STUDY ON TOOL PERFORMANCE OF DRILL COATED WITH DIAMOND-LIKE CARBON COATINGS FOR DRILLING ON DUPLEX STAINLESS STEEL GRADE UNS 31803

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ABSTRACT

Diamond-like carbon coatings are metastable amorphous films that exhibit unique combinations of properties such as high hardness and elastic modulus, low friction coefficients, optical transparency, good wear resistance, and excellent corrosion resistance. Thus, these films are commonly applied as wear-resistant protective coatings in the magnetic storage, automobile, biomedical industries, tooling, and others. Many researchers have reported that the introduction of additional elements, such as silicon, oxygen, nitrogen and various metals, improves the properties of diamond like carbon films. The methods used to create diamond like carbon films include ion beam assisted deposition, magnetron sputtering deposition, chemical vapor deposition and plasma-based ion implantation (PBII). The PBII process is considered one of the most promising techniques owing to its ability to uniformly implant and deposit ions into three-dimensional substrates with complex shapes. This research aims to study on tool performance of drill coated with diamond like carbon coatings for drilling on stainless steel. Tungsten carbide drill with diameter of 1 millimeter were coated with DLC, H-DLC, Si-O-DLC and Si-N-DLC films, prepared by Plasma based ion implantation process. The duplex stainless steel grade UNS S31803 sheets with thickness of 2 millimeter were drilled for 300 holes. The hole diameter and wear of coated drill were measured by optical microscope. The surface roughness of wall hole was measured by surface roughness tester. The results of hole number of drill coated with H-DLC, Si-O-DLC and Si-N-DLC films was successfully completed drilling for 300 holes number. The drill coated with DLC and Uncoated-drill were failed during test. This is due to the low hardness of DLC film (9.8 GPa) and high internal stress (2.85 GPa). The hole diameter of drill coated with H-DLC film was slightly increased while the surface roughness of hole wall decreased with the hole number increased. This is due to the higher hardness and lower internal stress of 12.2 GPa and 1.32 GPa, respectively.

1. INTRODUCTION

Diamond-like carbon (DLC) coatings deposited at low temperature are arousing more and more interest owing to their excellent desirable properties, which include extremely high hardness, high density, low friction coefficient, high ductility, chemical inertness, relatively high thermal conductivity and transparency across most of the electromagnetic spectrum. (Jianguo Deng,et al,1995)

Duplex stainless steel grade UNS S31803 has a lower co-efficient of thermal expansion and a slightly higher thermal conductivity than austenitic stainless steels. This is of particular advantage when designing heat exchangers. This is of particular advantage when designing heat exchangers. The higher thermal conductivity improves heat transfer and the lower thermal expansions reduces the stresses incurred due to the difference in thermal expansion between the carbon steel shell and the stainless steel used for the tubes. The co-efficient of thermal expansion of Duplex stainless steel grade UNS 31803 is close to that of carbon steel. (Olena,2004)

Selection of the most appropriate cutting tools is also critical in machining stainless steel. Generally, the requirements include good wear resistance, high strength and toughness, high hot hardness, good thermal shock properties and adequate chemical stability at elevated temperatures (Muhammad Imran,et.al,2014)

In the drilling process, Micro-manufacturing, the process of creating features measured in micrometers, is a rapidly growing worldwide industry.It is used, for example, in the miniaturization of common devices including actuators, motors, fuel cells, and gas turbines, and the production of packaging that links smaller devices, such as MEMS, to the macroscopic world. As technology shrinks and the demand for smaller devices grows, the ability to precisely shape new and existing materials at small scales becomes increasingly more important (M.C. Kang,et al,2010)

2. EXPERIMENT

2.1 Material

Duplex Stainless Steel grade UNS S31803 with 2 mm. thickness. Chemical composition showed in table1

Table 1. Chemical Composition of Duplex Stainless Steel grade UNS S31803 (Olena,2004)

Element weight%				
C	Cr	Ni	Mo	Mn
0.030	22.0	5.5	2.5	1.86

2.2 Drills

The small tungsten cabide drills with 1 mm diameter flute length (l) 5 mm. showed in figure 1. (Nuthanun Moolsadoo,2013)

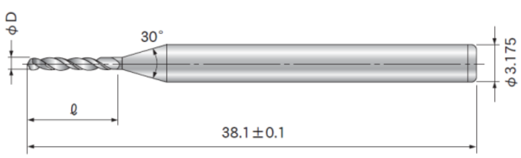

Figure 1. Small drills

2.3 Deposition Technique

Drilles were coated by conventional DLC (DLC), H-DLC, Si-O-DLC and Si-N- DLC films and deposited by Plasma-based Ion Implantation (PBII) method. The total deposited thickness of all films was approximately 500 nm. Film properties and PBII Coating condition showed in table 2-4 (Nuthanun Moolsadoo,2013)

Table 2. Adding Element and gas mixture

Film Type	Adding-Element	Gaseous mixture
Conventional DLC	-	C_2H_2
H-DLC	Hydrogen	C_2H_2+ H_2
Si-O-DLC	Silicon+Oxygen	C_2H_2+TMS+O_2
Si-N-DLC	Silicon+Nitrogen	C_2H_2+TMS+N_2

Table 3. Gas Mixture ratio of Films type

Film type	Gas flow(sscm)	Relative atomic content (at.%)		
		C	Si	O/N
Conventional DLC	-	-	-	-
H-DLC	2:1	-	-	-
Si-O-DLC	14:1:2	57	34	9(O)
Si-N-DLC	14:1:2	69	23	8(N)

Table 4. Films Property

Film type	Hardness(GPa)	Friction coefficient (μ)	Internal stress (GPa)
Conventional DLC	9.8	0.07	2.85
H-DLC	12.2	0.07	1.32
Si-O-DLC	10.0	0.04	0.15
Si-N-DLC	11.1	0.05	1.02

A series of cutting tests were conducted in a CNC Milling machining center (RXP300). The following machining conditions were used; a rotation speed of 6,000 rpm, a feed rate of 150 mm/min. under dry condition. The tool performance of each coated micro drill was evaluated by surface roughness of hole following the drilling of 1,60,150and 300 holes, respectively by Surr-Codder SE1200 Surface roughness test.

3.Result and Conclusion

3.1 Surface roughness of hole

Drills were coated with Conventional DLC is not able to drilling 300 hole. The surface roughness of wall hole was measured by surface roughness tester is shown in table 5. And Figure 2

Table 5. Surface roughness of wall hole

Film type	Hole Quantity	Number of test			Average
		1	2	3	R_a (µm)
H-DLC	60	0.750	1.088	1.154	0.996
	150	0.801	0.622	1.376	0.933
	300	0.777	0.497	1.000	0.758
Si-N-DLC	60	0.793	1.166	0.837	0.932
	150	0.777	0.471	0.626	0.624
	300	0.758	0.542	0.917	0.739
Si-O-DLC	60	1.463	1.155	-	1.309
	150	1.004	1.377	-	1.191
	300	1.054	0.986	-	1.020

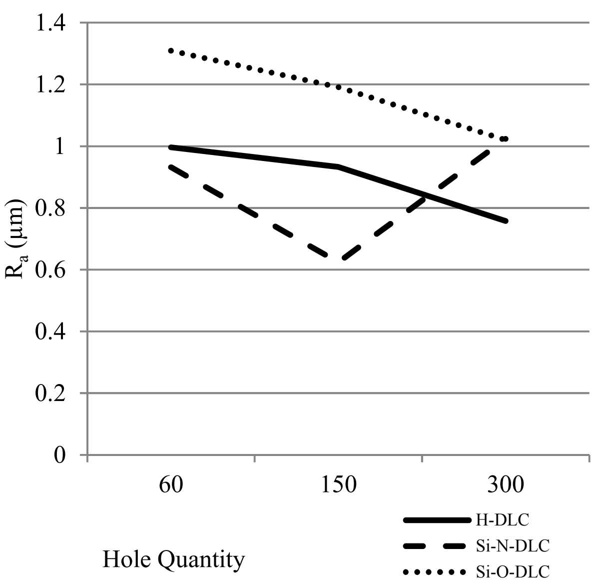

Figure.2 Graph show surface roughness of wall hole

Graph show surface roughness of wall hole on drills it coated with H-DLC and Si-O-DLC were decrease when the number of hole is increase. However surface of wall hole drilling with drills were coated with Si-N-DLC is high surface roughness but when number of hole is increase surface roughness is increase after 150 hole because in term of hardness of film properties Si-N-DLC is high hardness ,internal stress and friction coefficient.

Conclusion.

Study of tool performance of drill coated with diamond-like carbon coating for drilling on UNS S31803 in term of surface roughness of wall hole was investigated. The result showed the surface roughness of wall hole drilling with H-DLC, Si-O-DLC and Si-N-DLC, respectively. The results found that drills coated with Conventional DLC not able to drilling until 300 holes. This is due to low hardness and high friction coefficient, as well as high internal stress. Drilling tests show that the H-DLC coated drills enhance abrasive wear resistance. This is due to high properties of H-DLC shows high hardness and low friction coefficient properties.

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