Studies on Tool Life and Cutting forces for drilling operation using Uncoated and coated HSS tool

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Abstract - *Drilling is a machining operation of producing cylindrical hole in solid work piece by means of revolving tool called drill bit. Twist drills are the tools used to carry out drilling operation by rotating the cutting tool that normally has two cutting edges and two flutes with grooves formed in the body. Drill bit coatings make drill bit harder, more lubricated and sharper, heat resistance than uncoated drill bit. Coating the drill bit improves tool life, cutting quality and durability of drill bits. This paper compares the characteristics of 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 tool life and cutting forces required during machining of EN8 material for uncoated HSS and Titanium Nitride, Titanium Aluminium Nitride coated HSS drill bit are found out. Experimental results showed that TiAlN coated HSS twist drill had greater tool life compared to TiN coated HSS and uncoated HSS twist drill. Cutting forces such as thrust and torque were found out using drill tool dynamometer. The results showed that the maximum thrust force was developed in TiAlN coated HSS compared to TiN coated HSS and uncoated HSS whereas the torque produced in all the twist drills were at an average values.*

***Key Words*: Twist drills; Uncoated HSS drill; TiN and TiAlN Coated HSS drill; EN8 steel, Cutting forces.**

1. INTRODUCTION

Drilling is a type of machining operation by which cylindrical holes are created in hard work piece, by using a rotating tool called drill bit [6]. During drilling operation a chuck holds the drill bit and rotated at high speed. By using hand roll feed or automatic feed mechanism drill bit is compelled in contrast to strictly clamped solid work piece. The gentle cutting edges of turning drill bit creates a hole by removing excess material in form of chips which gets coiled and escapes across helical grooves provided on drill bit. Even drilling process looks simple, but it is essentially complex one. Comparing with other machining process the tool not only performs cutting act, it also force out chips or cut materials from solid work piece. Drilling can be done on plane or smooth and tilting surface, and on different material like composites, plastics, wood, ceramics and metals.

1.1 Drill Bit and work piece Materials

In manufacturing of drill bits wide varity of different materials are used. The different type of material chosen plays an important role in performance and life of drill bit. The commonly used materials are:

High speed steel: In present days for manufacturing of drill bits High speed steel is most widely used material. It is an alloyed steel of 14-22% tungsten with molybdenum, vanadium, cobalt and chhromium. HSS drills are classified in to two types namely M-type (10% molybdenum) and T-type(12-18% tungsten). About 95% of M-type series in manufacturing of HSS drills. It has some important characteristics properties like: Harder, Heat resistance, remain sharper during drilling of long time[6[.

Titanium nitride(TiN) coated drills: It is an hard ceramic material coated to HSS drills. Coated drill tolls are used to drill metal workpieces, since it has good mechanical properties. Coating HSS drill bit improves self-lubricating and hardness properties. The cutting tool life can be increased by two or more times to the HSS drills. TiN is very hard and inert material, thin film coatings is applied to metal parts. Titanium nitride is a combination of toughness, hardness and inertness. Physical vapor deposition (PVD) system is the environmental safe coating method, for coating thin film on HSS tool [5][7]. Applying TiN coating to metals improves surface chatacteristics. The coated TiN has gold colour with ultra hard material. It has very high chemical resistance which will not corrode during drilling. It has high temperature withstand capacity up to 600^0c, and non-toxic hence used for food processing equipment and medical surgicals. The coating is up to 3 micrometer thick. It has an wonderfull bond to base material that will not erupt, chip off or flake. TiN coated tools has 3-10 times long life capacity than uncoated tools.

Titanium Aluminium nitride (TiAlN): Titanium nitride developes thin film coating of Titanium Aluminium nitride (TiAlN), which offers very high temperature resistance than TiN. It has good hardness property at high temperature, and hence used in high temperature which exceeds limit of TiN. The coating is done by developing thin layer of aluminium oxide ceramic. It is an hard ceramic material coated to HSS drills. Coated drill tolls are used to drill metal workpieces, since it has good mechanical properties. Coating HSS drill bit improves self-lubricating and hardness properties. The cutting tool life can be increased by two or more times to the HSS drills. TiAlN coating can withstand higher temperature up to 800^{0}C, it has good oxidation resistance, low in friction and hard coating [5][7]. TiAlN used in high temperature applications, it is a complex structure of TiN and AlN which bond in crystalline matrix. It has 3-6 micrometer coating thickness, and has longer tool life of 3 to 10 times than uncoated tools. It has an wonderfull bond to base material that will not erupt, chip off or flake. Physical vapor deposition (PVD) system is the environmental safe coating method, for coating thin film on HSS tool.

EN8: In this experimental investgation EN8 steel is chosen as work piece 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 harden can be done to improve wear resistance, hardness ranges from 50-55HRC. EN8 is tempered between 550-600^{0}c. EN8 is normally supplied untreated, it is suitable for manufacturing gears, shafts, studs, bolts, keys, pins, connecting rods, axels, and rollers. When EN8 is heat treated it possess good homogenous metallurgical structure, by giving good machining properties

Table-1.1: EN8 Specification

EN 8 Mechanical properties	
Max Stress	700-850 n/mm^2
Yield Stress	465 n/mm^2 Min
0.2% Proof Stress	450 n/mm^2 Min
Elongation	16% Min
Impact KCV	28 Joules Min
Hardness	201-255 Brinell

EN8 Chemical composition	
Carbon	0.36-0.44%
Silicon	0.10-0.40%
Manganese	0.60-1.00%
Sulphur	0.050 Max
Phosphorus	0.050 Max
Chromium	–
Molybdenum	–
Nickel	–

1.2 Literature Review

Masato Okada et.al [1] presented a paper on "Cutting characteristics of twist drill having cutting edges for drilling and reaming". In this paper the cutting characteristics of a drill and reamer has conventional twist drill cutting edges appeared for reaming were investigated. A drill and reamer has three types of cutting edges they are drilling, semi finish and finishing. The cutting characteristics of conventional twist drill compared with reamer. The cutting characteristics were evaluated with thrust force, surface roughness, wear behavior, cutting torque of the cutting edges and temperature. The experiment consists of carbon steel work piece, the maximum temperature of 420^{0}c obtained at cutting edges of reaming even though depth of cut was small. The inner surface roughness with reamer was high to that of conventional drill, even at dry and low speed cutting conditions.

Gijven Meral et.al [2] presented a paper on "Multi-response optimization of cutting parameters for hole quality in drilling of AISI 1050 steel". In this experiment, the dimensional accuracy, surface roughness, circular and cylindrical deviation characterizing hole quality is investigated practically. The reference material AISI 1050 steel chosen to carry out experiment since it has wide applications in many areas. Uncoated HSS and coated TiAlN by physical vapor deposition (PVD) with different were used. Experiment was conducted on CNC drilling machine under dry cutting condition with varying feed rate and cutting speeds with depth of cut 17mm. After conducting each experiment hole properties such as dimensional accuracy, surface roughness, circular deviation and axial misalignment between outlet and inlet holes, finally hole quality was measured and results evaluated with statistical analysis was carried out to indicate effect of drill parameters on tests results. Drill parameters such as drill diameter, cutting speed, tool type and feed rate was optimized with multiple performance functional analysis. The coated tools compared with uncoated tools which gave positive results. The important parameter on surface roughness is drill diameter, the effective parameter on circular, dimensional accuracy and cylindrical deviation is cutting speed for both coated and uncoated tools except cylindrical deviation occurring in uncoated drill.

A. Meena et.al [3] presented a paper on "Specific cutting force, tool wear and chip morphology characteristics during dry drilling of austempered ductile iron (ADI)". Dry machining is eco friendly machining due to less environmental impact and manufacturing cost. The choice of dry drilling is influenced by cutting condition, machining operation and work piece material properties. The recent advancement of austempered ductile iron is considered because of its economic advantage to increasing demand for cost and weight efficient material. Austempered ductile iron is considered as hard machine material, thus dry drilling is experimented in this report. Drilling is carried out using coated carbide tools under dry cutting condition. The drilling of austempered ductile iron under different cutting parameters is studied in terms of tool wear analysis and specific cutting forces. The influence of cutting parameters on surface roughness and chip morphology is studied. The experimental study says that combination of higher cutting speed and low feed rate leads to higher thermal and mechanical loads on tool cutting edges resulting in higher cutting force values. This condition is further considered for chip morphology analysis in which segmented chips are formed at higher cutting speed with increase in feed rate. On basis of cutting conditions different modes of tool failure including flank wear, crater wear, built up edges, chipping and breakage are observed. Surface roughness depends on influence of chip morphology and tool wear on machined surface finish.

M. Pirtini et. al [4] presented a paper on “Forces and hole quality in drilling”. Drilling is one of the most applied machining processes in various industries such as aircraft, automotive and aerospace dies/molds, medical, home appliance and electronic equipment industries. Maximizing of competitiveness in the market, cycle times of drilling mechanism must be decreased. However, tight geometric tolerance necessity in designs demand that drilling hole precision must be maximized in production.

In this investigation, a new mathematical model based on the mechanics and dynamics of the drilling mechanism is improvised for the exaggeration of cutting force and hole quality. A new technique is also explained in order to obtain cutting coefficients directly from a group of comparatively simple calibration tests. It is easy to stimulate the cutting forces for different cutting conditions in the process of planning stage using only the model. In the structural dynamic model measured frequency functions of spindle and tool system are integrated into model to obtain hole profile.

Kadam M. S et.al [5] presented a paper on “Experimental analysis and comparative performance of coated and uncoated twist drill bit dry machining”. A practical research was carried out to check the effect of input machining parameters feed rate, cutting speed, point angle and diameter of drill bit on CNC machine under dry condition. The change in torque, chip load and machining time are obtained through series of research according to equations of response. The comparative study of single layer Titanium Aluminium Nitride (TiAlN) and High speed steel tool for EN31 steel under dry condition is done. The report describes Analysis of Variance to validate of established mathematical models for depth analysis of finish drilling process parameters on torque, machine time and chip load.

Dhanrajpatel et.al [6] presented a paper on “Analysis of drilling tool life”. The experiment was conducted to analyze drilling tool life with different parameters like forces, feed rate, tool material, tool geometry etc., which were affecting drill tool life.

2. EXPERIMENTAL WORK

2.1 Experimental Setup:

The experiment conducted for different drill bits with machining parameters are shown in below table and EN8 steel work material dimension as follows: 140mm*140mm*13 mm and 500mm*140mm*13 mm.

Fig-2.1: Experimental Set-up

Table-2.1: Machining parameters

Drill bit	Cutting Speed, m/min	Spindle Speed, RPM	Feed Rate, mm/rev	Depth of Cut, mm
Uncoated HSS	36.6	1165	0.012	10
TiN coated HSS	36.6	1165	0.012	10
TiAlN coated HSS	36.6	1165	0.012	10

Table -2.2: 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

2.2 Tool Life: To calculate the tool life of uncoated HSS and coated HSS drill bit modified Taylor's tool life equation is used that is: considering feed rate and depth of cut. Theoretical tool life is compared with practically achieved tool life.

The modified Taylor's tool life equation with respect to feed and depth of cut is given by:

$$T^{0.19} = \frac{257}{V*f^{\wedge}0.36*t^{\wedge}0.08}$$

Where, V= cutting speed, m/min

T= Tool life, minutes

f= feed, mm/min

t= depth of cut, mm

Tool life of Uncoated HSS drill is:

Theoretical calculation:

$$T^{0.19} = \frac{257}{36.6*24^{\wedge}0.36*10^{\wedge}0.08} = 26.23 \approx 27\text{minutes.}$$

Where, V= 36.6m/min

f= 24mm/min

t= 10mm

Practically total numbers of holes achieved are 20 holes, to drill one hole it has taken 48seconds. Therefore to drill 20 holes it takes:

20*48= 960seconds, 960/60= 16minutes.

By comparing theoretical and practical values, practically could not achieve the theoretical value.

Tool life of Titanium coated HSS drill is:

Theoretical calculation:

$$T^{0.19} = \frac{257}{36.6*24^{\wedge}0.36*10^{\wedge}0.08} = 26.23 \approx 27\text{minutes.}$$

Where, V= 36.6m/min

f= 24mm/min

t= 10mm

Practically total numbers of holes achieved are 80 holes, to drill one hole it has taken 25seconds. Therefore to drill 80 holes it takes:

80*25= 2000seconds, 2000/60= 34minutes.

By comparing theoretical and practical values, practically achieved values are more than theoretical value.

Tool life of Titanium Aluminium Nitride coated HSS drill is:

Theoretical calculation:

$$T^{0.19} = \frac{257}{36.6*24^{\wedge}0.36*10^{\wedge}0.08} = 26.23 \approx 27\text{minutes.}$$

T= 27minutes

Where, V= 36.6m/min

f= 24mm/min

t= 10mm

Practically total numbers of holes achieved are 110 holes, to drill one hole it taken 22seconds.

Therefore to drill 110 holes it takes:

110*22= 2420seconds, 2420/60= 41minutes.

By comparing theoretical and practical values, practically achieved values are more than theoretical value.

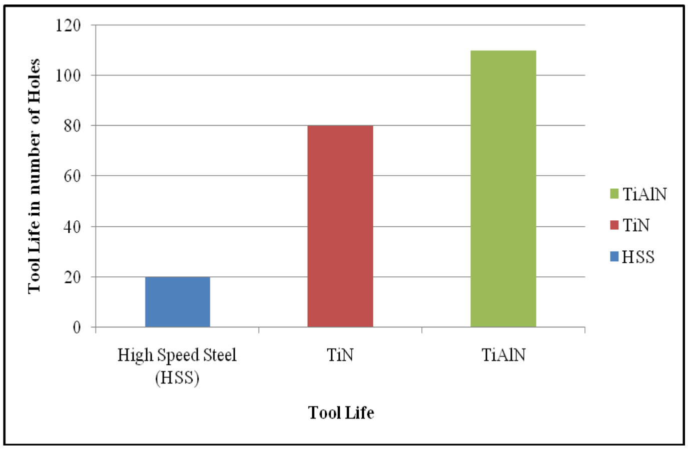

Fig- 2.2: Graph of tool life for Uncoated and Coated HSS drill in number of holes

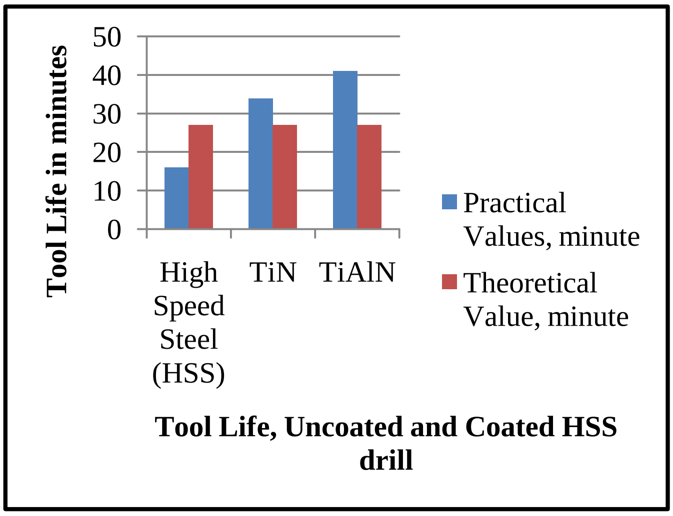

Fig- 2.3: Graph of comparison between practical and theoretical tool life in minutes

2.2 Cutting Forces: The cutting forces like torque and thrust force was calculated using drill tool dynamometer. The noted forces values are shown in below tables for different coated HSS drill tool and uncoated HSS drill tool.

Fig -2.4: Work piece placed on dynamometer

Uncoated HSS drill tool force data:

Table -2.3: Uncoated HSS drill tool torque and thrust forces

Uncoated HSS drill tool torque and thrust forces		
No. of holes	Torque, kg-m	Thrust, kgf
5	0.5	82
10	0.6	91
15	0.3	93
20	0.5	95

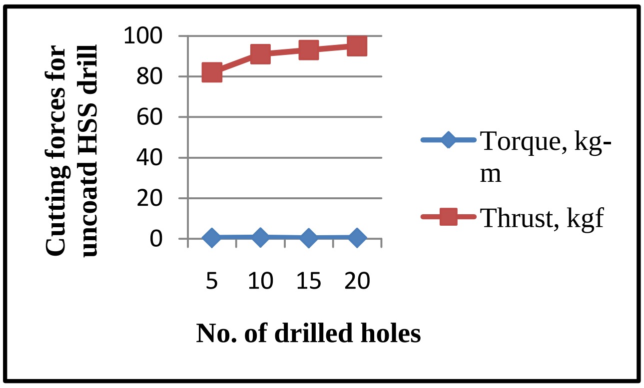

Fig -2.5: Graph of torque and thrust forces of uncoated HSS drill

Titanium Nitride (TiN) coated HSS drill tool torque and thrust force:

Table -2.4: TiN coated HSS drill tool torque and thrust forces

TiN coated HSS drill tool torque and thrust force		
No. of holes	Torque, kg-m	Thrust, kgf
10	0.2	22
20	0.3	34
30	0.3	36
40	0.3	40
50	0.5	35
60	0.5	65
70	0.5	69
80	0.6	76

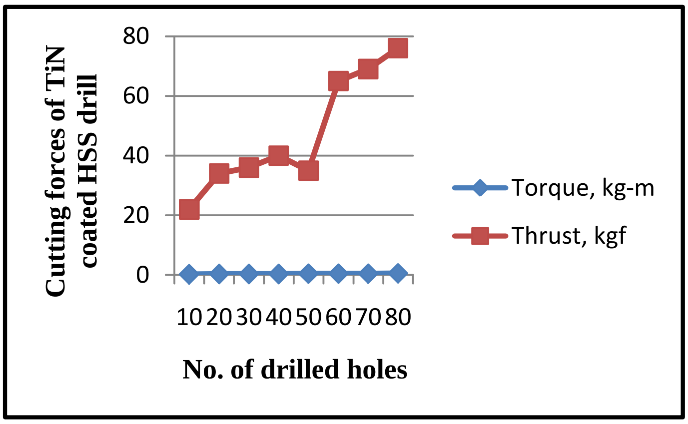

Fig -2.4: Graph of torque and thrust forces for TiN coated HSS drill

Titanium Aluminium Nitride (TiAlN) coated HSS drill torque and thrust forces:

Table- 2.5: TiAlN coated HSS drill tool torque and thrust force

TiAlN coated HSS drill tool torque and thrust force		
No. of holes	Torque, kg-m	Thrust, kgf
10	0.2	66
20	0.3	97
30	0.3	111
40	0.5	124
50	0.4	136
60	0.5	139
70	0.6	129
80	0.6	141
90	0.7	145
100	0.9	149
110	0.9	154

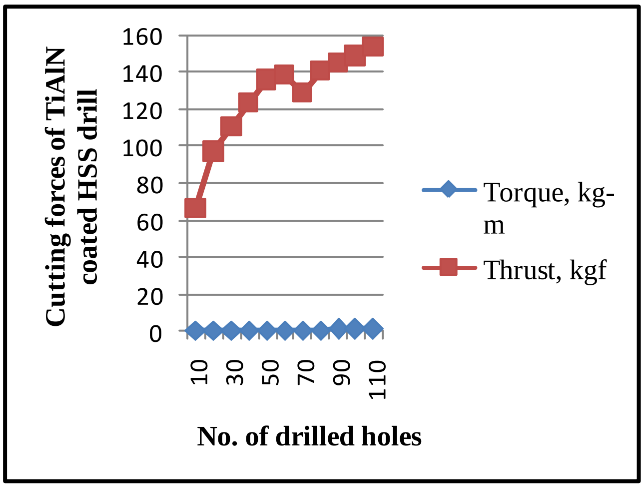

Fig- 2.6: Graph of torque and thrust force for TiAlN coated HSS drill

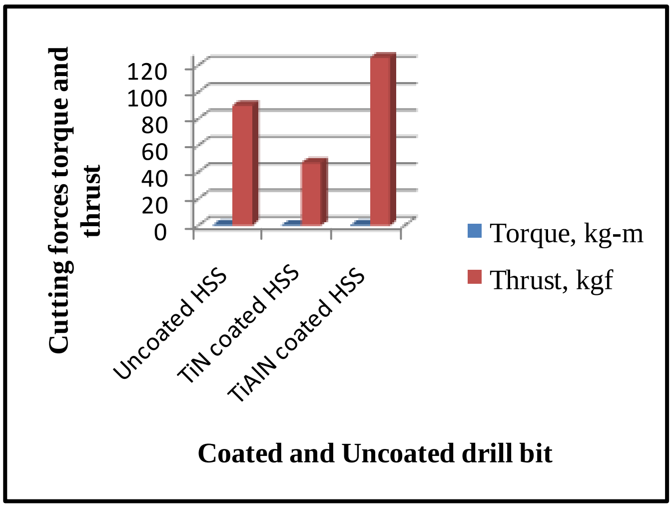

Fig- 2.7: Comparison of Uncoated and Coated HSS drill tool forces

3. CONCLUSIONS

In the present work, tool life was calculated theoretically using Taylor's tool life equation and compared with the experimental work. It was found experimentally that TiAlN coated HSS twist drill had greater tool life of 110 holes compared to TiN coated HSS of 80 holes and uncoated HSS of 20 holes twist drill. Cutting forces such as thrust and torque were found out using drill tool dynamometer. The results showed that the maximum thrust force of 126 kgf was developed in TiAlN coated HSS compared to TiN coated and uncoated HSS of 47 kgf and of 90 kgf, whereas the torque produced in all the twist drills were at an average of 0.5 Kgm.

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