutting performance of wiper and conventional tools in terms of tool wear. Experiments on the performance of wiper and conventional tools during the turning of AISI 4340 alloy steel were carried out by Abbas et al. [13]. They reported that wiper tools always showed lower values of minimum flank wear than conventional tools in all machining trials. Additionally, several studies found values of tool wear similar to or slightly better in wiper tool applications compared to conventional cutting tools [12]. Horváth et al. [14] studied tool wear when turning AISI 4340, and found that the minimum flank wear occurred with the wiper insert rather than conventional tools for all cutting lengths. Aouici et al. [15] investigated the cutting performance of ceramic wiper and conventional tools in the hard turning of AISI

4140. They demonstrated that the wiper ceramic cutting tools provided better machining performance than conventional tools in terms of flank wear. Khan et al. [16] also reported that wiper inserts produced longer tool life (30.57 min) compared to conventional ones (24 min) with a maximum tool wear of 200µm when hard turning hardened AISI D2 steel. A review of the literature indicates that various researchers have confirmed the merits of wiper inserts to attain better cutting performance when compared with conventional tools regardless of the workpiece material used. However, limited work so far has investigated the performance of wiper inserts compared to conventional inserts in terms of tool wear at different cutting conditions, particularly in the dry turning of aluminium alloys. Thus, the main objective of the present study is to find the optimum cutting conditions in terms of flank wear (V_B) using a Taguchi experimental design with different machining conditions when dry turning 6060 aluminium alloy. The study also compares the performance of conventional and wiper cutting tool in terms of tool wear and chip shape. It is worth mentioning here that this research is a continuation of a previous published study by the authors [17] which was investigated the influence of wiper and conventional tool on surface roughness when dry turning of 6060 aluminium alloy, while this study evaluated the effects of cutting parameters on tool wear and chip shape when dry turning of the same alloy using different carbide tool geometries. The outcomes of this work are expected to be immensely helpful to the metal cutting industry.

2. Design of Experiment (DoE)

The turning tests were performed using Taguchi's experimental method with an L9 orthogonal array. The four control factors were the cutting conditions of rotational cutting speed (N), feed rate (f), depth of cut (DoC), and tool type, and the response variable was tool flank wear (V_B). Table 1 shows the control factors and their corresponding levels. The analysis of means (ANOM) and variance (ANOVA) using Minitab 20 software was used to identify the optimal values of the control factors to obtain lower tool wear when dry turning 6060 aluminium alloy.

Table 1. Control factors and corresponding levels for tool wear

Control factors	Units	Levels			
		1	2	3	4
Feed rate	**mm/rev**	**0.1**	**0.15**	**0.2**	**0.25**
Rotational cutting speed	**rpm**	**1000**	**1200**		
Depth of cut	**mm**	**0.5**	**1.0**		
Tool type	**-**	**Wiper**	**Conventional**		

3. Experimental work

The workpiece material in this study is aluminium alloy 6060 in the form of bars. All turning tests were performed on a Computer Numerical Control (CNC) lathe machine (Pinacho Mustang 250) with power of 16 HP and maximum rotation speed of 2900 rpm.

Aluminium 6060 alloy samples with 35 mm diameter and 150 mm long were rigidly installed on the lathe machine. The chemical composition and mechanical properties of aluminium alloy 6060 are shown in Tables 2 and 3 respectively.

Table 2. Chemical composition of aluminium alloy 6060 [18]

Weight (%)	Al	Fe	Si	Mg	Mn	Zn	Cu
Minimum	97.8	0.1	0.3	0.35	0.0	0.0	0.0
Maximum	99.4	0.4	0.6	0.6	0.1	0.15	0.1

Table 3. Mechanical properties of 6060 aluminium alloy [18]

Property	Value
Ultimate tensile strength	374 N/mm^2
Yield strength	306 N/mm^2
Young's Modulus	185 N/mm^2
Elongation	15%
Density	2.710 g/cm^3

The tools used in this work were conventional (MP5-20S) and wiper (FW5-20S) coated PVD TiCN+Al_2O_3 + (TiCN) carbide tools from Walter Tools Co. Ltd., Germany. Both tool types have a similar ISO designation CNMG-120408 and the rhombic shape. Each test had a cutting length of 120 mm, and a fresh cutting tool was used for tool wear measurements. Table 4 shows the geometry of the cutting tool tips used in the machining tests. The insert tool was mounted on the tool holder coded as DCLNR-2020M12 from Sandvik Coromant Co., Sweden.

Table 4. Geometry of the wiper and conventional inserts used in the machining tests [19]

Nose radius (r_ε)	Rake angle (γ)	Cutting edge angle (K_r)	Clearance angle (α)	Included angle (ε)
0.8 mm	−6°	95°	0°	80°

Figure 1 shows the experimental set-up and tool wear measurement equipment, with images of the conventional and wiper inserts used in the trials, the CNC Pinacho Mustang 250 lathe machine and 6060 aluminium alloy machined bars, and the FL8000 upright metallurgical optical microscope used for tool wear measurement.

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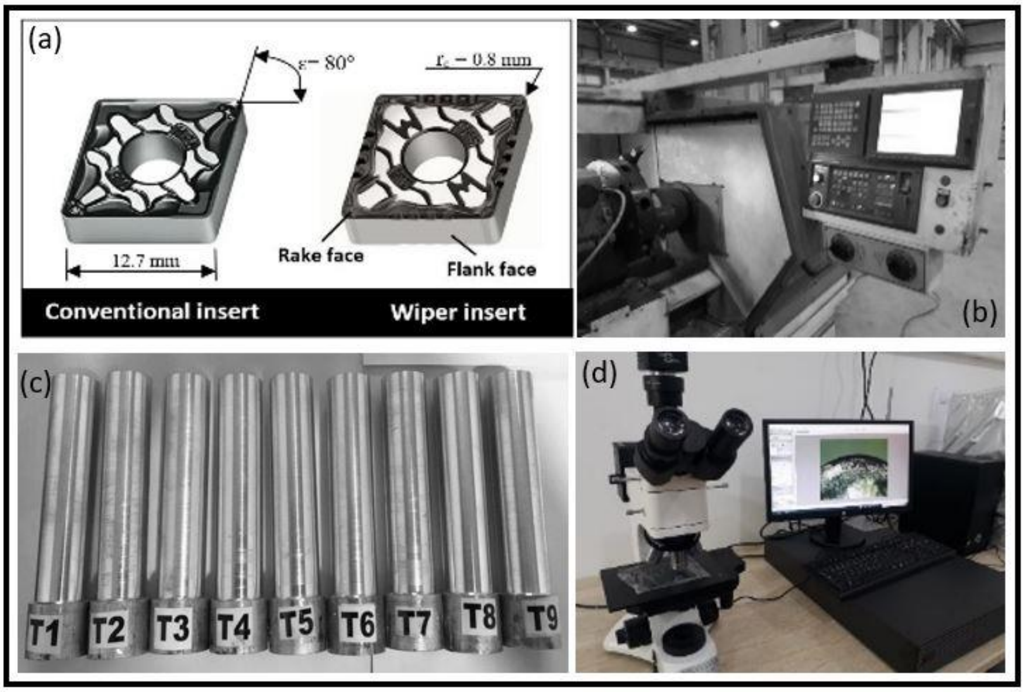


Figure 1. Experimental set-up: (a) cutting tools; (b) CNC Pinacho Mustang 250 machine; (c) 6060 aluminium machined bars; (d) FL8000 upright metallurgical optical microscope

4. Results and Discussion

4.1 Experimental data

Nine runs of turning trials using the Taguchi L_9 OA design for 6060 aluminium alloy at different cutting conditions using wiper and conventional tools have been performed. The values of control factors and tool wear measurements are shown in Table 5.

Table 5. Control factors and measured values of tool flank wear (V_B)

RUN	Feed rate (rev/min)	Cutting speed (rpm)	DoC (mm)	Tool type	V_B (µm)
1	0.25	1000	0.50	Conventional	102.5
2	0.25	1200	1.0	Wiper	115.1
3	0.20	1000	1.0	Conventional	101.6
4	0.20	1200	0.50	Wiper	110.9
5	0.15	1000	0.50	Wiper	100.8
6	0.15	1200	1.0	Conventional	107.2
7	0.10	1000	1.0	Wiper	98.2
8	0.10	1200	0.50	Conventional	102.7
9	0.10	1200	0.50	Wiper	102.0

4.2 Tool Wear Analysis

The effect of the four process factors of cutting speed, feed rate, tool type, and depth of cut on tool flank wear using the ANOM is shown in Figure 2.

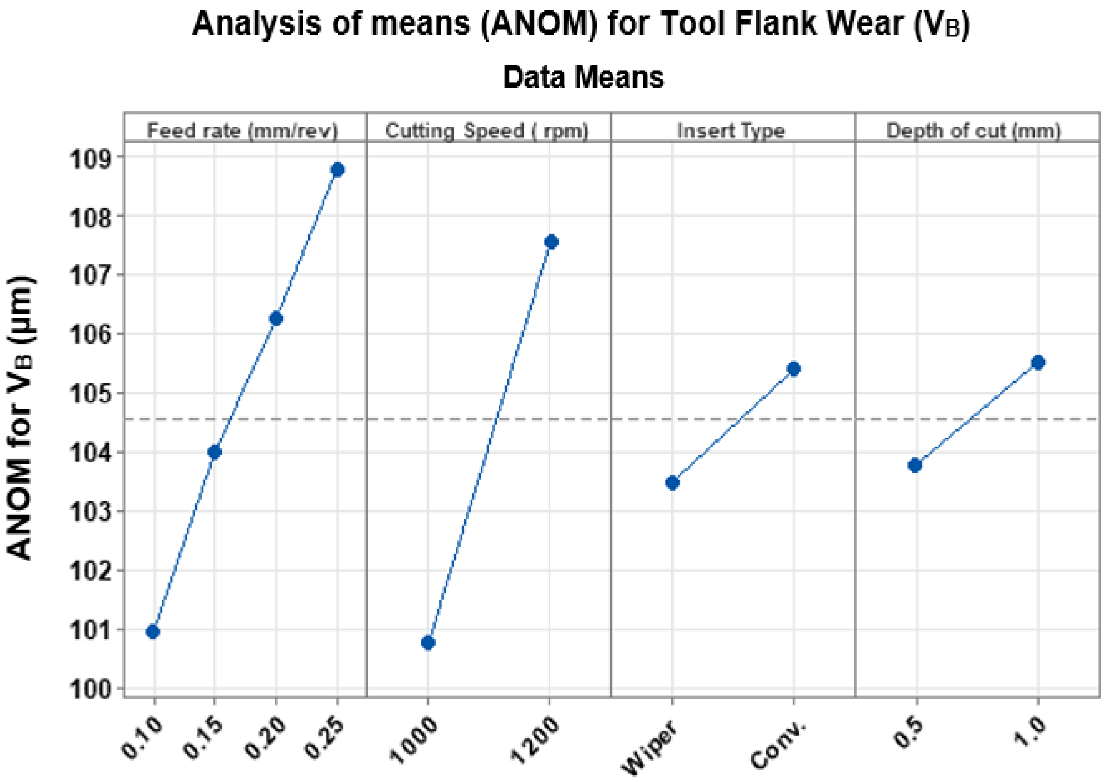


Figure 2. ANOM for tool flank wear (V_B)

The optimal cutting conditions that resulted in lower tool wear were a cutting speed of 1000 rpm, feed rate of 0.1 rev/mm, and depth of cut of 0.5 mm with the wiper cutting tool. It was found from the ANOVA shown in Table 6 that the variables with the most statistically significant effect on tool wear were cutting speed followed by feed rate, with percentage contribution ratios (PCRs) of 54.75% and 37.67% respectively. Meanwhile, cutting tool material and geometry and depth of cutting had less impact on tool wear. The wiper and conventional cutting tools exhibited similar cutting performance, because they are made of similar material (PVD-coated TiCN+Al_2O_3+TiCN tungsten carbide), while wiper geometry seemed to have an insignificant effect on tool wear. This confirms the notion that tool geometry is of more significance than tool wear for surface finish [20, 21]. However, the wiper insert showed more limited abrasion on the tool rake face compared with conventional insert at the maximum cutting speed of 1200 rpm, as shown in Figure. 3.

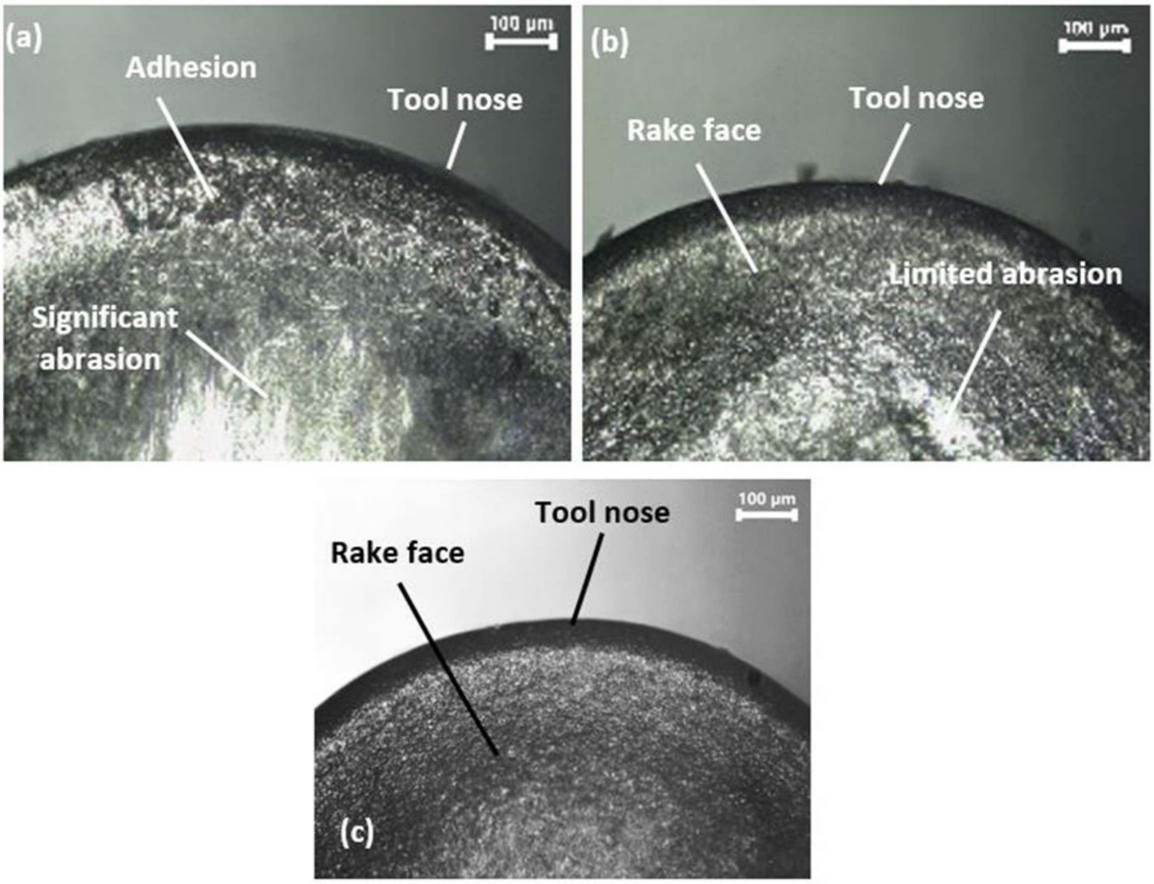


Figure 3. Tool wear for conventional tool (a) and wiper tool (b) at cutting speed of 1200 rpm, 0.1 feed rate and 0.25 mm depth of cut, while (c) fresh insert tool before the turning tests

Table 6. ANOVA results for tool flank wear (V_B)

Source	DF	SS	MSS	F	P	PCR
Feed rate (mm/rev)	3	109.091	36.364	12.19	0.05*	37.67 %
Rotational cutting speed (rpm)	1	129.149	129.149	43.30	0.022*	54.75 %
Insert type	1	11.468	11.468	3.84	0.189	4.86%
Depth of cut (mm)	1	6.463	6.463	2.17	0.279	2.72%
Error	2	5.965	2.983			
Total	8	262.862				

S= 1.72704   R-Sq= 97.47%   R-Sq (adj) = 89.88%

DF = Degrees of freedom
SS = Sum of squares
F= F-test value

* Significant at the 5% level and confidence level of 95%
P = Probability (P ≤0.05)

These trends are to some extent in accordance with findings in the available literature [13-15] that wiper inserts show better cutting performance compared to conventional tools. Figure 4 shows the interaction effects for tool wear ($\mathbf{V_B}$) of the cutting parameters tested. There are noticeable mutual interactions among all the parameters evaluated, particularly between feed rate and tool type as well as between feed rate and depth of cut. Nevertheless, other pairs of parameters exhibit only slight interaction, especially cutting speed and depth of cut as well as cutting speed and tool type. Additionally, the parallel trends of the plot lines also suggest a lack of interaction particularly between cutting speed and feed rate.

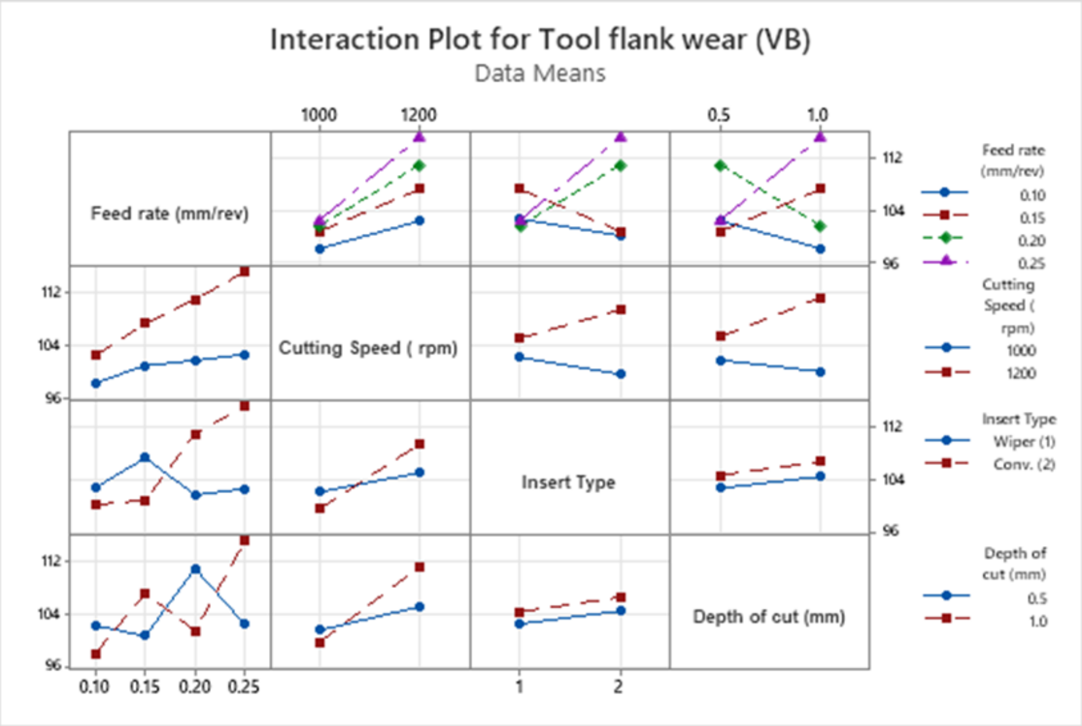


Figure 4. Interaction plot for tool flank wear (VB)

This agrees with the ANOVA results, suggesting that cutting speed and feed rate have a more substantial impact on tool wear than the other machining parameters of tool type and depth of cut. Figure 5 includes images captured of cutting temperature recorded at the maximum cutting speed of 1200 rpm for the wiper and conventional inserts using an Hti-type thermal imaging camera (HT-19 model). It can be concluded from these images that there was a slight difference in cutting temperature of about 6 ºC between the wiper and conventional tool at the same cutting condition, and this supports the tool wear results mentioned above.

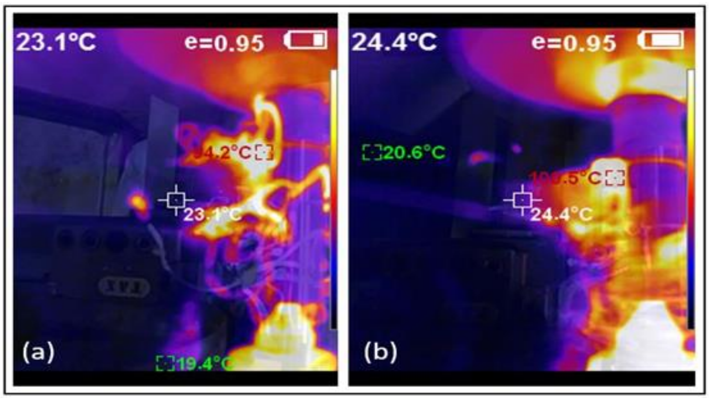


Figure 5. Captured images of cutting temperature obtained at the maximum cutting speed of 1200 rpm for wiper tool (a) and conventional tool (b) using an Hti-type thermal imaging camera (HT-19 model)

4.3 Chip Shape

Figure 6 shows the shapes of all collected chips during the dry turning (without coolant) of aluminium alloy 6060 under all cutting conditions (runs 1 to 9). Another machining test under wet (with coolant) cutting conditions (run 10) was also performed for comparison purposes only. In general, at the beginning of cutting, a long irregular continuous curled shape was observed for all chips produced during all dry machining tests. These long irregular continuous shapes were probably produced due to the high ductility of aluminium alloy 6060, which prevents the chip from breaking during the dry cutting process. After that, the shape of the chip then changed from a curled shape to a string-like shape that wrapped around the insert tip and the machined part at the end of the cutting process. This could be attributed to heat accumulated during the dry cutting process. It was seen that the radius of the curled chip increased with cutting length. This can probably also be attributed to the heat accumulated during the process of dry cutting the aluminium alloy 6060, which softens the metal and thus reduces the brittleness in the shear zone during the chip formation phase. Unexpectedly, however, the parameters of cutting speed, feed rate, depth of cut and tool type had little impact on chip shape during dry cutting compared to the wet cutting condition for the same 6060 aluminium alloy, where Figure 6 (run 10) shows a uniform continuous curled chip shape during wet turning. This finding differs somewhat from that of a recent study [22] which reported that chip shapes are similar under both dry and wet cutting conditions when turning Ti6Al4V alloy. However, it was revealed in that research that the properties of the workpiece material strongly affect chip formation in metal cutting, which explains the difference in chip shape from one metal to another [22].

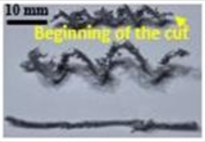
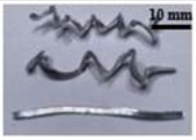
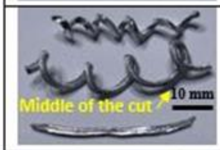
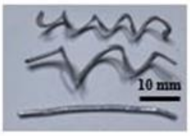
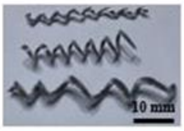
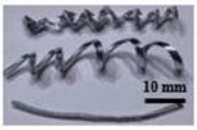
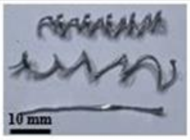
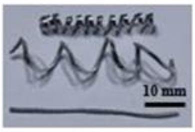
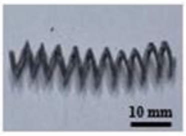
	**Run No. 1:** 1000 rpm, 0.25mm/rev, 0.5 mm and conventional tool (Dry turning)		**Run No. 6:** 1200 rpm, 0.15 mm/rev, 1 mm and conventional tool (Dry turning)
	**Run No. 2:** 1200 rpm, 0.25 mm/rev, 1 mm and wiper tool (Dry turning)		**Run No. 7:** 1000 rpm, 0.1 mm/rev, 1 mm and wiper tool (Dry turning)
	**Run No. 3:** 1000 rpm, 0.2 mm/rev, 1 mm and conventional tool (Dry turning)		**Run No. 8:** 1200 rpm, 0.1 mm/rev, 0.5 mm and conventional tool (Dry turning)
	**Run No. 4:** 1200 rpm, 0.2 mm/rev, 0.5 mm and wiper tool (Dry turning)		**Run No. 9:** 1200 rpm, 0.1 mm/rev, 0.5 mm and wiper tool (Dry turning)
	**Ru n No. 5:** 1000 rpm, 0.15 mm/rev, 0.5 mm and wiper tool (Dry turning)		**Run No. 10:** 1200 rpm, 0.1 mm/rev, 0.5 mm and wiper tool (Wet turning)

Figure 6. Chip shape when dry and wet turning 6060 aluminium alloy in all cutting conditions

5. Conclusions

This study has investigated the impact of cutting parameters on tool wear and chip shape when dry turning 6060 aluminium alloy using different carbide tool geometries. Four different control factors were selected in this study: namely, cutting speed, feed rate, tool type, and depth of cut. The following conclusions were drawn:

- A combination of a cutting speed of 1000 rpm, feed rate at 0.1 mm/rev, and depth of cut of 0.5 mm achieved lower tool wear when dry turning 6060 aluminium alloy using wiper tools.
- Cutting speed was the most statistically significant factor in minimising tool wear, followed by feed rate, with PCRs of 54.75% and 37.67% respectively. This confirms that the relationship between cutting speed and tool wear is proportional. The interactions of cutting speed and feed rate also significantly affected tool wear. Tool type and depth of cut had only a slight impact on tool wear when dry turning 6060 aluminium alloy.
- Significant abrasion and mild adhesion were observed on the rake face of the conventional tool, whereas only limited abrasion marks were observed on the wiper tool.
- All turning trials produced long irregular continuous curled chips at the beginning of the cutting process, which then changed from a curled to a string-like shape that wrapped around the cutting tool and the machined part at the end of the turning test.

- All cutting parameters of cutting speed, feed rate, depth of cut and tool type had only little impact on chip shape when dry turning 6060 aluminium alloy.

6. Recommendations for future work

The authors would like to encourage researchers to study the chip shape produced under wet turning of 6060 aluminium alloy at the same cutting conditions selected in this study and compare the results with the outcomes discussed at the above chip shape section.

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7. References:

[1] Stojanovic, B. and I. Epler, Application of aluminum and aluminum alloys in engineering. Journal of Applied Engineering Letters, 2018.
[2] Wei, Y., et al., Solid-state additive manufacturing high performance aluminum alloy 6061 enabled by an in-situ micro-forging assisted cold spray. Journal of Materials Science Engineering, 2020. 776: p. 139024.
[3] Czerwinski, F., Thermal stability of aluminum alloys. Journal of Materials, 2020. 13(15): p. 3441.
[4] Santos, M., et al., Machining of aluminum alloys: a review. The International Journal of Advanced Manufacturing Technology, 2016. 86: p. 3067-3080.
[5] Summers, P., et al., Overview of aluminum alloy mechanical properties during and after fires. Journal of Fire Science Reviews, 2015. 4: p. 1-36.
[6] Okokpujie, I. and L. Tartibu, A mini-review of the behaviour characteristic of machining processes of aluminium alloys. Journal of Materials Today: Proceedings, 2022. 62: p. 4526-4532.
[7] Prabhuswamy, N., et al., Machinability studies of aluminium 6061 cut by abrasive water jet. Journal of Materials Today: Proceedings, 2018. 5(1): p. 2865-2870.
[8] Geier, N., J. Davim, and T. Szalay, Advanced cutting tools and technologies for drilling carbon fibre reinforced polymer (CFRP) composites: A review. Journal of Composites Part A: Applied Science Manufacturing, 2019. 125: p. 105552.
[9] Umroh, B. The Optimum Cutting Condition when High Speed Turning of Aluminum Alloy using Uncoated Carbide. in IOP Conference Series: Materials Science and Engineering. 2019. IOP Publishing.
[10] Rizzo, A., et al., The critical raw materials in cutting tools for machining applications: A review. Journal of Materials, 2020. 13(6): p. 1377.

[11] Kumar, A. and S. Pradhan, Investigations into hard turning process using wiper tool inserts. Journal of Materials Toadys: Proceedings, 2018. 5(5): p. 12579-12587.

[12] Kiyak, M., I. Sahin, and O. Cakir. Application of wiper insert in cutting tool technology. in Proceedings of ICAS2016 1st International Conference on Advances in Sciences. 2016.

[13] Abbas, A., et al., Comparative evaluation of surface quality, tool wear, and specific cutting energy for wiper and conventional carbide inserts in hard turning of AISI 4340 alloy steel. Journal of Materials, 2020. 13(22): p. 5233.

[14] Horváth, R. and D. Agota, Analysis of surface roughness of aluminum alloys fine turned: United phenomenological models and multi-performance optimization. Journal of Measurments, 2015. 65: p. 181-192.

[15] Elbah, M., et al., Comparative assessment of wiper and conventional ceramic tools on surface roughness in hard turning AISI 4140 steel. Journal of Measurments, 2013. 46(9): p. 3041-3056.

[16] Khan, S., et al., Experimental investigations on wiper inserts' edge preparation, workpiece hardness and operating parameters in hard turning of AISI D2 steel. Journal of Manufacturing Processes, 2018. 34: p. 187-196.

[17] Gariani, S., T. Dao, and K. Jegandi, Performance Evaluation of Conventional and Wiper Carbide Tools When Turning 6060 Aluminium Alloy: Analysis of Surface Roughness. International Journal of Industrial and Manufacturing Engineering, 2023. 17(2): p. 36-41.

[18] Jha, S., D. Balakumar, and R. Paluchamy, Experimental analysis of mechanical properties on AA6060 and 6061 aluminum alloys. International Journal of Engineering Research and Applications 2015. 5(4): p. 47-53.

[19] Coromant, S. Cutting Tool Materials. 2024 [cited 2024 Accessed on 06/06/2024]; Available from: https://www.sandvik.coromant.com.

[20] Ince, M. and İ. Asiltürk, Effects of cutting tool parameters on surface roughness. International Journal of Engineering Sciences 2015. 4: p. 15-22.

[21] Gariani, S., T. Dao, and A. Lajili, Influence of Tool Geometry on Surface Roughness and Tool Wear When Turning AISI 304L Using Taguchi Optimisation Methodology. International Journal of Mechanical and Industrial Engineering2023. 17(11): p. 405-411.

[22] Leksycki, K. and E. Feldshtein, On the analysis of chip shaping after finishing turning of Ti6Al4V titanium alloy under dry, wet and MQL conditions. Journal Archives of Mechanical Technology and Materials, 2019. 39.

Nomenclature	
CNC	Computer Numerical Control
V_B	Principal tool flank wear
ANOM	Analysis of means
ANOVA	Analysis of variance
DoC	Depth of cut
PVD	Physical Vapour Deposition
TiCN	Titanium Carbo-Nitride
Al_2O_3	Aluminium Oxide
PCR	Percentage Contribution Ratio