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Thermal Investigation on Coated and Uncoated HSS Twist Drill using ANSYS Software

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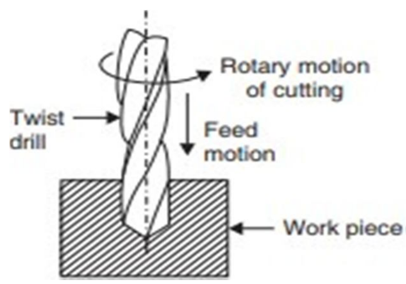
Abstract: In drilling, a cylindrical hole is produced in workpiece, removing the material inside the workpiece. The cutting tool used in drilling operation is called 'Twist Drill'; it rotates and allows the material to be removed from the workpiece in the form of chips and thus drill the hole. Cutting fluids or coolants are used to perform this operation smoothly. The coating on the drill bits helps to reduce friction in the cut and the heat buildup in the drill bit. Coating also helps in protecting against corrosion. The present work focuses on the features of uncoated High Speed Steel (HSS) Twist Drill bit and Titanium Nitride (TiN) and Titanium Aluminium Nitride (TiAlN) coated on HSS Drills. The workpiece material was Mild Steel and the drilling operation was done using normal machining condition i.e. in presence of coolant. The cutting parameters used are cutting speed (35.5 m / min), spindle speed (1500 rpm), feed rate (0.2 mm / rev.), depth of cut (10 mm). These parameters were kept constant. Temperatures were measured with the help of thermal imaging camera and with the help of ANSYS software thermal analysis were done. Experimental results showed that the average rise in temperature of uncoated HSS tool was higher as compared to TiN coated and TiAlN coated HSS tools. TiAlN coated drills showed the least average rise in temperature.
Keywords: High Speed Steel (HSS) Drill, TiN and TiAlN Coated HSS Twist Drill, Mild Steel (MS), Thermal Analysis, ANSYS Software.

I. INTRODUCTION

Drilling, it's a process of making hole in the workpiece by rotary motion of the cutter/drill or it can also enlarge a hole. In drilling operation circular holes are produced in hard workpiece, by rotation of the Twist Drill. Generation of hole takes place by the rotation of the cutting tool edge, which employ greater force on the workpiece, which is fixed on the table. The drill is fed into the workpiece and the drilling operation is carried out by removing the material from the workpiece. The cutting edge of twist drill produces a hole by removal of excess material from the workpiece. The material gets removed in the form of chips.



Compression of the workpiece material takes place in front of the tool tip of the Drill. Due to which it experiences high temperature shear and plastic flow, when the stress in the workpiece material, just ahead of the cutting tool (Drill) it reaches a value greater than the ultimate strength of the workpiece material, particles will shear to form a element which is known as Chip. These chips gets removed up along the face of the work. Drilling can be done on different types of material like plane or smooth and tilted surfaces; it can also be done on composites, plastics, wood, ceramics and metals.

Drill bits can be manufactured by using different types of materials. The performance and life of drill bit depends on the material which is chosen to manufacture the drill bit. Most commonly used material for manufacturing of drill bits is HSS. There are different grades of HSS available in the market. When we apply coating on these HSS twist drill its performance and tool life increases as well as it provides superior mechanical properties. It can be treated as surface treatment process which is used to increase rigidity and red hardness of the cutting tool. It increases the tool life in addition to it improves quality of machined surface. In contrast to uncoated tools, coated tools increase the rate of production. There are different types of coating which are used to coat drill bits, in this paper we will be focusing on TiN coating and TiAlN coating.

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II. LITERATURE REVIEW

Puneeth H V et.al [1] presented a paper on "Studies on Tool Life and Cutting Forces for Drilling operation using Uncoated and Coated HSS Tool". The paper focuses on the traits of HSS twist drill. The coating which were used are; Titanium Nitride (TiN) and Titanium Aluminium Nitride (TiAlN). The workpiece material selected was EN8 which was machined in dry drilling condition, output variables like tool life along with cutting forces which are required in machining the workpiece for coated and uncoated HSS twist drill bit was found out. After carrying out the experiment the outcome proved that the TiAlN coated HSS drill bits has better tool life in contrast to TiN coated drill and uncoated drill. With the help of drill tool dynamometer, thrust force and torque was obtained. The outcome showed that the highest thrust force was incorporated in TiAlN coated HSS twist drill. While the torque formed in all the drills was at an average value.

Rhander Viana et.al [2] personated a paper on "Evaluation of the Performance of Coated HSS Drills in Machining of Al - Si Alloy". In this paper four different types of coating were used: TiN/TiCN , TiAlN, TiN/TiAlN and Tin/TiAlN/WCC. High Speed Steel twist drill performance was evaluated in machining of an ISO 3522 aluminium-silicon (Al-Si8Cu3Fe) alloy. Coolant was used while carrying out the experiment.

The output parameters were tool life, which was indicated in the number holes machined and thrust force were used to study the performance of cutting tool. Comparative trials were also carried out with uncoated tools. The results obtained after experimentation shows that the coated drills presented superior performance when compared to the uncoated tools. TiN/TiCN coated HSS twist drill showed the best performance by allowing the highest number of holes machined. There was a slight variation in the trust force for all the cutting tools investigated.

Ismail Tekaut et.al [3] presented a paper on "Experimental analysis and theoretical modeling of cutting parameters in the drilling of AISI H13 steel with coated and uncoated drill". The paper contains drilling experiments which were conducted on the AISI H13 work steel. AlCrN coated and uncoated carbide drills were used having Dia. 14mm. Four distinct cutting speeds were used (60, 75, 90 and 108 m/min) and three distinct feed rates (0.15, 0.20 and 0.25 mm/rev) were utilized. After experimental work was carried out, the results showed that the feed rate was directly proportional to the thrust force.

It was also observed that in uncoated drills as the cutter speed was increased the thrust force was also increased while the torque decreased. Contrast to that, in coated drills as the cutter speed increase both thrust force and torque were decreased. Analysis was done of the stress which were taking place in the drill and on the basis of that a mathematical model was prepared with the help of finite element method and ANSYS software.

Noor Atiqah Badaluddin et.al [4] presented a paper on "Coating of Cutting Tools and their Contribution to Improve Mechanical Properties: A Brief Review". In this paper a brief review of coating on cutting tools is given. Benefits of coated tools and its different types are studied. Coated tools are at greater advantage when we consider the mechanical and tribology properties. Even the end result of the product is good as compared to uncoated tools. Various types of coating are applied on tools to increase its performance.

The paper examines cutting tools and their functions. Coating and their ranked formation was also discussed in order to help researchers in understanding the suitable coating formation for cutting tool use.

Guangchao Hao et.al [5] presented a paper on "Influences of TiAlN coatings on cutting temperature during orthogonal machining H13 Hardened Steel". In this paper friction test of H13 hardened steel at evaluated temperature using TiAlN coated and uncoated tool was carried out. The outcomes of TiAlN coated and uncoated drills were differentiated and it was seen that the coefficient of friction (COF) between TiAlN coated and uncoated tools was reduced to 0.63 at 800^{o}C.

III. OBJECTIVE AND METHODOLOGY

A. Objectives

The main objective of this investigation was to compare average rise in temperature while machining of uncoated high speed steel (HSS), Titanium Nitride (TiN) coated drill and Titanium Aluminium Nitride (TiAlN) coated drill. Workpiece used for machining was Mild Steel. The input parameters like speed, feed and depth of cut were kept constant throughout the operation.

B. Methodology

From the literature review, TiN coated HSS and TiAlN coated HSS Twist Drills were selected in the machining of Mild steel. To obtain temperature while machining of coated and uncoated drills thermal imaging camera was used. After the results were obtained thermal analysis was carried out using ANSYS software.

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IV. EXPERIMENT WORK

A. Experimental Setup

The drilling operation was performed on vertical bench drilling machine which is shown in the Fig. 4.1. During drilling operation coolant was used. In this experiment the material of the workpiece was Mild Steel. Three different HSS twist drills were used to carry out drilling operation; these drills are TiN coated, TiAlN coated and uncoated HSS drills.

Fig.-4.1 Vertical Bench Drilling Machine

B. Drill Material

The material selected for drill was high speed steel (HSS) with grade AISI M-2. AISI M-2 is tungsten-molybdenum high-speed steel. The carbon content in M-2 grade is higher due to which it provides higher wear resistance and it can with stand higher temperature without losing hardness.

Table-4.1 Chemical composing of HSS (M-2)

Element	Content (%)
Carbon (C)	0.78-1.05
Manganese (Mn)	0.15-0.40
Silicon (Si)	0.20-0.45
Tungsten (W)	5.50-6.75
Molybdenum (Mo)	4.50-5.50
Chromium (Cr)	0.20-0.45
Vanadium (V)	1.75-2.20
Nickel (Ni)	0.3

There are three different HSS twist drills which were used to carry out the experiment. The machining variables such as cutting speed, spindle speed, feed rate and depth of cut are kept constant. The HSS drill bits specification was also kept same for all drills.

(a) Uncoated (b) TiN Coated (c) TiAlN Coated

Fig.-4.2 Fig. - 4.2 HSS Twist Drill

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Table-4.2 Machining Parameters

HSS drill bit	Cutting speed (m/min)	Spindle Speed (rpm)	Feed Rate (mm/rev.)	Depth of Cut (mm)
Uncoated	35.5	1500	0.2	10
TiN Coated	35.5	1500	0.2	10
TiAlN coated	35.5	1500	0.2	10

Table-4.3 HSS Drill bit specification

Drill Material	Diameter (mm)	Flute Length (mm)	Overall Length (mm)	Helix Angle (Deg.)	Point Angle (Deg.)
Uncoated	8	110	150	30	118
TiN Coated	8	110	150	30	118
TiAlN coated	8	110	150	30	118

C. *Workpiece Material*

In this experiment, mild steel was preferred as the workpiece material. It’s a ferrous metal made from iron and carbon.

Table-4.4 Chemical Composition of Mild Steel (MS)

Element	Content (%)
Carbon (C)	0.25-0.290
Copper (Cu)	0.20
Iron (Fe)	98.0
Manganese (Mn)	1.03
Phosphorous (P)	0.040
Silicon (Si)	0.280
Sulphur (S)	0.050

V. RESULTS AND DISCUSSIONS

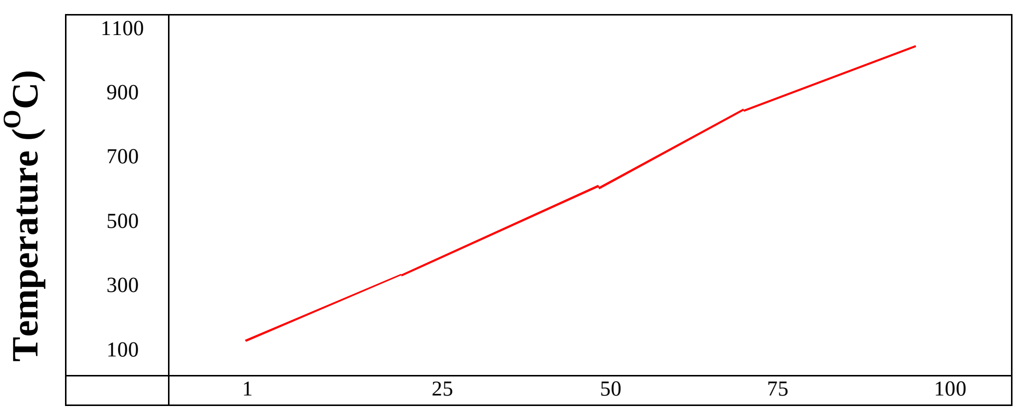
Thermal imaging camera was used to measure the temperature at cutting tool surface.

A. *Uncoated HSS Tool Analysis*

Total 100 holes were drilled on Mild Steel with uncoated HSS twist drill and following temperature were obtained at cutting tool surface.

Table 5.1 Uncoated HSS drill temperatures

No. of Holes	1	25	50	75	100
Temperature	30^o	241.96^o	506.17^o	770.39^o	990.1^o



No. of Holes

Graph 5.1 No. of Holes drilled vs. Temperature distribution in uncoated HSS drill

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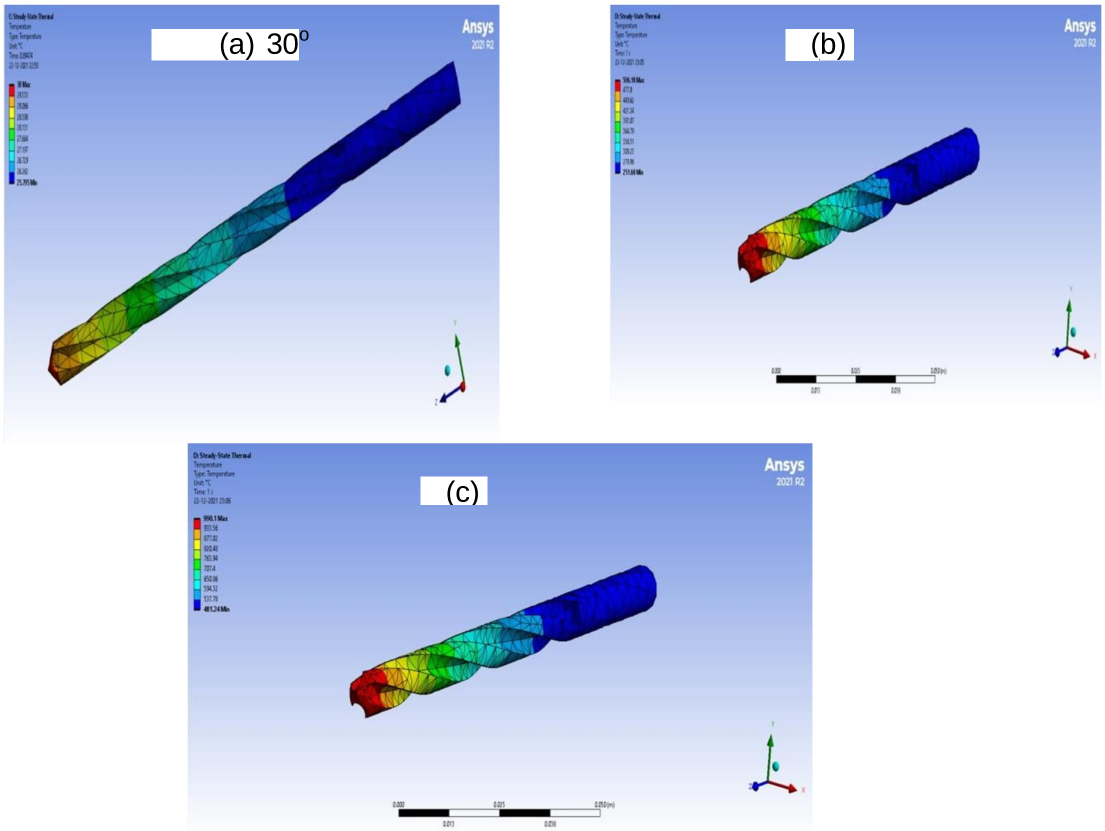


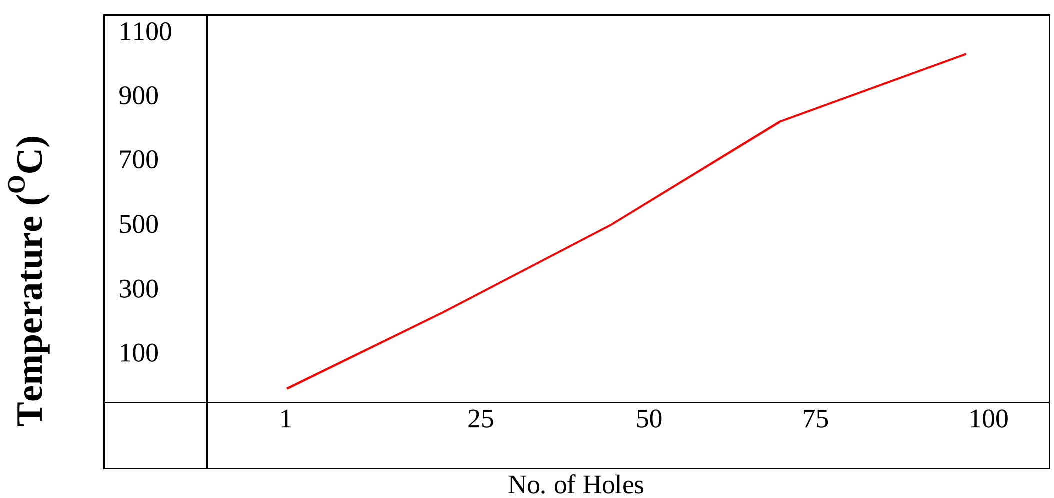
Fig. 5.1 Temperature analysis of Uncoated HSS drill

B. *TiN Coated HSS tool Analysis*

Total 100 holes were drilled on Mild Steel with TiN coated HSS twist drill and following temperature were obtained at cutting tool surface.

Table 5.2 TiN Coated HSS Drill Temperature

No. of Holes	1	25	50	75	100
Temperature	30°	230.42°	484.167°	756.11°	964.927°



Graph 5.2 No. of Holes drilled vs. Temperature distribution in TiN coated HSS drill

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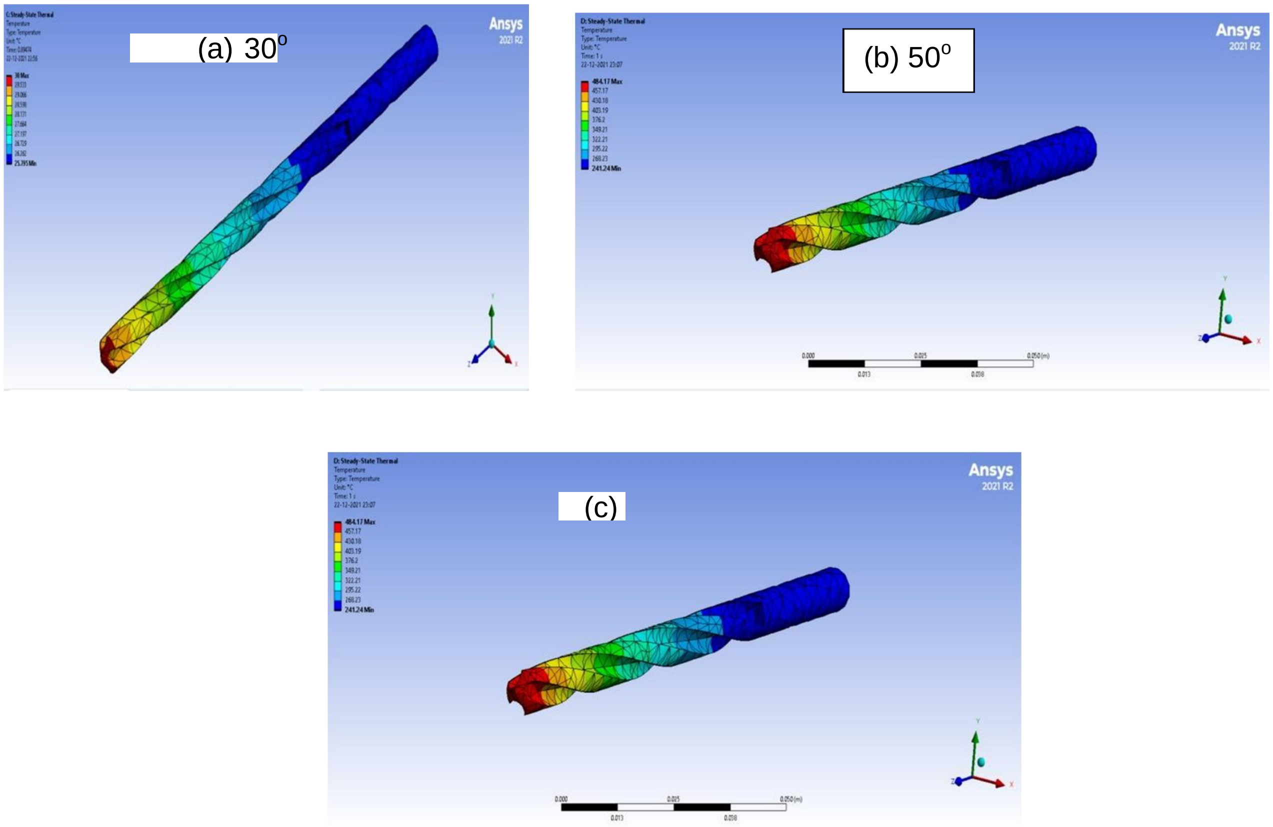


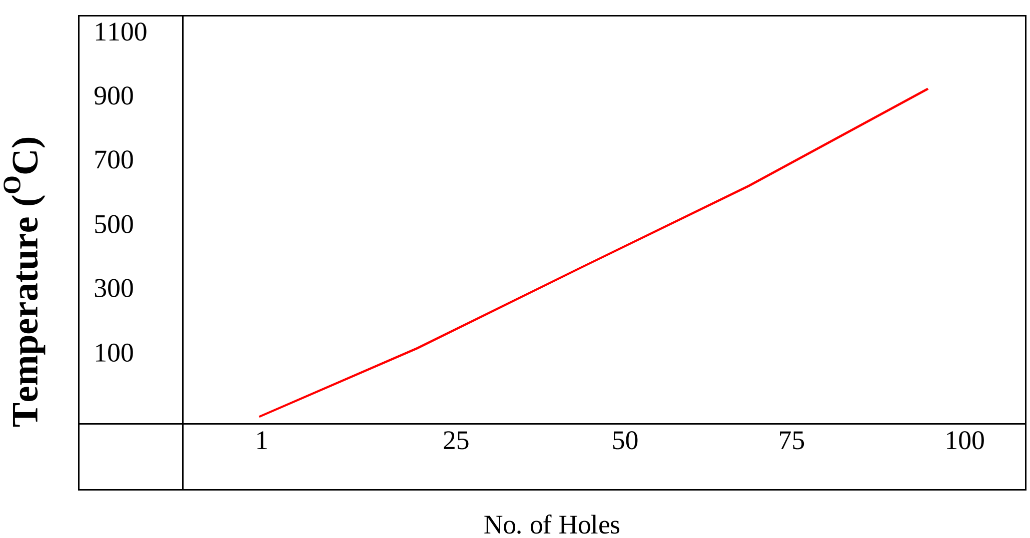
Fig. 5.2 Temperature analysis of TiN coated HSS drill

C. TiAlN Coated HSS tool Analysis

Total 100 holes were drilled on Mild Steel with TiAlN coated HSS twist drill and following temperature were obtained at cutting tool surface.

Table 5.3 TiAlN coated HSS drill temperatures

No. of Holes	1	25	50	75	100
Temperature	30°	227.43°	454.723°	683.09°	908.543°



Graph 5.3 No. of Holes drilled vs. Temperature distribution in TiAlN coated HSS drill

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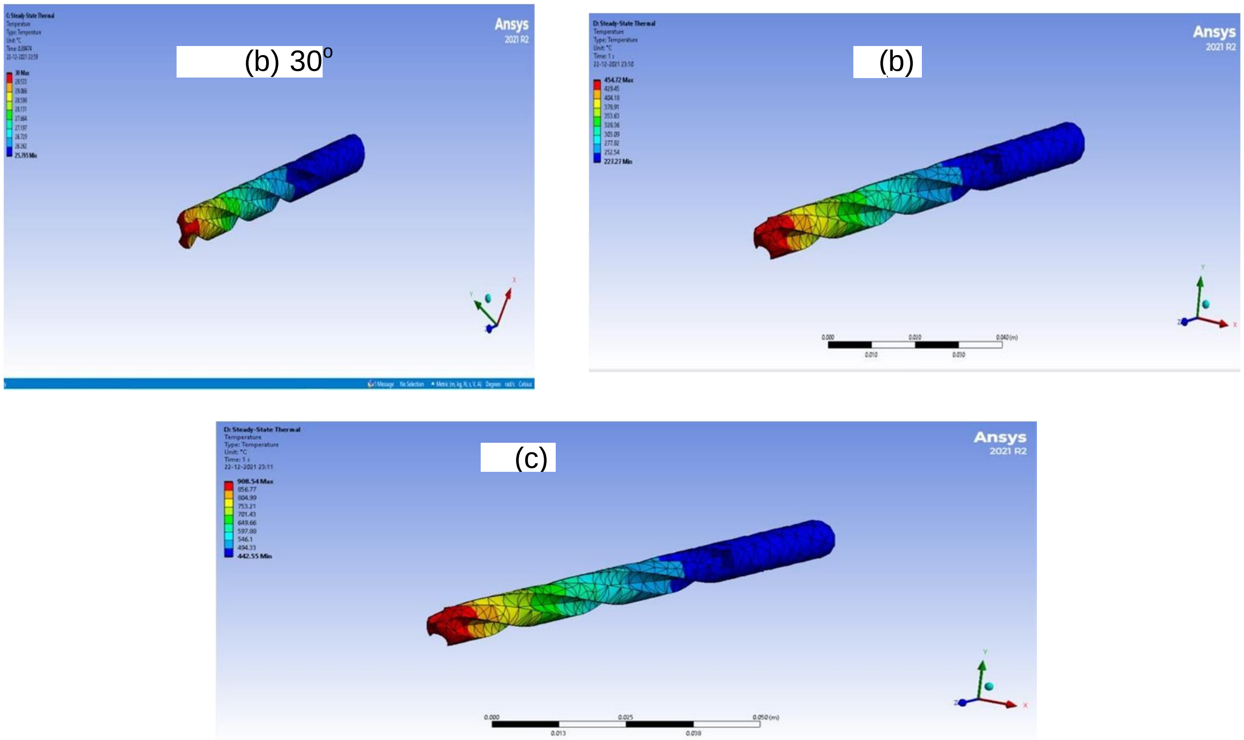
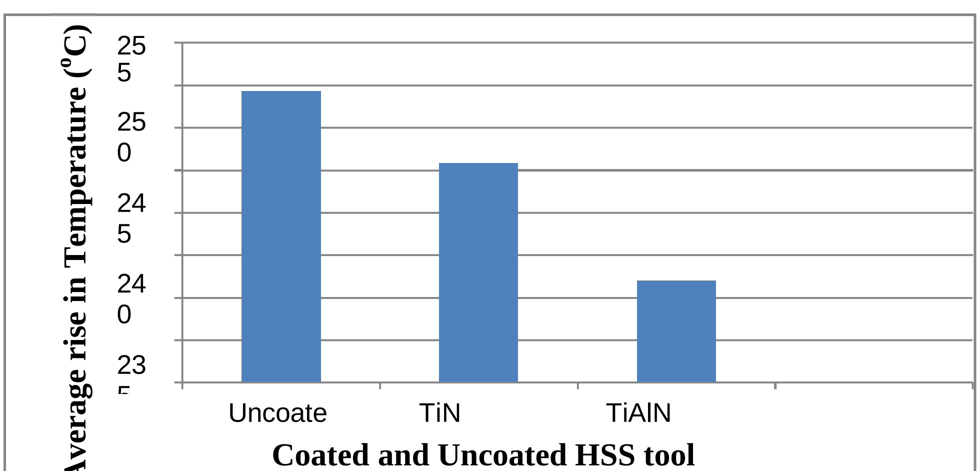


Fig. 5.3 Temperature analysis of TiAlN coated HSS drill

After measuring the temperature at cutting tool surface and carrying out thermal analysis in ANSYS, with the obtained temperatures it was found that the average rise in temperature at uncoated cutting tool surface is higher than the TiN coated and TiAlN coated HSS twist drills. Subsequently observing and comparing the results it was identified that the average rise in temperature at cutting tool surface of TiAlN coated HSS twist drill was less in comparison to TiN coated.

Table 5.4 Average rise in temperature for coated and uncoated HSS drill

Drill Tool	Average rise in temperature (°C)
Uncoated	249.38
TiN Coated	240.83
TiAlN	227.01



Graph 5.4 Comparison of rise in Temperature in coated and uncoated HSS tool

VI. CONCLUSION

Thermal analysis was conducted on uncoated, TiN coated and TiAlN coated HSS twist drill. The temperature was obtained using thermal imaging camera. Average rise in temperature was calculated and results were analyzed and compared. It was observed that the average rise in temperature of uncoated tool during normal machining conditions was higher than the TiN coated and TiAlN coated HSS tools. The maximum operating temperature of TiAlN coated HSS twist drill is higher with respect to TiN coated drills and uncoated drills. Due to which the average rise in temperature of TiAlN coated drills at cutting tool surface was less as compared to TiN coated.

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