COATING CHARACTERIZATION OF TiN & TiAIN ON BURR FORMATION IN DRILLING – PRAGMATIC INVESTIGATION

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Coating Characterization of TiN & TiAlN on Burr Formation in Drilling – Pragmatic Investigation

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Abstract - Burrs are source of dimensional errors, jamming and misalignment in the assembly process. They may cause short circuits in electrical components and may reduce the fatigue life of the part. Furthermore, burrs can be a safety hazard to personnel because they are usually sharp. This scientific research investigates the characterization of 8 mm diameter, 120° point angle of coated drill tool in burr formation. The exit burrs were investigated using two different types of popular coatings, namely TiN and TiAlN. The effect of cutting speed and feed rate of the tool in burr formation onto the workpiece are discussed. In this study, the exit burr height was measured using optical microscope. Moderately harder material, 304L series stainless steel was used in the evaluation of the super coatings. The experiments were conducted using CNC HAAS Milling Machine. These experiments can be classified as hard drilling based on the experimental values and machining conditions.

Keyword: TiN, TiAlN, drill tool, burr formation, coating characterization

I. INTRODUCTION

In every machining process, burr is formed as a result of plastic deformation. In drilling operation, usually burrs are produced on both the entrance and the exit surfaces of the work piece. The entrance burr forms on the entrance surface as material near the drill undergoes plastic flow. The exit burr is a part of the material extending off the exit surface of the work piece. Most burr-related problems in drilling are caused by the exit burr because the exit burr is much larger than the entrance burr [2]. Burrs are source of dimensional errors, jamming and misalignment in the assembly process. They may cause short circuits in electrical components and may reduce the fatigue life of the part. Furthermore, burrs can be a safety hazard to personnel because they are usually sharp. The existence of burrs on a work piece is source of the dimensional errors. The burr may reduce the fatigue life of the parts since the hardened and brittle burr material can act as a crack initiation point. Debris of the burrs can cause serious damage on the moving parts [8]. By reducing the burr formation, the cost of deburring can be minimized and on the other hand, it will improve the product quality and productivity. These are the main reasons of why the researchers are still keep trying to avoid the formation of a drilling burr or at least to minimize it, or sometimes, to control the type of the burr. The formation of the drilling burr depends on many parameters such as characteristics of work pieces (material properties, geometries, surface roughness, etc.), drills (material properties, geometries, tool wear, temperature, chip formations, etc.), and process parameters (cutting speed, feed rate, usage of coolant, rigidity of machine, temperature, etc.).

Titanium nitride (TiN) is an extremely hard, ceramic material (~85 HRC or 24.5 GPa), often used as a coating on titanium alloy, steel, carbide, and aluminium components to improve the substrate's surface properties [1]. TiN has excellent infrared (IR) reflectivity properties, reflecting in a spectrum similar to elemental gold (Au). Depending on the substrate material and surface finish, TiN will have a coefficient of friction ranging from 0.4 to 0.9 versus itself (non-lubricated). Typical formation is a face-centered cubic crystalline structure with a roughly 1:1 stoichiometry. TiN will oxidize at 600°C at normal atmosphere, and has a melting point of 2930°C. The most common use for TiN coating is for edge retention and corrosion resistance on machine tooling such as drill bits and milling cutters, often improving their lifetime by a factor of three or more. Because of TiN's metallic gold color, it is often used to coat costume jewellery and automotive trim for decorative purposes. TiN is also widely used as a top-layer coating, usually with nickel (Ni) or chromium (Cr) plated substrates, on consumer plumbing fixtures and door hardware. TiN is non-toxic, meets FDA guidelines and has seen use in medical devices and bio-implants, as well as aerospace and military applications. Figure 1 shows the sample of TiN drill tools used in this research.

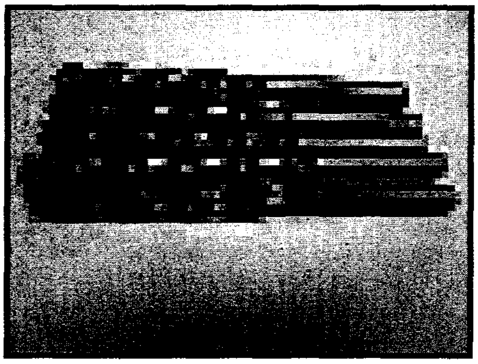

Figure 1: Laminated samples of TiN coated 8mm drill tools

TiAlN is another coating frequently used for extreme conditions, where, it is considered superior to TiN, where the the characteristics were designed to run at even higher temperatures than the TiN coating. It produces to obtain good results in Stainless Steel, nickel based alloys, high temperature, and titanium alloys. These coatings permits the high speed semi-dry or dry machining operations and increases speed rate 50% over uncoated tool. Figure 2 shows the sample of TiAlN coated drill tools used in this empirical research.

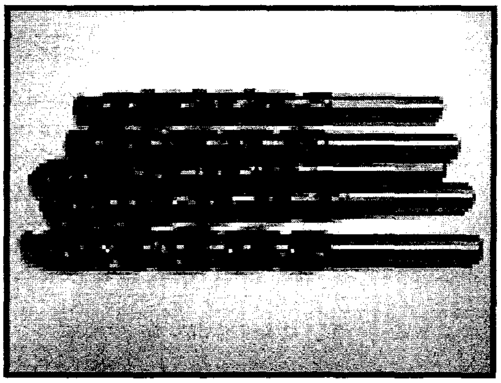

Figure 2: Laminated samples of TiAlN coated 8mm drill tools

II. LITERATURE REVIEW

Many authors have investigated and still starving in their research in minimizing or eliminating the burr formation in metal cutting industries. The researchers often investigate the drill tool geometry and also properties of related material such as aluminium, stainless steel, mild steel, etc.

In manufacturing process there are many key processes in reducing the burr formation. M. Abdel Mohsen Mahdy has studied in economic drilling conditions for a given deburring radius [1]. He describes about electrochemical deburring (ECD) to provide a simple and economical approach to selectively remove burr from inaccessibl areas with consistent result and absolute uniformity. Kiha Lee and David A. Dornfeld have studied in Micro-burr formation and minimization through process control [2] and the authors described about micro-burr formation in machining. Tungsten–carbide micro-mills were used to cut holes (in a drilling-like process) to investigate top burr formation. The researchers also investigated about function of machining variables, e.g. feed rate, cutting speed and cutting edge radius, to help illuminate the micro-burr formation mechanisms.

Simon S.F. Chang and Gary M. Bone carried out studies in burr size reduction in drilling by ultrasonic assistance [3]. They have investigated about the effect of ultrasonic assistance on burr size, chip formation, thrust forces and tool wear. A recent and promising method for reducing burr size in metal cutting is the use of ultrasonic assistance, where high-frequency and low-amplitude vibrations are added in the feed direction during cutting Begon˜a Pen˜aa, Gorka Aramendia, Asuncio´n Riveroa and Luis N. Lo´pez de Lacalleb have studied in monitoring of drilling for burr detection using spindle torque [4]. The author has used high speed machining centre (Agil-2) developed by Fatronik which is 3-axis CNC machine of linear motors and Fidia control.

Sung-Lim Ko, Jae-Eun Changa, and Gyun-Eui Yang have studied in burr minimizing scheme in drilling [5] and they describe about minimizing burr formation, it is proposed that a step drill be used and the authors studied about burrs formation by a step drill with step edges were smaller in size comparing with those produced by a conventional drill with a point angle that was larger than 130°. Sung Lim Ko and jing Koo Lee have analyzed burr formation in drilling with a new concept drill [6]. The authors studied about the drilling operations with a new concept drill and were compared with a conventional HSS drill. Kiha Lee has investigated in optimization and quality control in burr formation using design of experiment in drilling of intersecting holes [7]. The drilling process of the crankshaft of automobile engine was elaborated by author.

Berlin Shyu has studied about burr reduction by Tool Design [8]. The author studied about a computer simulation framework which helps user to easily produce the CAD of drills and other tools with finite element analysis verification for burr prevention. Karina Lei engineered burr formation in drilling intersecting hole [9] and the author developed a model for specific type of burr formation. The model was based on material properties and yield stress theory. The emphasis was on comparing two specific drill geometries. L. Ken Lauderbaugh Saunders studied in a finite element model of exit burrs for drilling of metals [10]. The author describes about the modeling work of Saunders and Mauch is extended using the Finite Element method.

III. EXPERIMENTAL SETUP AND PROCEDURE

In this experiment, CNC HAAS VF-1 milling machine has been used for drilling. An image analyzer was used to measure the formed burr height. The burr formation by drill tool of 8mm with 120° point angle coated with two different coatings namely TiN & TiAlN have been compared. They were investigated with the same machining conditions and experimental values. Drilling speed and feed have been considered as the prime parameters as they were amongst the significant in burr formation process. These experiments were conducted by the attempt of drilling 30 holes on a stainless steel plate using the same drill tool until the tool meets catastrophic failure in dry condition. The machining parameters and work material details are as shown in table 1.

Table 1: Machining parameters used for TiAlN & TiN

<table>
<tr><th colspan="2">Speed (m/min)</th><th colspan="2">Feed (mm/rev)</th></tr>
<tr><td>Low</td><td>High</td><td>Low</td><td>High</td></tr>
<tr><td>16</td><td>20</td><td>0.12</td><td>0.2</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><th colspan="4">Workpiece</th></tr>
<tr><td>Material</td><td colspan="3">Stainless steel (304L series)</td></tr>
<tr><td>Thickness</td><td colspan="3">10 mm</td></tr>
<tr><td>Hardness</td><td colspan="3">243 BH</td></tr>
</table>

Eight randomized experiments were conducted based on the 2^3 factorial design as per the DOE matrix shown in Table 2. Three replication has been conducted which totals up to 24 experiments. The experimental work by TiN coated drill tool is shown in figure 3. The results discussed here are the average of three replications carried out to avoid in reducing biasness.

Table 2: DOE matrix

Run	Speed	Feed	Coating
1	1	1	TiN
2	-1	1	TiN
3	1	-1	TiN
4	-1	-1	TiAlN
5	1	-1	TiAlN
6	-1	1	TiAlN
7	-1	-1	TiN
8	1	1	TiAlN

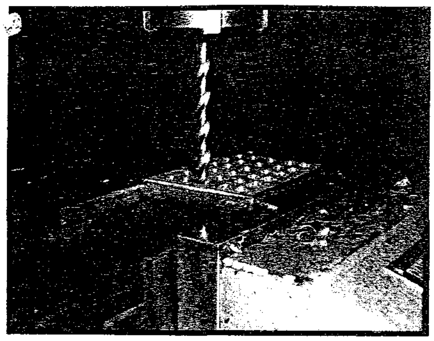

Figure 3: TiN coated drilling on stainless steel workpiece

IV. RESULTS AND DISCUSSION

The burr formation after the drilling process with 8 mm TiAlN & TiN drill tools is discussed. The comparison of both the coating types was investigated at different levels of cutting speed and feed. From the analyzed data and the histograms shown in figure 4 and 5, TiAlN coating shows better characteristics than TiN at both machining levels of machining conditions by producing lower burr height. Burr height for TiN coating is greater that TiAlN coating. The results resides to TiAlN which presence lower burr heights and agrees well with most of the researchers on some common metallic work material.

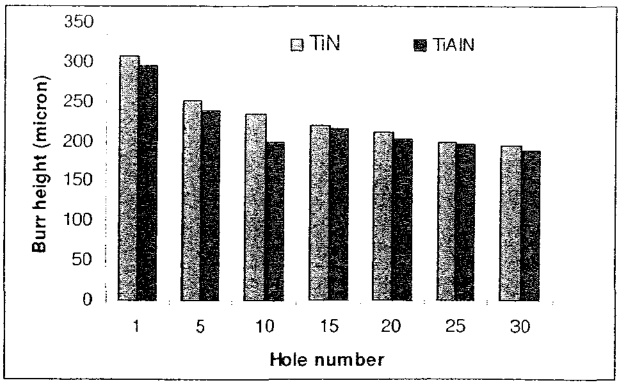

Figure 4: Burr formation (height) for low level machining (Experiment 4 vs. experiment 7) of TiN & TiAlN coated drill tools.

With reference to figure 5, The seriousness in the burr height is worst for high level maching experiments where at hole number 5, 15, 19 and 26, the burr height formed by TiAlN coating was greater than TiN. This could be to the non-homogenous material impurities, missing data in averaging the replication result, control of parameters, etc. It can also concluded that the parameters used such as cutting speed and feed rate have significant affect on burr formation within the range of experimental parameters.

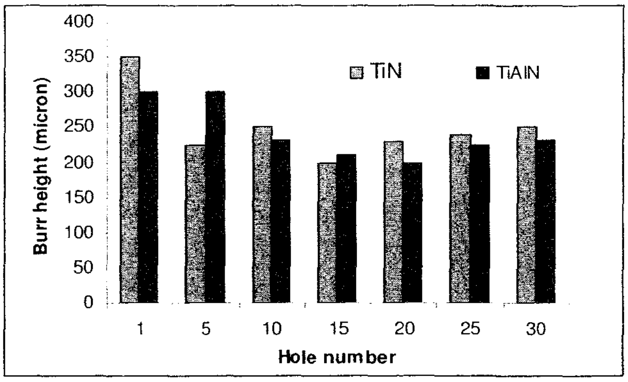

Figure 5: Burr formation (height) for high level machining (Experiment 1 vs. experiment 8) of TiN & TiAlN coated drill tools.

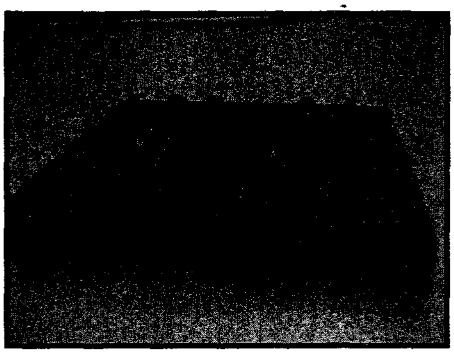

Figure 6: Drill cap formation for TiAlN observed during the experiments.

The final worked metal piece by TiAlN found to be producing more drill caps than TiN as shown in figure 6 as compared to TiN coating. Therefore, some simple rework is still required to remove the caps before finishing/final assembly stage. From this investigation, it is learned that the hardness of the coating has proportionally good result on burr formation, but the drill caps are still produced on this specified 304L series stainless steel material within the range of experimental values applied in this experiment.

V. CONCLUSION

As for this investigation, conclusion can be drawn saying that, in both low and high level machining conditions, the TiAlN coating performs better as compared to TiN. Anyhow, a slight draw back is that, too many drill caps are produce as compared to TiN for the same range of experimental values with 5mm drill tool. Therefore, can be concluded that TiAlN coating gives better reduction of burr formation in drilling with Stainless steel (304L series) and can be strongly recommended if there is a mechanism of removing drill caps easily without much affecting on the production time, rate and cost.

VI. FUTURE WORK

From the investigation, it is found that the profiles of drill caps formed are proportional with the number of drilled holes. Therefore, this investigation can be extended for tool wear and drill caps correlation statistical modeling or artificial intelligence modeling. Relatively, further investigations can be made to find out the influence of diameter, machining condition, material, etc. in burr formation with the same comparative coatings.

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VIII. REFERENCES

[1] M. Abdel Mohsen Mahdy, *"Economic Drilling Conditions For A Given Deburring Radius"*, Journal of Materials Processing Technology. Vol. 110. pp. 197-205, 2001

[2] Kiha Lee, David A. Dornfeld, *"Micro-Burr Formation And Minimization Through Process Control"*, Journal of Precision Engineering. Vol. 29. pp.246-252, 2005.

[3] Simon S.F. Chang, Gary M. Bone, *Burr Size Reduction In Drilling By Ultrasonic Assistance*, International Journal of Robotics and Computer-Integrated Manufacturing. Vol. 21. pp.442-450, 2005.

[4] Begon˜a Pen˜aa, Gorka Aramendia, Asuncio´n Riveroa, Luis N. Lo´pez de Lacalleb, *"Monitoring Of Drilling For Burr Detection Using Spindle Torque"*, International Journal Of Machine Tools & Manufacture. Vol. 45. pp.1614-1621, 2005.

[5] Sung-Lim Ko, Jae-Eun Changa, Gyun-Eui Yang, *"Burr Minimizing Scheme In Drilling"*, Journal Of Materials Processing Technology. 2003.

[6] Sung Lim Ko and jing Koo Lee, *"Analysis Of Burr Formation In Drilling With A New Concept Drill"*, Jurnal Of Material Processing Technology. Vol. 113. pp.392-398, 2001.

[7] Kiha Lee, *"Optimization and Quality Control in Burr Formation Using Design of Experiment (II): Drilling Of Intersecting Holes"*, The Consortium on Deburring and Edge Finishing (CODEF). pp. 1-3, 2000.

[8] Berlin Shyu, *"Burr Reduction by Tool Design"*, The Consortium on Deburring and Edge Finishing (CODEF). pp. 26-29, 2000.

[9] Karina Leis, *"Burr Formation in Drilling Intersecting Holes"*, The Consortium on Deburring and Edge Finishing (CODEF). pp. 35-38, 2000.

[10] L. Ken Lauderbaugh Saunders, *"Finite Element Model of Exit Burrs For Drilling Of Metals"*, International Journal of Finite Elements in Analysis and Design. Vol. 40. pp.139-158, 2003.

BIOGRAPHIES

Mr. Sivarao is a research academia in manufacturing engineering faculty, Universiti Teknikal Malaysia Melaka (UTeM). He is currently active in his research area namely precision machining, cutting tools and artificial intelligence in the area of manufacturing. He also presented his research findings at many international events including University of California (USA), University of Calgary (Canada), Feng Chia University (Taiwan), etc. He has also published several numbers of research papers in national and international conference proceedings and journals.

Besides his research work, Mr. Sivarao is also a reviewer for;

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His research work on invention & innovation has also won him several medals in the national and international invention competitions including international exhibitions of inventions, Geneva year 2007.

Mr. Rahim is a deputy dean (academic) of the manufacturing engineering faculty, Universiti Teknikal Malaysia Melaka (UTeM). He specializes in design and development of manufacturability in the area of manufacturing engineering. His innovative and creativeness in design and development of newly invented products has enabled him to win a medal in the competition of Malaysia Technology Expo (MTE) year 2007.

Mr. Taufik is an expatriate from Indonesia serving the manufacturing engineering faculty, University Teknikal Malaysia, Melaka. He has published a number of scientific research papers at international and national level. He specializes in the area of manufacturing design and development mainly involving concurrent and robust engineering; His invention capability has also made him to win a medal in the invention competition of Malaysia Technology Expo (MTE) year 2007.

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