Proceedings of Malaysian International Tribology Conference 2015, pp. 310-311, November 2015

Performance of TiCN and TiAlN coated twist drills

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Keywords: TiCN TiAlN Coated-drill, tool life, wear

ABSTRACT – The high speed steel (HSS) and TiCN and TiAlN coated drills were subjected to drilling tests. Based on test results, it could be concluded that increased in hardness of the coated drill is not the only factor to improve the tool life. Other factors such as the thermal conductivity, friction coefficient and adhesion strength of the coating elements also play important roles in improving the tool life of the drill. Microstructural examination showed that the abrasion, adhesion and thermal wear mechanisms are operated during drilling process.

1. INTRODUCTION

The main objective of depositing a thin hard film coating such as TiN, TiAlN, TiCN, TiZrN on the drill and cutting inserts is to improve the tool life. Hard thin film coating can be applied to cutting tool, mould and dies, machine elements, and automotive parts. Earlier researchers have showed that an increase in tool life may be due to the following phenomena; (i) increase in hardness, (ii) greater bonding energy of the coating elements, and (iii) lower friction coefficient [1].

TiAlN coated cutting tool has improved the dry machining performance be due to the fact that this coating is able to maintain high hardness and resistance to oxidation at high operating temperatures [2]. Aboukhashaba in his tests on TiN-coated and TiCN-coated drills, found that the coated drill required less thrust force and gave lower values of axial during drilling [3]. The objective of this study is to study the effect of hard coating on drilling performances during drilling of carbon steel. The failure mechanism of the drill during drilling process will also be discussed.

2. METHODOLOGY

A commercial uncoated HSS, TiCN-coated and TiAlN-coated drills were subjected to drilling performance tests using a CNC milling machine. The drilling performance test was conducted on 25 mm thick medium carbon steel plate (1.39 % C, 0.25% Si, 0.19% Mn, 0.25 %, 5.39% Cr, 0.51 % Mo, 0.82 % V, 0.07% W, 0.05% P and balance Fe). The drilling parameters were set at a spindle rotation of 1,600 rpm, feed rate of 20 mm/min, and the depth of cut was set at 20 mm. Pecked-drilling by lifting the drill once every 5 mm depth of drilling is practiced in this test so that that the chip can be removed smoothly during drilling tests, thus reducing the heat. In this present work, lubrication was not in use during this drilling experiment test to expedite the coating failure. The drill life was defined as the number holes drilled until the drill was unable to drill further into the work piece. The microstructural changes on the worn surfaces were observed using Field Emission Scanning Electron Microscopy (FE-SEM) Model LEO 1525.

3. RESULTS AND DISCUSSION

3.1 Drill Performance

The uncoated drill showed the worse cutting performance where it can drill up to 36 holes only (Table 1). Large defects of chipping and tool wear are observed on uncoated HSS drill (Figure 1). It can be seen that the drill coated with TiCN coating film out-performed the other coated drills with the tool life of 28 folds as compared with uncoated drill. This could be due to it higher hardness and lower coefficient of friction (COF) properties. It was observed from Table 1 that there is no simple correlation between hardness and friction coefficient with tool life improvement. Based on the above observations, generally it could be concluded that the tool life improvement was due to the improvement of hardness, friction coefficient and thermal conductivity properties. It could also be concluded that type of compound coating elements employed on the drill have a significant effect on the drill life.

Table 1 Drilling performance test results.

	Hardness (HV)	**COF**	**No. of drilled holes**	**No. of drilled holes**
HSS	766	0.60	36	36
TiAlN	1698	0.30	835	835
TiCN	3153	0.25	1014	1014

3.2 Wear Mechanism

It can be seen on Fig. 1a that a build-up edge (BUE) was formed on the cutting lip of uncoated HSS drill after drilling 15 holes. This phenomenon was taught to be due to the process of micro-welding at the cutting lip and the chip interface during drilling. With subsequent drilling, microcrack was observed on the build-up edge due to plastic deformation. Finally, build-up material becomes unstable to the local shear resulting material transfers to the opposite mating surface. This is a symptom of adhesive wear. The uncoated drill was unable to further penetrate into the work piece after 36 drilling holes as a result of severe adhesive mechanism on the drill flank as shown in Fig. 1b.

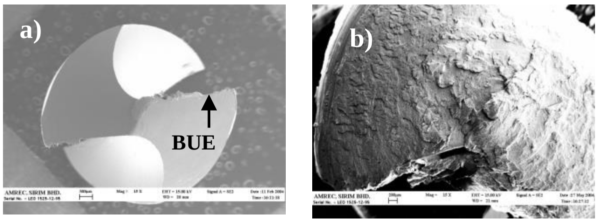
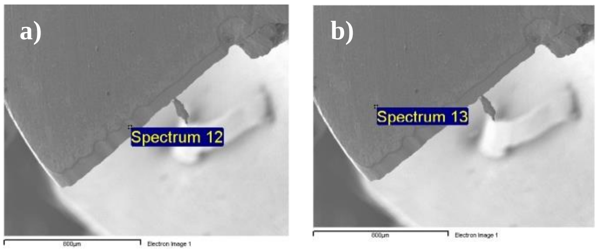


Fig. 1. SEM on HSS steel drill; (a) Build-up edge, (b) Severe adhesive on drill flank.

For TiAlN-coated drill, it was observed that the cutting lip was only abraded-off after drilling of 728 holes (Fig. 2a) and still capable to drill until up to 835 holes before catastrophic failure occurred. EDAX analysis on the worn area confirmed that the abraded-off area has exposed the substrate material (Fe, Cr, Mn). EDAX analysis on the flank, flute, and land of the coated drill showed this area was still covered with TiCN coating film (Fig. 2b).



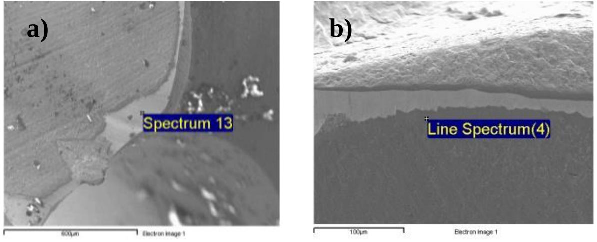
Element	Weight%
C K	**7.91**
O K	11.98
Cr K	1.38
Mn K	1.26
Fe K	77.47

Element	Weight%
C K	4.23
N K	2.98
Al K	12.46
Ti K	78.57
Fe K	1.76

Fig. 2. EDAX on TiAlN-coated drill; (a) SEM image on cutting lip and its elemental composition, (b) SEM image on drill land and its elemental composition.

Whereas, the cutting lip of TiCN-coated was only abraded-off after drilling of 913 holes (Fig. 3) and the drill still capable to drill until up to 1014 holes before catastrophic failure occurred. EDAX analysis on the cutting lip confirmed that the abraded-off area has exposed the substrate material (Fig. 3a). EDAX analysis on the flank, flute, and land of the coated drill showed these areas were still covered with TiCN coating film (Ti, C, N) as shown in Figure 3b.

SEM examination observation on the worn surface shows that wear mechanism of abrasive, adhesive and thermal were operated during drilling as shown in Figure 4.



Element	Weight%
C K	14.66
O K	26.72
V K	0.43
Cr K	0.62
Fe K	56.75
W M	0.82

Element	Weight%
C K	9.78
N K	17.18
Ti K	72.06
Fe K	0.98

Fig. 3 EDAX on TiCN-coated drill; (a) SEM image on cutting lip and its elemental composition, (b) SEM image on drill land and its elemental composition.

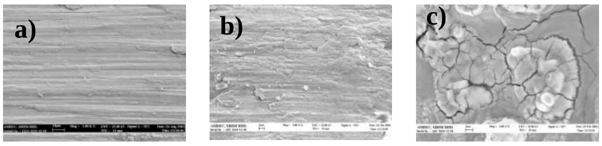


Fig. 4 Wear mechanism on worn surface; (a) abrasive, (b) adhesive, and (c) thermal.

4. CONCLUSIONS

This study reveals the improved tool life of the coated drill is depending on many factors such as type of coating element employed, coating thickness, hardness, friction coefficient and thermal conductivity. The microstructural investigation revealed that the wear mechanisms operated during drilling were abrasion, adhesion and thermal.

5. ACKNOWLEDGEMENTS

This research was supported by Ministry of Education, Malaysia with ERGS grant no. 600-RMI/FRGS 5/3 (39/2012) and Universiti Teknologi MARA. The authors are grateful to SIRIM Berhad for providing research facilities.

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