International Journal of Research in Advent Technology, Vol.6, No.5, May 2018
E-ISSN: 2321-9637
Available online at www.ijrat.org

Studies on Chip morphology, Hole deviation and Temperature distribution for drilling using HSS, TiN and TiAlN coated HSS tool

Puneeth H V [1], Dakshayini[2], Dr. M S Ganesha Prasad [3]
Assistant Professor, Department of Mechanical Engineering, New Horizon College of Engineering[1]
Assistant Professor, Department of Mechanical Engineering, Global Academy of Technology[2]
Professor & Head, Department of Mechanical Engineering, New Horizon College of Engineering[3]
Email: hvpuneeth@gmail.com[1], *dakshudakshayini@gmail.com*[2],*msgprasad@gmail.com*[3]

Abstract- This paper compares the characteristics of uncoated HSS drill bit with Titanium Nitride (TiN) and Titanium Aluminium Nitride (TiAlN) coated on HSS for machining of EN8 material under dry machining condition. Parameters such as chip morphology, hole deviation, and temperature distribution during machining of EN8 material for uncoated HSS and Titanium Nitride, Titanium Aluminium Nitride coated HSS drill bit were studied. Experimental results on chip morphology by SEM (Scanning Electron Microscope) showed that spiral (tight and loose helix), spiral cone, fan shape, thin continuous, spiral overlap, ribbon, helical, and discontinuous chips were produced. Hole deviation was calculated using digital vernier caliper and it was found that there was a maximum deviation in TiN coated HSS tool drilled holes and marginally reduced deviation in TiAlN and uncoated HSS tool drilled holes. Temperature distribution was measured using thermal imaging camera and there was a maximum temperature in TiAlN coated HSS drill tool for more number of holes and comparatively less temperature in TiN and uncoated HSS tool.

Index Terms- HSS drill; TiN and TiAlN Coated HSS drill; EN8 steel; hole deviation; SEM

1. INTRODUCTION

Drilling involves the creation of holes that are right circular cylinders. This is accomplished most typically by using a twist drill by rotating it against the workpiece [5].

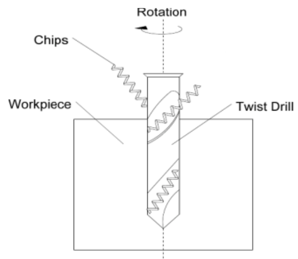


Fig 1.1 Drilling Process

During drilling operation, the influence on the surface roughness, torque, and thrust force depends on the size and shape of the generated chips [1–3]. Long chips are not desirable and should be avoided as they cannot slide freely along the flutes and may twist along the drill body, while small discontinuous broken chips can be readily removed from the drilled hole. Also, the rotation of the chips along the flute could impact the hole wall and consequently its surface finish. As a result, knowledge on the mechanism of chip formation and chip morphology during drilling is essential to obtain the required chips.

After drilling hole in the work piece, the final shape and its deviation is measured using digital vernier caliper. For many applications importance is given for measurement of hole diameter. The hole deviation is checked in different direction to the hole diameter. The digital vernier has a least count of 0.001mm. The hole deviation is measured at top surface of hole, middle and bottom surface of hole.

The heat produced during metal cutting or drilling process is scattered to cutting tool, work piece and chip, the generated heat is distributed in non – uniform way. Because of non-uniform deformation at deformation zone there will be higher temperature at chip near tool surface. Higher temperature is observed at chip and cutting tool. To measure the temperature at cutting tool surface, thermal imaging camera was used. It can measure from -10ºC to +350ºC.

Fig 1.2 Thermal Imaging Camera

2. OBJECTIVE AND METHODOLOGY

2.1. *Objectives*

The main objective of this investigation was to study the characteristics such as chip morphology, hole deviation and temperature distribution of uncoated HSS drill bit with Titanium Nitride (TiN), and Titanium Aluminium Nitride (TiAlN), coated HSS drill bit for machining of EN8 material.
These characteristics were studied under constant speed, feed and depth of cut.

2.2. *Methodology*

From the literature review, HSS, TiN coated HSS and TiAlN coated HSS twist drills were selected for machining of EN8 material.
To study the above mentioned characteristics, different methodologies were involved such as chip morphology by SEM, hole deviation by digital vernier, and temperature distribution using thermal imaging camera.

3. EXPERIMENTAL SETUP

Radial drilling machine was used under dry machining condition to carry out investigations of uncoated HSS and coated HSS twist drills in drilling of EN8 steel workpiece.

Fig 3.1 Experimental set-up of drilling machine

In the current experimental investigation, EN8 steel was chosen as workpiece material. EN8 is an unalloyed medium carbon steel; it has a greater tensile strength compared with mild steel. EN8 can be machined at any condition; surface hardening can be done to improve wear resistance. Hardness ranges from 50-55HRC. EN8 is tempered between 550-600ºC. It is suitable for manufacturing gears, shafts, studs, bolts, keys, pins, connecting rods, axels, and rollers. EN8 is also used in manufacturing of Continuous Variable Transmission (CVT) clutch.

Fig 3.2. EN8 workpiece

The chemical composition and mechanical properties are mentioned below.

Table 3.1. EN8 Steel properties

EN8 Chemical composition		EN 8 Mechanical properties	
Carbon	0.36-0.44%	Max Stress	700-850 n/mm^2
Silicon	0.10-0.40%	Yield Stress	465 n/mm^2 Min
Manganese	0.60-1.00%	0.2% Proof Stress	450 n/mm^2 Min
Sulphur	0.050 Max	Elongation	16% Min
Phosphorus	0.050 Max	Hardness	201-255 Brinell

The experiment was conducted for different drill bits with machining parameters as shown in below table 2. The EN8 steel workpiece material dimensions was 140*140*13mm.

Table 3.2. Machining parameters

Drill bit	Cutting Speed, m/min	Spindle Speed, RPM	Feed Rate, mm/rev	Depth of Cut, mm
Uncoated HSS	36.6	1165	0.024	10
TiN coated HSS	36.6	1165	0.024	10
TiAlN coated HSS	36.6	1165	0.024	10

Table 3.3. Drill bit specification

Drill material	Diameter,mm	Point angle, deg	Helix angle, deg	Flute length, mm
Uncoated HSS	10	118	35	82.30
TiN coated HSS	10	118	35	94.63
TiAlN coated HSS	10	118	35	85.19

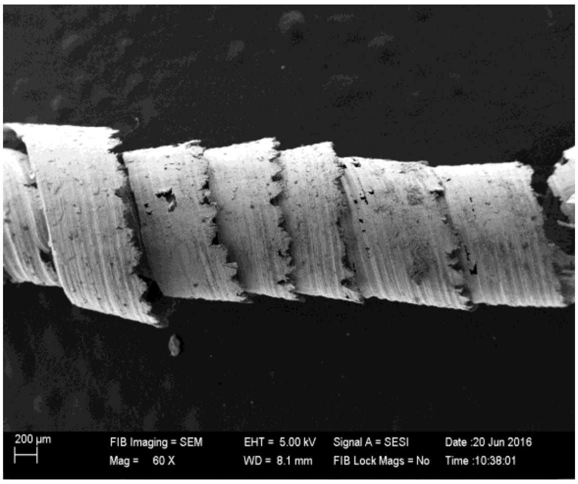
4. RESULTS AND DISCUSSION

4.1 Chip Morphology

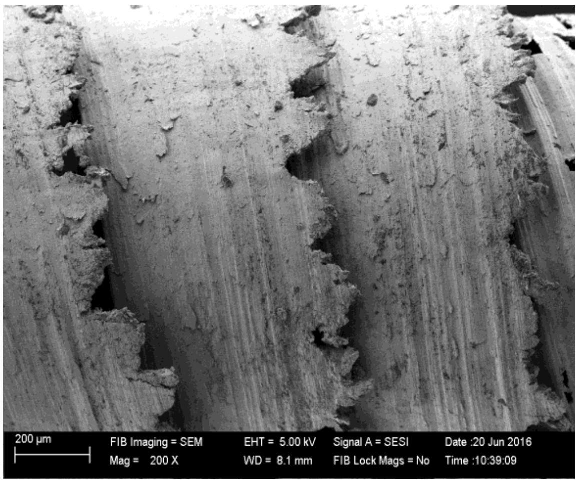
The chips produced during drilling differs in shape and size due to change in process parameters, work piece and tool material and drill geometry.

The obtained different shape and size of chips are analyzed and characterized using Scanning Electron Microscope (SEM).

4.1.1 Uncoated High Speed Steel (HSS) tool drilled chips

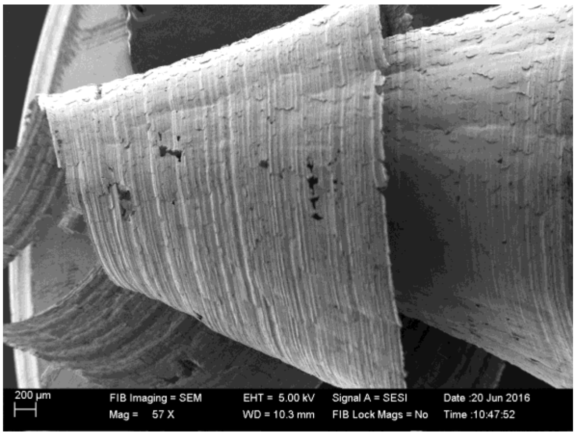


(a)

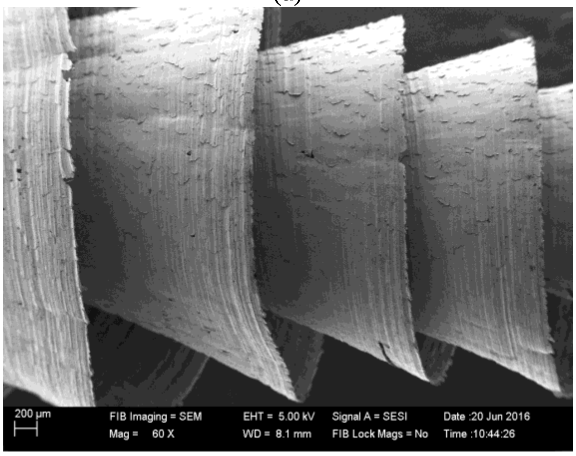


(b)

Fig 4.1 (a) & (b) Spiral (tight helix) groove edges type chip formation



(a)



(b)

Fig 4.2(a) & (b) Spiral cone type chip formation

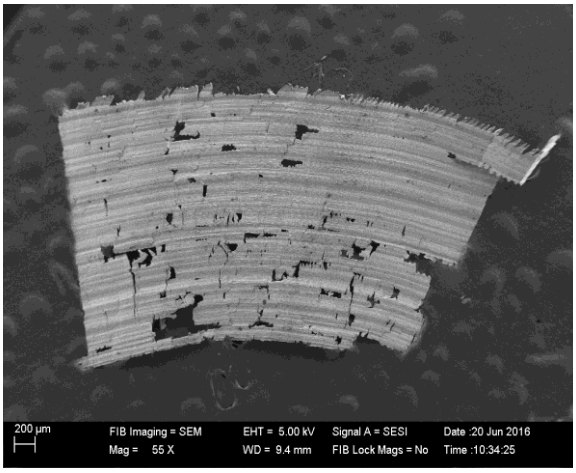


Fig 4.3 Fan shape chip formation

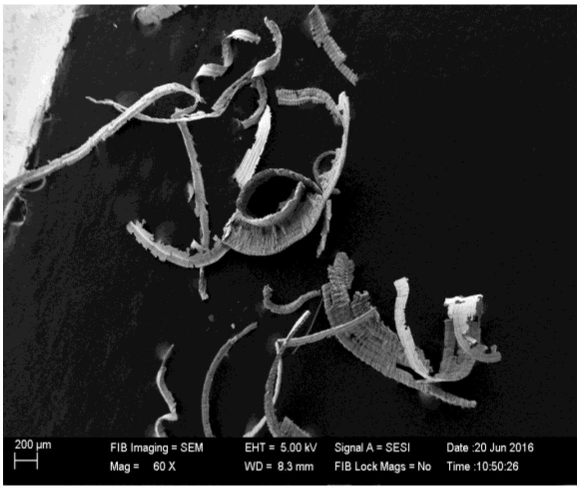
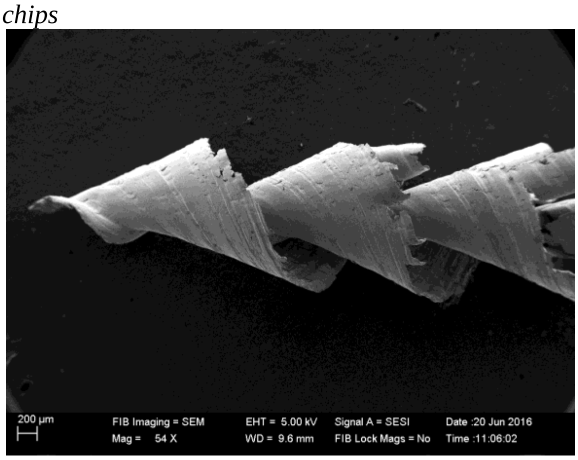


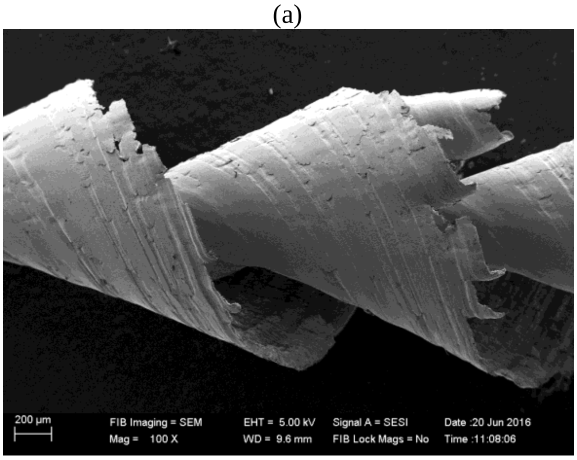
Fig 4.4 Thin continuous type chip formation

From the SEM results, the different chips obtained in machining of EN8 steel using uncoated HSS tool at cutting speed 36.6m/min and feed rate 0.024mm/rev were: Spiral (tight helix) grove edges, spiral cone type, fan shape and thin continuous types chips.

4.1.2Titanium Nitride (TiN) coated HSS tool drilled chips

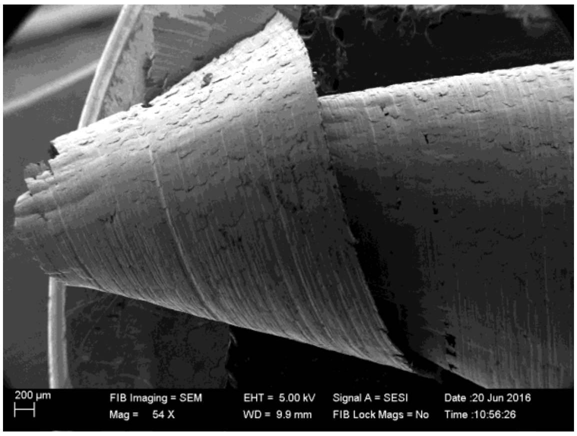


(a)

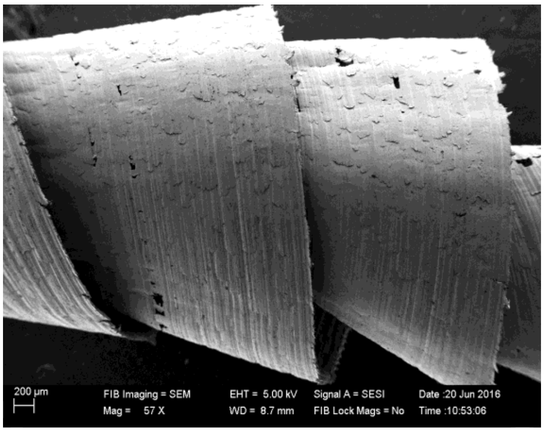


(b)

Fig 4.5(a) & (b) Small spiral (loose helix) cone type chip formation

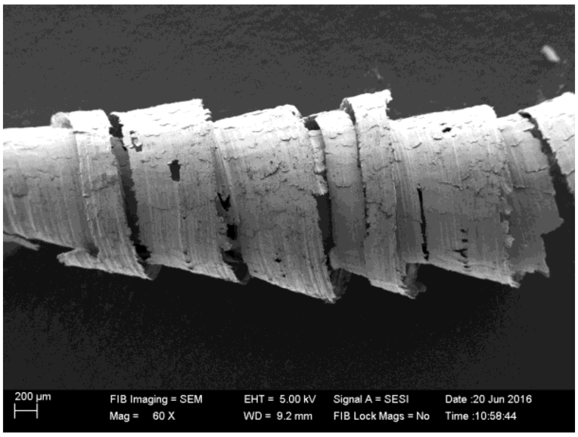


(a)

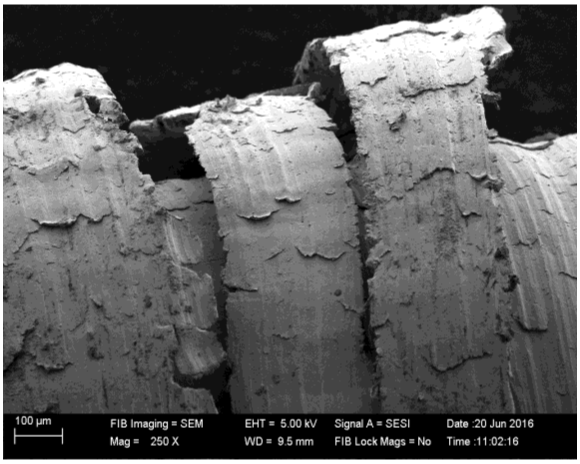


(b)

Fig 4.6(a) & (b) Large spiral cone type chip formation



(a)



(b)

Fig 4.7 (a) & (b) Spiral overlap type chip formation

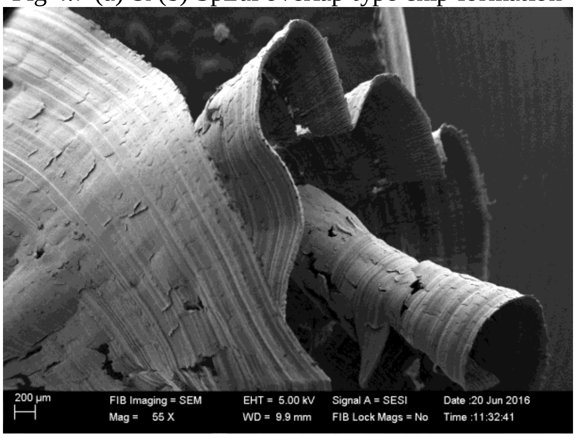


Fig 4.8 Ribbon (wave) chip

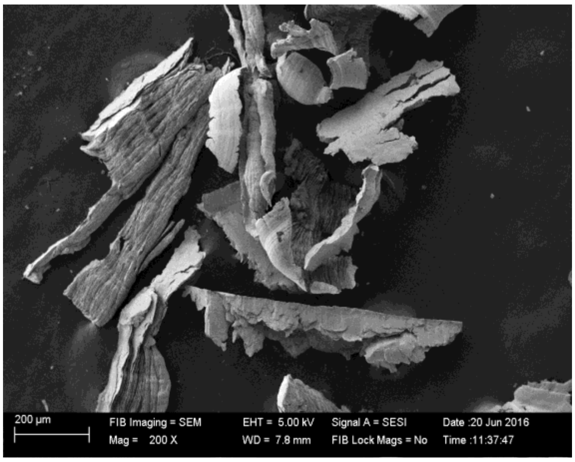


Fig 4.9 Discontinuous type chips

The chips obtained in machining of EN8 steel using TiN coated HSS tool at cutting speed 36.6m/min and feed rate 0.024mm/rev were: Small spiral (loose helix) cone, large spiral cone, spiral overlap, ribbon (wave) and discontinuous types of chips.

4.1.3 Titanium Aluminium Nitride (TiAlN) coated HSS tool drilled chips

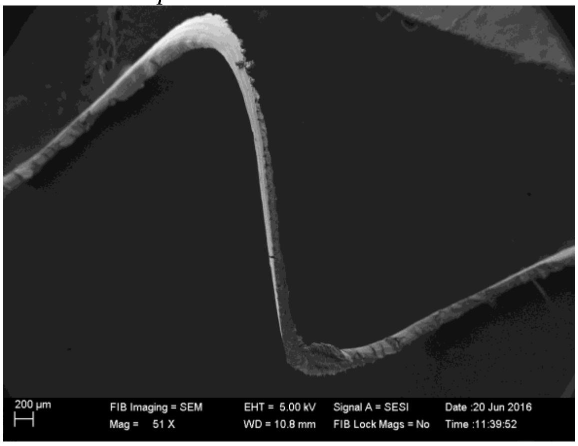
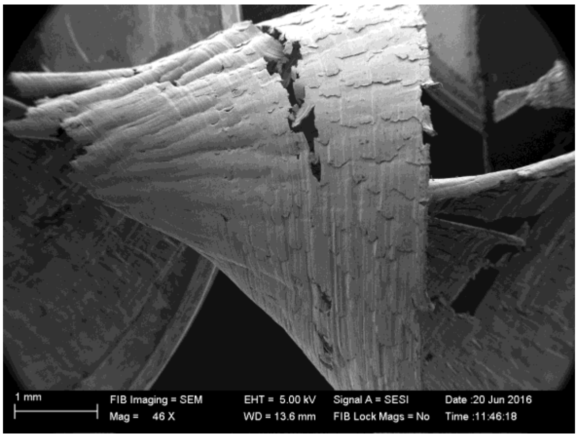
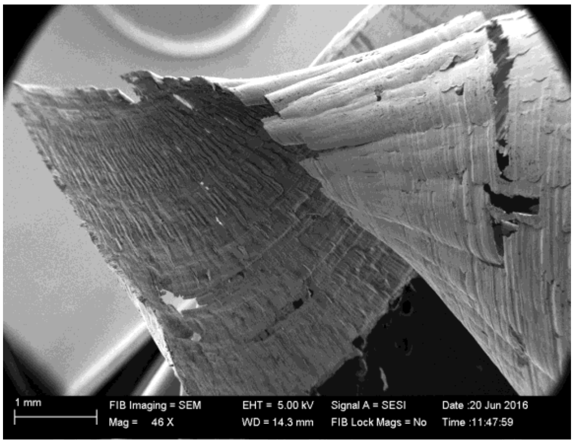


Fig 4.10 Helical (loose helix) type chip formation



(a)



(b)

Fig 4.11 (a) & (b) Spiral type chip formation

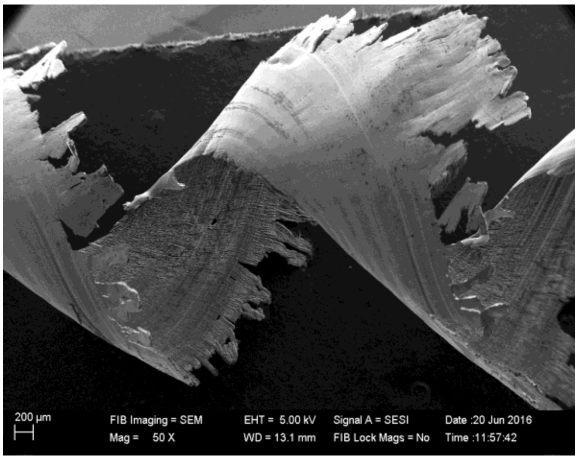


Fig 4.12 Small spiral type chip formation

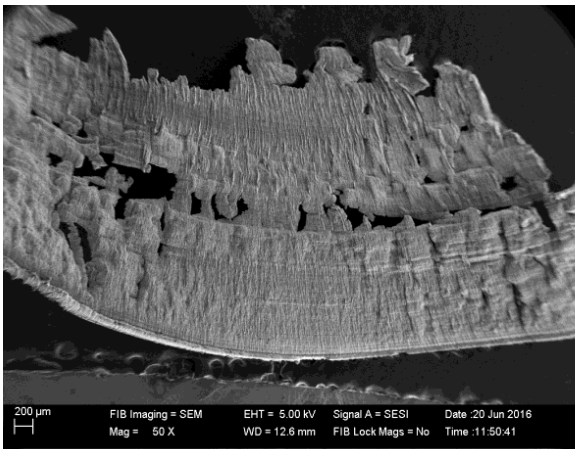


Fig 4.13 Continuous chip

The chips obtained in machining of EN8 steel using TiAlN coated HSS tool at cutting speed 36.6m/min and feed rate 0.024mm/rev were: Helical (loose helix), spiral, small spiral and continuous type of chips.

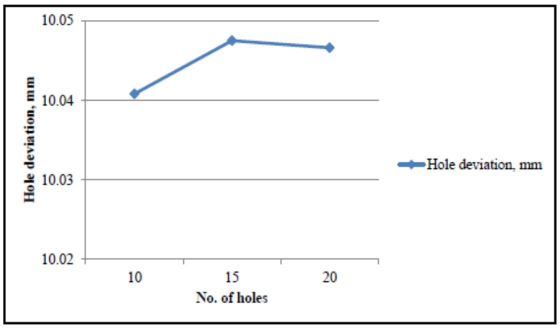
4.2 Hole Deviation

After drilling the holes in work piece, the final shape and its deviation was measured using digital vernier caliper. The hole deviation is measured at top, middle and bottom portion with different direction of each hole for every 10 intervals and average is taken for every 10th interval hole.

4.2.2 Uncoated High Speed Steel (HSS) drill tool drilled hole deviation

Table 4.1: Uncoated HSS drill tool drilled hole deviation data

Uncoated High Speed Steel (HSS) drill tool drilled Hole Deviation						
Holes	Position	⊖	⦶	⦸	⊘	Average Hole Deviation, mm
10	Top	10.09	10.06	10.06	10.06	10.04083333
	Middle	10.03	10.02	10.02	10.02	
	Bottom	10.1	10.01	10	10.02	
15	Top	10.14	10.09	10.11	10.08	10.0475
	Middle	10.05	10.03	10.02	10	
	Bottom	10.01	10.01	10.02	10.01	
20	Top	10.12	10.14	10.12	10.1	10.04666667
	Middle	10.01	10.04	10.02	10.02	
	Bottom	10.02	10	9.97	10	



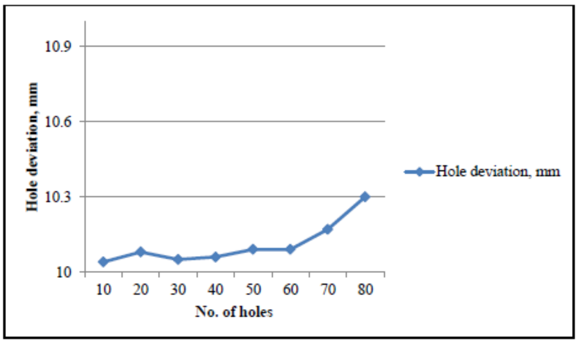
Graph 4.1 Hole deviation of uncoated HSS tool drilled holes

The above graph represents gradual increase and constant hole deviation in uncoated HSS drill tool.

4.2.3 Titanium Nitride (TiN) coated HSS drill tool drilled hole deviation

Table 4.2: TiN coated HSS drill tool drilled hole deviation data

Titanium Nitride (TiN) coated HSS drilled hole deviation						
Holes	Position	⊖	⦶	⦸	⊘	Average Hole Deviation, mm
10	Top	10.01	10	10.05	10.08	10.04
	Middle	10	10.06	10.07	10.04	
	Bottom	10	10.05	10.06	10.06	
20	Top	10.11	10.13	10.17	10.08	10.08666667
	Middle	10.06	10.1	10.08	10	
	Bottom	10.04	10.07	10.02	10.02	
30	Top	10.06	10.06	10.1	10.06	10.05666667
	Middle	10.06	10.08	10.03	10.07	
	Bottom	10.05	10	10.07	10.05	
40	Top	10.08	10.11	10.13	10.12	10.06777778
	Middle	10.05	10.07	10.01	10.09	
	Bottom	10.06	10.07	10.03	10.05	
50	Top	10.13	10.14	10.11	10.15	10.09888889
	Middle	10.09	10.09	10.08	10.09	
	Bottom	10.08	10.09	10.08	10.08	
60	Top	10.16	10.16	10.09	10.19	10.09777778
	Middle	10.11	10.09	10.09	10.1	
	Bottom	10.04	10.07	10.07	10.08	
70	Top	10.29	10.07	10.32	10.25	10.17111111
	Middle	10.21	10.1	10.2	10.2	
	Bottom	10.1	10.1	10.15	10.18	
80	Top	10.24	10.35	10.3	10.25	10.3
	Middle	10.3	10.3	10.28	10.25	
	Bottom	10.31	10.3	10.32	10.32	



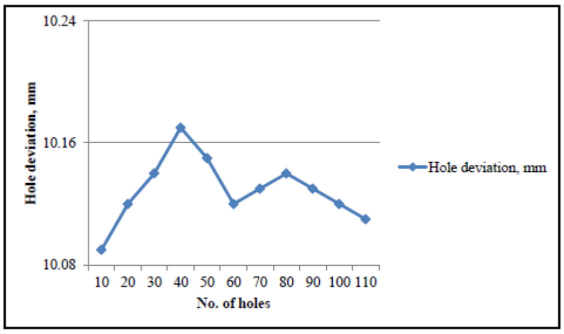
Graph 4.2 Hole deviation of TiN coated drill tool drilled holes

The above graph represents continuous hole deviation while drilling holes using TiN coated HSS drill tool.

4.2.4 Titanium Aluminium Nitride (TiAlN) coated HSS drill tool drilled hole deviation

Table 4.3: TiAlN coated HSS drill tool drilled hole deviation data

Titanium Aluminium Nitride (TiAlN) coated HSS drilled hole deviation						
Holes	**Position**	⊖	⦶	⦸	⊘	**Average Hole Deviation, mm**
10	Top	10.06	10.1	10.14	10.13	10.0925
	Middle	10.08	10.1	10.12	10.12	
	Bottom	10.12	10.11	9.9	10.13	
20	Top	10.15	10.11	10.16	10.14	10.12333333
	Middle	10.06	10.1	10.16	10.15	
	Bottom	10.08	10.12	10.15	10.1	
30	Top	10.17	10.16	10.1	10.16	10.1425
	Middle	10.17	10.14	10.13	10.17	
	Bottom	10.11	10.14	10.11	10.15	
40	Top	10.21	10.2	10.24	10.21	10.17416667
	Middle	10.19	10.18	10.19	10.17	
	Bottom	10.12	10.13	10.15	10.1	
50	Top	10.2	10.21	10.18	10.21	10.15083333
	Middle	10.1	10.21	10.11	10.16	
	Bottom	10.09	10.15	10.08	10.11	
60	Top	10.16	10.16	10.17	10.14	10.12833333
	Middle	10.11	10.12	10.15	10.09	
	Bottom	10.11	10.13	10.09	10.11	
70	Top	10.19	10.16	10.17	10.18	10.1375
	Middle	10.13	10.08	10.15	10.15	
	Bottom	10.14	10.08	10.12	10.1	
80	Top	10.18	10.18	10.17	10.18	10.14
	Middle	10.14	10.13	10.1	10.14	
	Bottom	10.08	10.13	10.12	10.13	
90	Top	10.19	10.18	10.2	10.18	10.13416667
	Middle	10.14	10.08	10.15	10.14	
	Bottom	10.1	10.08	10.08	10.09	
100	Top	10.17	10.16	10.17	10.2	10.12416667
	Middle	10.1	10.11	10.13	10.11	
	Bottom	10.11	10.07	10.1	10.06	
110	Top	10.21	10.18	10.17	10.16	10.11666667
	Middle	10.09	10.07	10.1	10.09	
	Bottom	10.07	10.09	10.09	10.08	

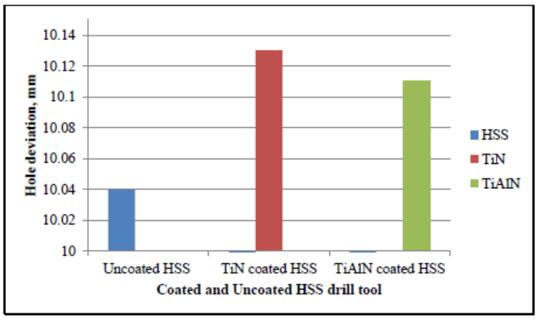


Graph 4.3 Hole deviation of TiAlN coated drill tool drilled hole

The above graph represents increase and decrease of hole deviation during drilling holes using TiAlN coated HSS drill tool.

Table 4.4: Average hole deviation of coated and uncoated HSS tool drilled holes

Average hole deviation of coated and uncoated HSS tool drill holes	
Drill tool	**Average hole deviation, mm**
Uncoated HSS tool	10.04
TiN coated HSS tool	10.13
TiAlN coated HSS tool	10.11



Graph 4.4 Comparison of hole deviation for coated and uncoated HSS drill tool drilled holes

The above graph represents comparison of hole deviation for coated and uncoated HSS tool drilled holes and it is observed that the hole deviation is minimum during drilling holes using uncoated HSS tool, the hole deviation is average during drilling holes using TiAlN coated HSS tool and there is a maximum hole deviation during drilling holes using TiN coated HSS tool.

4.3 Temperature Distribution

To measure the temperature at cutting tool surface thermal imaging camera was used.

4.3.1Uncoated HSS tool temperature

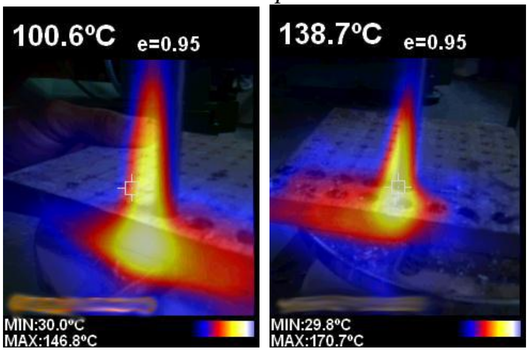
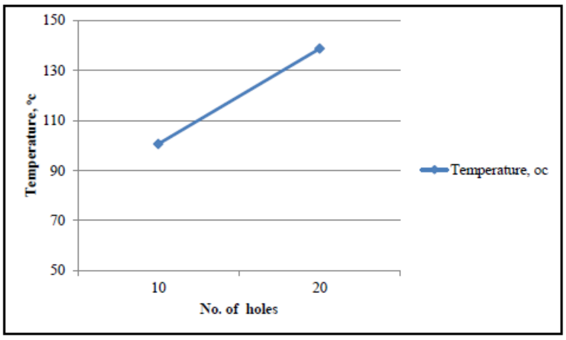


Fig 4.14Temperature of HSS tool at (a) 10th and (b) 20th hole



Graph 4.5 Graph of temperature distribution of uncoated HSS tool

4.3.2Titanium Nitride (TiN) coated HSS tool temperature

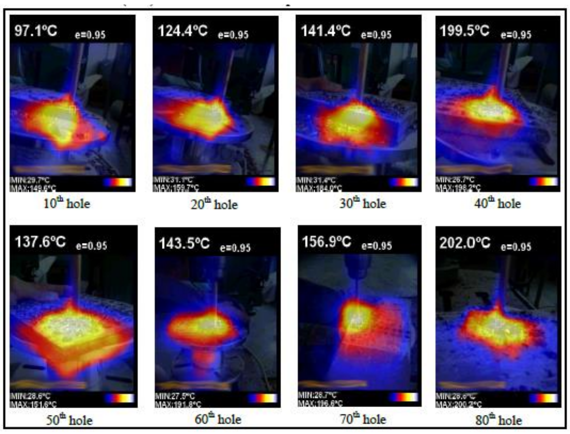
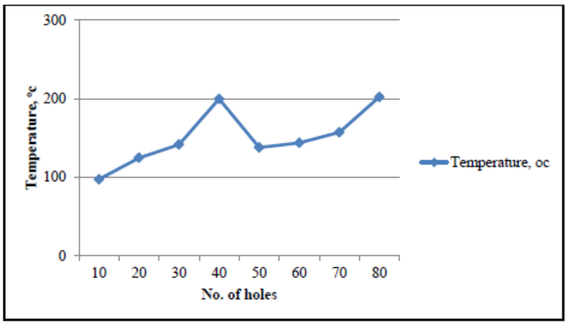


Fig 4.15Temperature distribution of TiN coated HSS tool



Graph 4.6 of temperature distribution of TiN coated HSS tool

The above graph represents temperature distribution during drilling holes using TiN coated HSS tool. It represents that there is a continuous increase in temperature.

4.3.3 Titanium Aluminium Nitride (TiAlN) coated HSS tool temperature

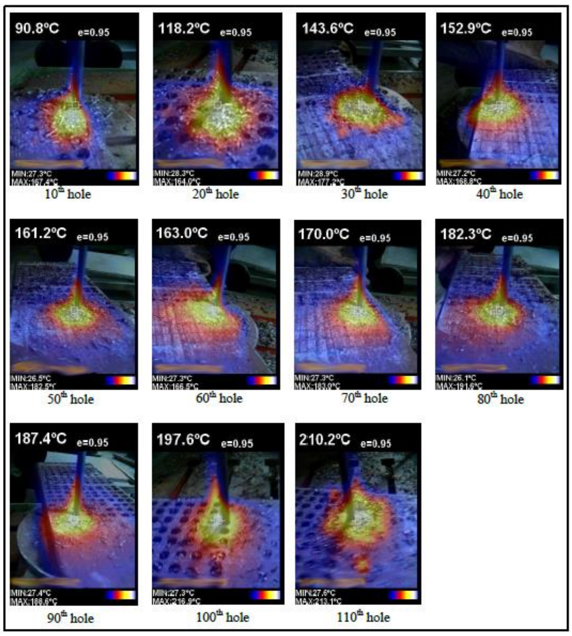
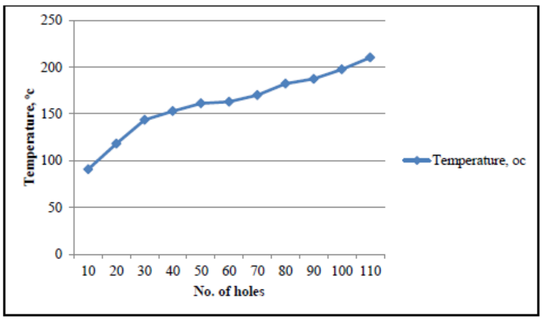


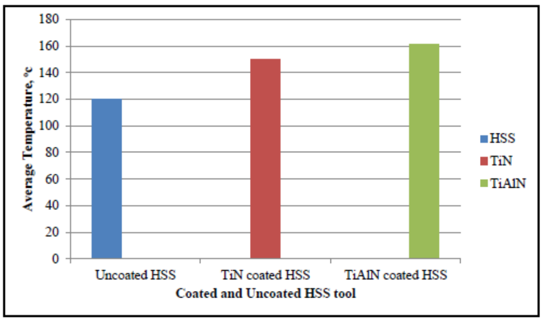
Fig 4.16 Temperature distribution of TiAlN coated HSS tool



Graph 4.7 Temperature distribution of TiAlN coated HSS tool

Table 4.5: Average temperature distribution for coated and uncoated HSS tool

Average temperature distribution for coated and uncoated HSS tool	
Drill tool	**Temperature, °C**
Uncoated HSS	119.65
TiN coated HSS	150.3
TiAlN coated HSS	161.56



Graph 4.8 Comparison of temperature distribution in coated and uncoated HSS tool

In the above graph it represents that Titanium Aluminium Nitride (TiAlN) coated HSS drill tool can withstand maximum temperature of 210ºC for 110 holes. Titanium Nitride (TiN) coated HSS drill can withstand 202ºC for 80 holes and uncoated HSS tool can withstand only 138.7ºC for 20 holes.

5. CONCLUSION

In the present work, various types of chips formed during the drilling were examined using SEM. It was found that spiral (tight and loose helix), spiral cone, fan shape, thin continuous, spiral overlap, ribbon, helical, and discontinuous chips were produced.
Hole deviation was calculated using digital vernier caliper and it was found that there was a maximum deviation of 10.13mm in TiN coated HSS tool drilled holes and there was a marginally reduced deviation in TiAlN and uncoated HSS tool drilled holes of 10.11mm and 10.04mm. Temperature distribution was measured using thermal imaging camera and there was a maximum temperature in TiAlN coated HSS tool of 161.56ºC for more number of holes and there was a comparatively less temperature in TiN and uncoated HSS tool of 150.3ºC and 119.65ºC tool.

REFERENCES

[1] Mustafa Bakkal, Albert J. Shih, Samuel B. Mcspadden, C.T. Liv, Ronald O Scattergood "Light emission, Chip morphology, and burr formation in drilling the bulk metallic glass" International Journal of Machine Tools and Manufacture 45(2005) 741-752.

[2] Kadam M.S, Pathak S.S "Experimental Analysis and comparative performance of coated and uncoated Twist drill bit dry machining" ISSN: 2249-5762(online) IJRMET vol.1, Issue 1, Oct 2011.

[3] A. Meena, M. EI Mansori "Specific cutting forces, tool wear and chip morphology characteristics during dry drilling of Austempered ductile iron (ADI)" Int. J. Adv. Manuf. Technol (2013)69: 2833-2841.

[4] Kadam M.S, Pathak S.S "Experimental Analysis and comparative performance of coated and uncoated Twist drill bit dry machining" ISSN: 2249-5762(online) IJRMET vol.1, Issue 1, Oct 2011.

[5] Masaliko Sato, Tomoyuki Aoki, Hisataka Tanaka, Satoshi Takeda "Variation of temperature at the bottom surface of a hole during drilling and its effects on tool wear" International Journal of Machine tools and manufacture 68(2013) 40-47.

[6] A. Daymi, M. Boujelbene, S. Ben Salem, B. Hadj Sassi, S. Torbaty "Effect of the cutting speed on the chip morphology and cutting forces" 2009, Volume 1, Issue 2, 77-83.

[7] R.J. Talib, M.R.M. Toff and H.M. Ariff "Wear Mechanism of TiN, TiAlN and TiCN coated drills during drilling of carbon steel" Journal of physical science, Vol.18(1), 75-85, 2007.

[8] Anil Jindal "Analysis of tool wear rate in drilling operation using scanning electron microscope (SEM)" Journal of Minerals and Materials Characterization and Engineering, Vol.11, No.1, PP.43-54, 2012.

[9]Masato Okada, Naoki Asakawa, Yusuke Fujita, Makoto Nikawa "Cutting characteristics of twist drill having cutting edges for drilling and reaming" Journal of Mechanical Science and Technology 28(5)(2014).