Experimental Analysis and Comparative Performance of Coated and Uncoated Twist Drill Bit Dry Machining

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Abstract
An experimental investigation was conducted to determine the effect of the input machining parameters cutting speed, feed rate, point angle and diameter of drill bit on Hass Tool Room Mill USA made CNC milling machine under dry condition. The change in chip load, torque and machining time are obtained through series of experiments according to central composite rotatable design to develop the equations of responses. The comparative performance of commercially available single layer Titanium Aluminum Nitride (TiAlN) and HSS tool for T105CR1 EN31 steel under dry condition is done. The paper also highlight the result of Analysis of Variance (ANOVA) to confirm the validity and correctness of the established mathematical models for in depth analysis of effect of finish drilling process parameters on the chip load, torque, and machining time.

Keywords
Chip load, Torque, Machining time, ANOVA

I. Introduction
Drilling is the process of making hole in solid body but, most difficult machining processes because of chip-flow restrictions, poor heat dissipation, and rapid wear, which severely limits the productivity. Twist drills used for hole making probably have one of the most complex shapes in machine tooling. There are lots of studies being carried out in twist drill to identify machinability of drilling; like model testing (Chao Miao, 2009) [3] tool wear, surface roughness, burr formation.
To fulfill the industrial requirements like - the accuracy, the automation, high speed drilling and the possibility to drill difficult-to-cut materials. The modern economical and ecological requirements can be satisfied by a new dry treatment technology i.e. without any lubricant. So it is necessary to use the wear resistant coatings. The coating is deposited on the drill mainly by the PVD technology. Titanium nitride (TiN), titanium carbon nitride (TiCN) and diamante are used as coating materials. The last one is characterized by fabrication difficulties and high prices. Titanium aluminum nitride (TiAlN) coating is applicable at high temperatures and can be used in dry drilling.

II. Literature review
Gaitonde et. al. [11] considered input parameters- cutting speed, feed, point angle for composite material & tool cemented carbide (K20) twist drill to decrease delamination factor with increase in cutting speed. The study also suggests low values of feed rate & point angle combination for reducing the damage. Neural network was used to monitor geometric properties of tool wear by C. sanjay [4], Panda [9], Patra [6], Paliwal [7]. Gaitonde et.al [11] show the effects of cutting speed, feed rate and point angle on delamination factor.
Panda et al. deals with prediction of flank wear of drill bit using back propagation neural network (BPNN). Drilling operations have been performed in mild steel work-piece by high-speed steel (HSS) drill bits over a wide range of cutting conditions. Significant process parameters have been used as input for BPNN and drill wear has been used as output of the network. C. Sanjay et. al. [4] focus on Back propagation neural networks detection of drill wear. In his work, tool used was HSS drill and workpiece cast iron was used. Drill size, feed, spindle speed, torque, machining time and thrust force are given as inputs to the ANN and the tool wear was estimated. Drilling experiments with 8mm drill size were performed by changing the cutting speed and feed at two different levels. It is assumed that tool wear depends on the cutting speed, feed, machining time and thrust force. Kim et. al. [5] highlighted on unstable drilling process results from the insufficient supply of cutting fluid and bad chip removal as machining depth increases. Generally, the one-step feed-length (OSFL) of peck drilling is one and a half times longer than the drill diameter in conventional drilling.
Patra et. al. [6]. in their work on multilayer neural network with back propagation algorithm (BPNN) has been applied to predict the average flank wear of a high speed steel (HSS) drill bit for drilling on a mild steel workpiece. Root mean square (RMS) value of the spindle motor current, drill diameter, spindle speed and feed-rate inputs to the network and drill wear was the output. The performance of the trained neural network were tested for new cutting conditions, and found to be in very good agreement to the experimentally determined drill wear values. The accuracy of the prediction of drill wear using neural network was found to be better than that using regression model.
Sharif et. al. [10] investigated the performance of uncoated-WC/Co and TiAlN–PVD coated-carbide twist drills when drilling titanium alloy, Ti–6Al4V. The effect of cutting speed on tool wear, tool life and surface finish of the hole when drilling using coolant were reported. Results showed that non-uniform flank wear, chipping and catastrophic failure were the dominant modes of tool failure for both coated- and uncoated-drills. It was found that at all cutting speeds tested were TiAlN-coated-drill significantly outperformed uncoated-drill in terms of tool life and surface finish. Titanium alloy advantages are high strength-to-weight ratio, low density, excellent corrosion resistance, excellent erosion resistance and low modulus of elasticity.

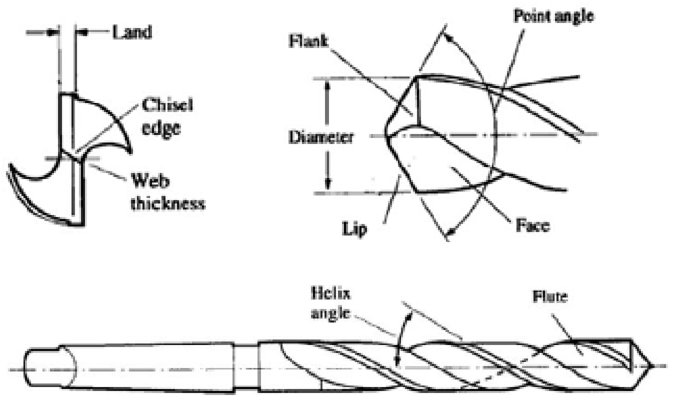


Fig.1 : Tools used in the experiment and drill geometry

Table 1: Chemical composition of EN31 (T105Cr1) steel

%C	%Si	%Mn	%Cr
0.9-1.2	0.1-0.35	0.2-0.4	1.0-1.6

III. Experimental set-up and Design of experiment

In this study, EN31 steel with the chemical composition given in Table 1 was selected as the workpiece material. The tests were carried out on Hass Tool Room Mill USA made CNC milling machine with TiAlN and HSS drill bit with dry conditions (fig. 2). The carbide drill with TiAlN coating having diameter 6mm and 8mm with 120° and 135° point angle was used for the experimentation. TiAlN serves as an insulator to the drill substrate and sends heat into the chips, rather than the drill. This allows drill to operate at higher speed without sacrificing tool life. The machining parameter considered are drill diameter, spindle speed, feed rate point angle under dry condition.

The machining tests were performed on Hass Tool Room Mill USA made with spindle speed 4000 rpm, Torque 45Nm @ 1200rpm, Power 9KVA 3ph or 240V AC. Holes were produced upto 10 mm depth with plunging depth 0.2mm. In this experimentation responses considered are chip load, torque, and machining time. Factors and their levels by experimentation shown in table 2 where as the design of experiment is shown in table 3. The design of experiment is based on response surface methodology using central composite design with extreme values of each independent parameter. There were six more experiments with midpoint values of each parameter making total number of experiments as 32. The obtained regression equations are the functions of speed, feed, drill diameter and point angle. After drilling operation was carried out on Hass milling machine upto depth of 10 mm containing plunging depth 0.2mm, Minitab 15 software used to generate regression equations for machining time in seconds, Toque in Nm, chip load, and residual plots fig. (a-f).

Residual plots show difference between observed value and its corresponding fitted value. Machining of T105CR1 EN31 steel material on CNC milling machine was done to study the comparative performance of commercially available TiAlN and HSS drill bit under dry conditions as shown in fig. 4, 5 and 6.

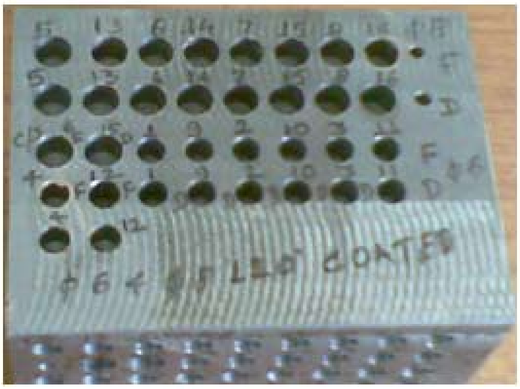


Fig.2 Workpiece

Table 2: Factors and their level for experimentation

Factor/level	-2	-1	0	+1	+2
Spindle rpm (X1)	800	1000	1200	1400	1600
Feed (X2)	0.10	0.12	0.14	0.16	0.18
Drill Dia. (X3)	6	6	6	8	8
Point angle (X4)	135°	120°	135°	120°	135°

IV. Statistical Analysis

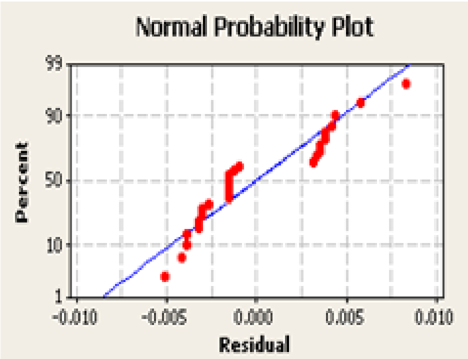
Table 3: Experimental data for TiAlN coated and HSS twist drill for machining of T105CR1 EN31 steel material under dry conditions.

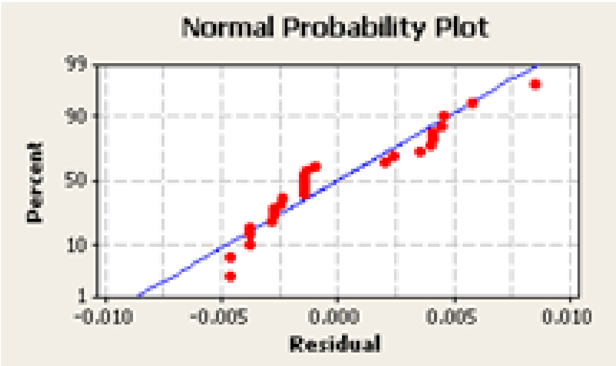
Run	X1	X2	X3	X4	TiAlN			HSS Dry		
					Tm (Sec.)	Torque (N-m)	Chip load	Tm	Torque	Chip load
1	-1	-1	-1	-1	42	55.30	0.059	42	55.22	0.060
2	+1	-1	-1	-1	43	53.43	0.042	43	39.57	0.041
3	-1	+1	-1	-1	33	57.0	0.112	40	55.34	0.112
4	+1	+1	-1	-1	38	55.13	0.080	38	40.09	0.079
5	-1	-1	+1	-1	43	54.89	0.060	45	55.22	0.059
6	+1	-1	+1	-1	44	53.00	0.042	43	38.50	0.042
7	-1	+1	+1	-1	38	55.48	0.112	37	53.95	0.112
8	+1	+1	+1	-1	38	53.59	0.080	35	39.43	0.080
9	-1	-1	-1	+1	43	55.69	0.060	42	55.30	0.060
10	+1	-1	-1	+1	42	53.90	0.043	44	40.01	0.043
11	-1	+1	-1	+1	35	56.78	0.112	40	55.09	0.110
12	+1	+1	-1	+1	37	55.48	0.080	35	40.20	0.080

13	-1	-1	+1	+1	43	54.00	0.060	44	55.22	0.059
14	+1	-1	+1	+1	43	52.65	0.043	42	38.50	0.043
15	-1	+1	+1	+1	34	55.90	0.112	41	54.10	0.112
16	+1	+1	+1	+1	36	54.63	0.080	36	40.03	0.080
17	-2	0	0	0	36	67.58	0.105	36	69.18	0.105
18	+2	0	0	0	38	33.70	0.052	36	35.89	0.052
19	0	-2	0	0	45	45.11	0.033	44	47.96	0.033
20	0	+2	0	0	31	44.88	0.120	33	69.00	0.120
21	0	0	-2	0	39	45.04	0.070	40	44.99	0.070
22	0	0	+2	0	36	44.96	0.070	38	47.00	0.070
23	0	0	0	-2	39	45.11	0.070	41	45.02	0.070
24	0	0	0	+2	39	44.81	0.070	39	44.97	0.070
25	0	0	0	0	39	44.93	0.070	39	44.99	0.070
26	0	0	0	0	39	45.08	0.070	38	45.03	0.070
27	0	0	0	0	39	45.00	0.070	39	45.01	0.069
28	0	0	0	0	39	44.93	0.070	39	44.99	0.070
29	0	0	0	0	39	45.08	0.070	38	45.03	0.070
30	0	0	0	0	39	45.00	0.070	39	45.01	0.069
31	0	0	0	0	39	45.08	0.070	38	45.03	0.070
32	0	0	0	0	39	45.00	0.070	39	45.01	0.069

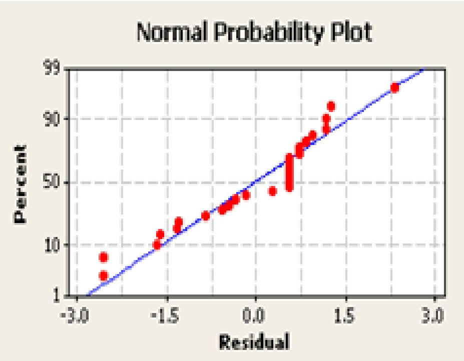
The obtained regression equations after analysis from experimental data for TiAlN tool are
Tm = 56.6 + 0.00292 X1 - 0.0636 X2 + 0.055 X3 - 0.0834 X4
Torque = 151 - 0.0169 X1 + 0.0079 X2 - 0.542 X3 - 0.615 X4
Ch Load = 0.0803 - 0.000063 X1 + 0.000426 X2 - 0.000101 X3 - 0.000030 X4

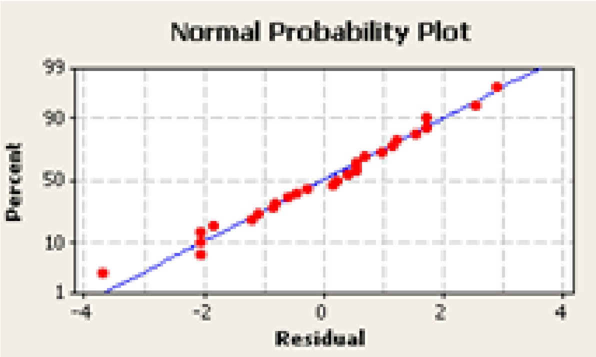
The obtained regression equations for HSS dry (without coolant) tool are
Tm = 72.8 - 0.00313 X1 - 0.0553 X2 - 0.095 X3 - 0.154 X4
Torque = 80.2 - 0.0395 X1 + 0.0387 X2 - 0.492 X3 + 0.094 X4
Chip load = 0.0773 - 0.000063 X1 + 0.000425 X2 - 0.000041 X3 - 0.000012 X4





(a)





(b)

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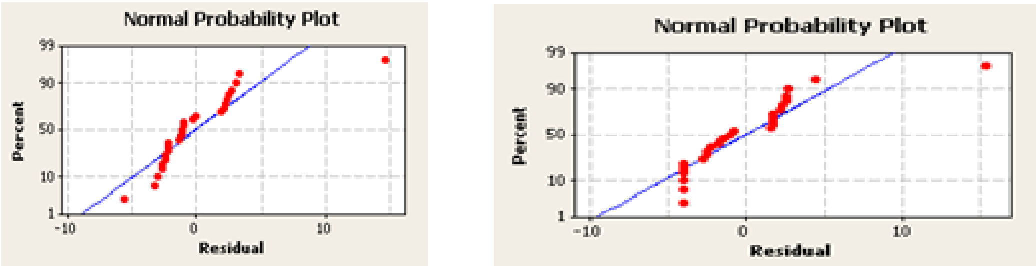

(c)
Fig. 3: Normal probability Plots TiAlN and HSS plot for a) chip load, b) machining time, c) torque

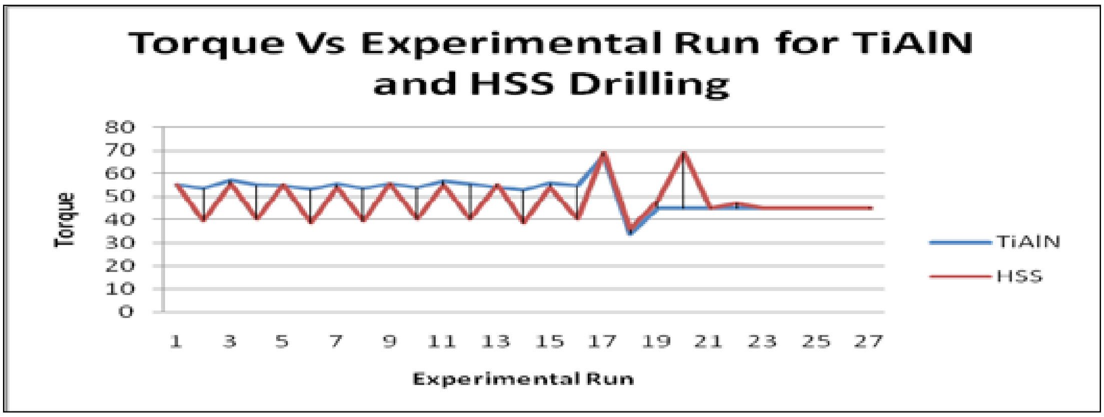

Fig. 4: Torque Vs Number of experiments for different input machining parameters for machining T105CR1 EN31 steel under dry condition for TiAlN and HSS drill bit

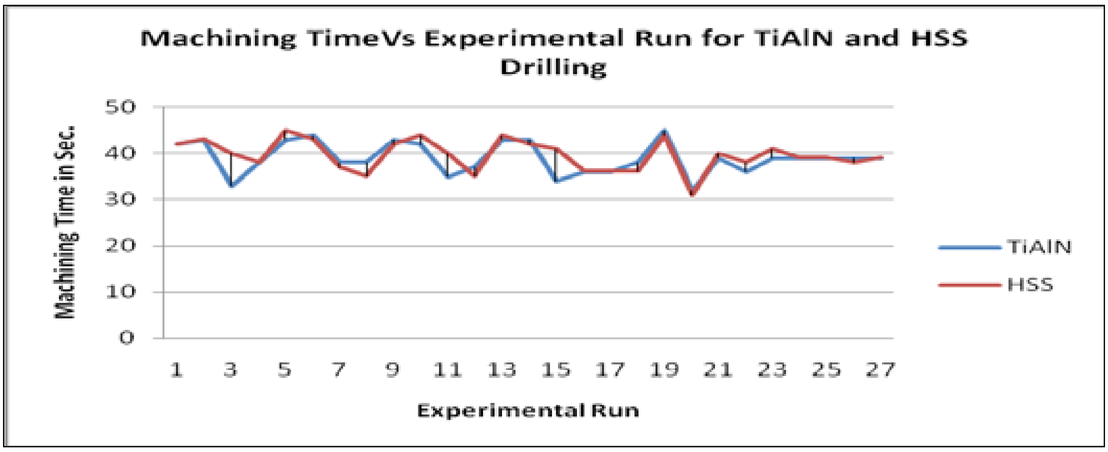

Fig. 5: Machining Time Vs Number of experiments for different input machining parameters for machining T105CR1 EN31 steel under dry condition for TiAlN and HSS drill bit

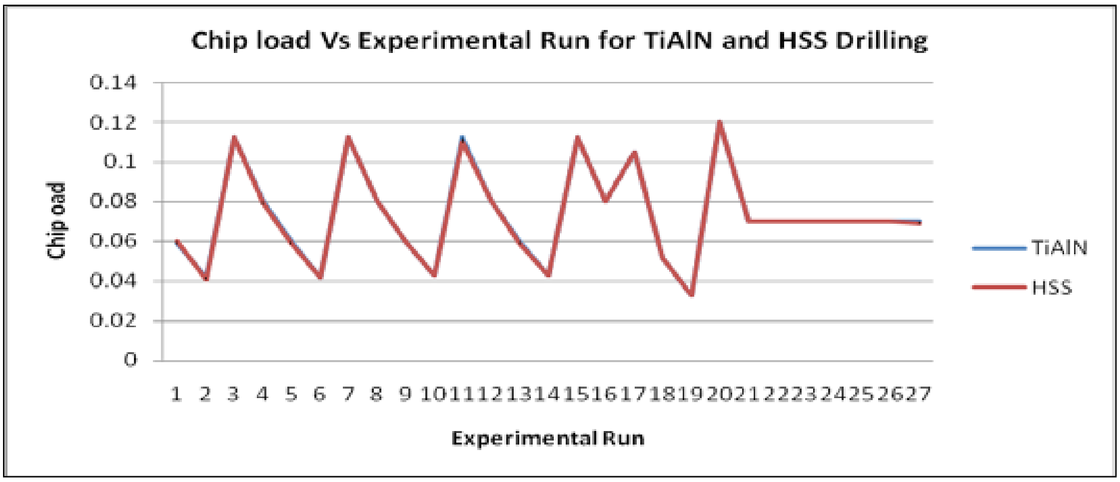

Fig. 6: Chip load Vs Number of experiments for different input machining parameters for machining T105CR1 EN31 steel under dry condition for TiAlN and HSS drill bit

V. Conclusion

The comparative performance of the commercially available carbide insert enhance the machined components with an added advantage of eliminating coolant management. Machining of EN31 steel (T105CR1) on Hass Tool Room Mill USA made CNC milling machine was done. Comparative performance of commercially available single layer Titanium Aluminum Nitride and HSS tool cemented carbide inserts under dry condition is done. From the experimental observation it is possible to conclude as under:

Fig. indicate that

1. The machining time is minimum when the cutting speed is 1200rpm feed rate is 0.18 mm/rev diameter of drill is 6.0 mm and point angle is 135°.
2. The chip load is minimum when cutting speed is1200 rpm feed rate is 0.10 mm/rev diameter of drill is 6.0 mm and point angle is 135°.
3. The torque is minimum when cutting speed is1600 rpm feed rate is 0.14 mm/rev diameter of drill is 6.0 mm and point angle is 135°.

Machining time and Torque in Titanium Aluminum Nitride inserts (TiAlN) less as compared to HSS where as chip load remains same.

VI. Acknowledgement

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