

COMPARATIVE EXPERIMENTAL INVESTIGATION FOR REDUCING HIGH SPEED STEEL TOOL WEAR RATE BY CRYOGENIC PROCESS

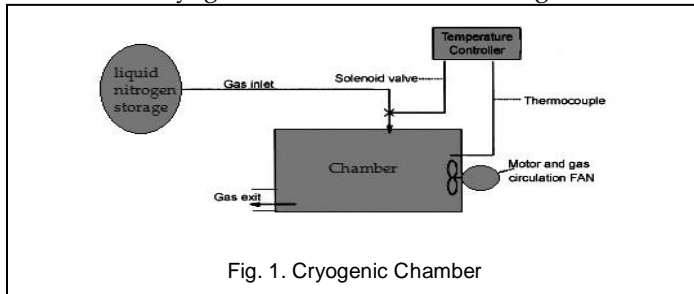
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Abstract—The main objective of this research is to find the optimum working condition to reduce tool wear rate in HSS drill bit. Cryogenic treatment on HSS drill bit has shown changes in its properties like increased hardness; increase in wear resistance which results in increase in tool life. During drilling operation tool wear depends on many factors but we have concentrated on 3 major factors which we can change i.e. drilling speed, feed rate and tool condition. We have compared untreated HSS drill bit with Cryogenic Treated HSS drill bit using taguchi's analysis. Taguchi analysis gives us the optimum working condition for HSS drill bit which shows that cryogenic Treated tool is better than non treated tool.

Index Terms— Cast Iron , Cryogenic Process, Drilling, Hardness ,High Speed Steel Drill bit, Taguchi analysis, Optimum Working Condition, Tool Wear Rate.

1 INTRODUCTION

Deep cryogenic Treatment system is the methodology of "ultra low temperature" processing of material to enhance their metallurgical properties. The materials are treated in the cryogenic chamber as shown in Fig. 1.



The process involves reducing and raising the temperature. Thermal control is achieved by continuously monitoring inputs and regulating the flow of liquid nitrogen into the chamber and alternating the heat. Precise program control takes the cycle through three phases of descend, soak, and ascend with no fear of thermal shock. The complete temperature variation with respect to time is shown in Fig. 2.

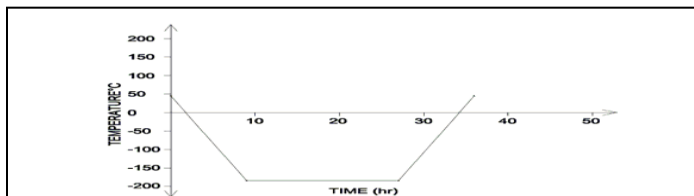


Fig. 2. Cooling Curve

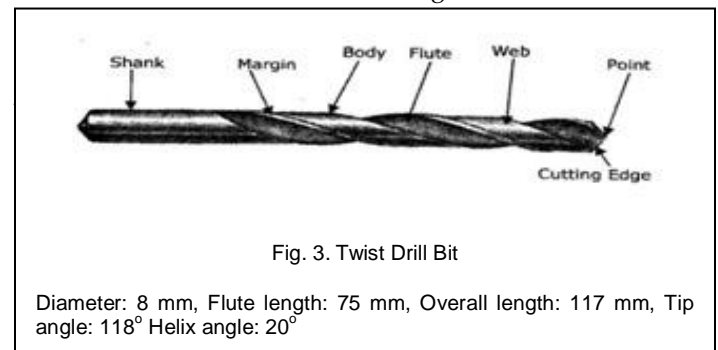
It is imperative that a slow descend is followed by a soak period of around 24 hours at -196°C and then raised to room temperature with a slow ascend.

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The twist drill bit is the type used in almost all the drilling operations today. It comprises a cutting point at the tip of a cylindrical shaft with helical flutes. In present work, we used the twist drill bit of following specifications

Diameter: 8 mm, Flute length: 75 mm, Overall length: 117 mm, Tip angle: 118° Helix angle: 20°

The twist drill bit used is shown in Fig. 3.



High speed steel (HSS) is a form of tool steel. HSS bits are much more resistant to heat. They can be used to drill metal, hardwood, and most other materials at greater cutting speeds than carbon steel bits. HSS tools are so named because they were developed to cut at higher speeds. Developed around 1900 HSS is the most highly alloyed tool steels. The tungsten (T series) was developed first and typically contains 12 - 18% tungsten, plus about 4% chromium and 1 - 5% vanadium. Most grades contain about 0.5% molybdenum and most grades contain 4- 12% cobalt.

Cryogenic treatment on HSS will result in the conversion of retained austenite into martensite. This results in increase in hardness of HSS drill bit due to increase in density of dislocation and gaps.

Calculation of optimum working condition for HSS drilling bit for drilling cast iron has not been reported yet.

2 EXPERIMENTAL STUDY

Our experimental aim is to compare the treated tool and untreated tool; we have calculated the thrust force, torque using drill tool dynamometer at different drilling speed, feed rate and tool condition (treated tool and untreated tool).

And surface roughness is the most important parameter which we always desire to reduce to minimum. Hence, we have calculated the surface roughness of drilled holes using talysurf. And we have calculated the hardness of treated HSS drill bit using Rockwell hardness machine.

2.1 Hardness Test

Hardness test of cryogenic treated HSS drill bit was done using Rockwell hardness machine which works on C scale and values are in HRC and load of 150 Kgf is used to calculate hardness and 120° diamond cone is used to penetrate the HSS drill bit. The calculated values are given in Table 2.

TABLE 1
ROCKWELL HARDNESS TEST

S. NO	TOP	MIDDLE	BOTTOM
NON TREATED	49	49	49
CRYOGENIC TREATED	58	64	68

Top, middle and bottom represents the area of the shank of tool. Hardness Values are in HRC

We can say that cryogenic treated HSS drill bit has very high Hardness compared with non treated drill bit.

2.2 Drilling Test

During drilling operation tool wear depends on many factors but we have concentrated on 3 major factors which we can change i.e. drilling speed, feed rate and tool condition. Drilling was performed to calculate thrust force and torque on HSS drill bit using drill tool dynamometer. Hence, we will find the optimum condition for minimum thrust force and torque to reduce tool wear. We have repeated drilling process three times for each experimental set up. Taguchi's method is used to find the optimum condition for drilling cast iron using HSS drill bit. We have selected four different speeds: A: 500, 700, 900, and 1100 (rpm). And two different feed rate: B: 0.05, 0.08 (mm/rev). And two different tool conditions: Cryogenic Treated Tool (CT) and Non Treated Tool (NT).

We have assigned four coded values for different speed, feed rate, and tool condition shown in Table 1.

TABLE 2
CODED VALUES

CODED VALUE	SPEED (rpm)	FEED RATE (mm/rev)	TOOL CONDITION
1	500	0.05	CT
2	700	0.08	CT
3	900	0.05	NT
4	1100	0.08	NT

2.3 Taguchi's Analysis

Taguchi's L16 rule fits for our experimental conditions. Taguchi's L16 layout is given in table 2.

TABLE 3
TAGUCHI'S L16 LAYOUT

S. No	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	1	4	4
5	2	1	2
6	2	2	1
7	2	3	4
8	2	4	3
9	3	1	3
10	3	2	4
11	3	3	1
12	3	4	2
13	4	1	4
14	4	2	3
15	4	3	2
16	4	4	1

The values of speed, feed rate and tool condition in Taguchi's L16 layout is shown in table 3.

TABLE 4
EXPERIMENTAL VALUES IN PLACE OF CODED VALUES

S. NO	SPEED (rpm)	FEED RATE (mm/rev)	TOOL CONDITION
1	500	0.05	CT
2	500	0.08	CT
3	500	0.05	NT
4	500	0.08	NT
5	700	0.05	CT
6	700	0.08	CT
7	700	0.05	NT
8	700	0.08	NT
9	900	0.05	NT
10	900	0.08	NT
11	900	0.05	CT
12	900	0.08	CT
13	1100	0.05	NT
14	1100	0.08	NT
15	1100	0.05	CT
16	1100	0.08	CT

We have calculated thrust force and torque three times for each experimental condition using drill tool dynamometer. Surface roughness of every drilled hole is also calculated. The experimental reading for torque (TO), thrust force (TH) and surface roughness (R) is shown in table 4.

TABLE 5
EXPERIMENTAL READINGS FOR TORQUE (TO) AND THRUST FORCE (TH) AND SURFACE ROUGHNESS (R)

S. No.	SPEED rpm	FEED RATE mm/rev	TOOL COND.	TO1 Kg-m	TO2 Kg-m	TO3 Kg-m	TH1 Kg-f	TH2 Kg-f	TH3 Kg-f	R1 μ m	R2 μ m	R3 μ m
1	500	0.05	CT	0.09	0.1	0.1	52	54	52	5.33	5.27	5.08
2	500	0.08	CT	0.11	0.1	0.11	55	53	56	4.78	5.12	4.38
3	500	0.05	NT	0.13	0.12	0.13	60	59	61	6.1	5.82	5.63
4	500	0.08	NT	0.13	0.13	0.14	73	71	70	5.05	5.14	4.93
5	700	0.05	CT	0.11	0.13	0.11	57	56	60	5.19	4.63	5.62
6	700	0.08	CT	0.12	0.11	0.11	67	65	64	5.22	5.24	4.91
7	700	0.05	NT	0.13	0.13	0.14	73	71	70	5.6	5.12	4.72
8	700	0.08	NT	0.14	0.15	0.14	78	75	78	6.31	6.1	5.98
9	900	0.05	NT	0.14	0.13	0.12	76	73	75	6.11	6.24	5.87
10	900	0.08	NT	0.15	0.17	0.17	84	88	86	5.11	5.15	5.04
11	900	0.05	CT	0.13	0.12	0.11	61	62	60	6.53	6.16	6.34
12	900	0.08	CT	0.11	0.1	0.11	68	66	69	5.24	5.92	5.88
13	1100	0.05	NT	0.16	0.16	0.17	80	79	81	4.92	5.57	5.36
14	1100	0.08	NT	0.18	0.19	0.21	90	91	88	6.11	6.3	6.14
15	1100	0.05	CT	0.12	0.11	0.11	65	64	68	4.9	5.11	5.32
16	1100	0.08	CT	0.12	0.14	0.1	72	75	70	5.79	5.23	5.63

TO represent readings of torque during drilling and suffix 1, 2 and 3 refers to repetition of same process for high accuracy.

TH represents readings of thrust force. R represents readings of surface roughness.

Based on the readings obtained, we will calculate the SN ratio for thrust force, torque, surface roughness.

List of formulas for calculating SN ratio:

$$Sm: \text{Sum of squares due to mean} = \frac{(T_1 + T_2 + T_3)^2}{N}$$

$$St: \text{Total Sum of Squares} = (T_1)^2 + (T_2)^2 + (T_3)^2$$

$$Se: \text{Error Sum of squares} = St - Sm$$

$$Ve: \text{Error Variance (mean square)} = \frac{Se}{N-1}$$

$$SN: \text{Signal to noise ratio} = 10 \log \frac{\left(\frac{1}{N}\right)(Sm - Se)}{Ve}$$

Model calculation of SN ratio for thrust force:

$$Sm1 = \frac{(52+54+52)^2}{3} = 8321.333$$

$$St1 = (52)^2 + (54)^2 + (52)^2 = 8324$$

$$Se1 = 8324 - 8321.333 = 2.666667$$

$$Ve1 = \frac{2.666667}{3-1} = 1.333333$$

$$SN1 = 10 \log \frac{\left(\frac{1}{3}\right)(8321.33 - 2.666)}{1.333} = 33.17994$$

SN1 is the SN ratio for thrust force for cryogenic treated tool at drilling speed 500 rpm, feed rate 0.05mm/rev.

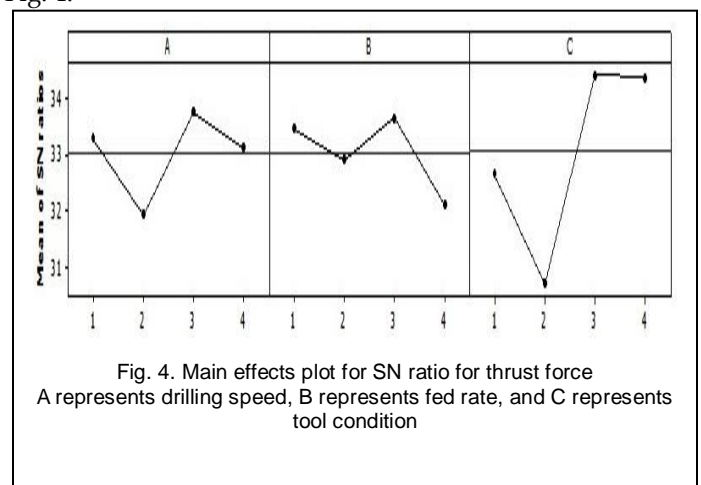
Similarly SN2, SN3, SN4 ... SN16 has been computed for thrust force.

After calculating SN ratio for each experiment, the average SN value is calculated for each drilling speed, feed rate and tool condition.

$$\text{Where, } SN_{A1} = \frac{33.179 + 31.072 + 35.562 + 33.384}{4} = 33.299$$

SN_{A1} is the average of SN ratio for drilling speed of 500 rpm. Similarly, SN_{A2}, SN_{A3}, SN_{A4} are calculated for drilling speed of 700, 900, 1100 respectively.

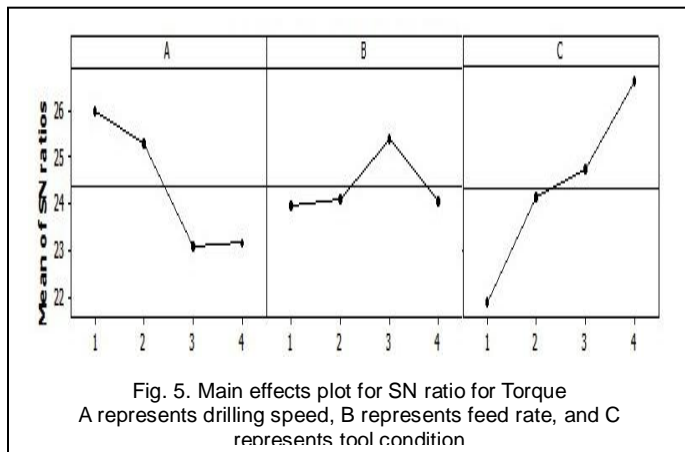
Similarly, SN_{B1}, SN_{B2}, SN_{B3}, SN_{B4} are calculated for feed rate of 0.05, 0.08, 0.05, 0.08 respectively. SN_{C1}, SN_{C2}, SN_{C3}, SN_{C4} are calculated for tool condition of CT, CT, NT, NT respectively. Main effect graph is plotted for mean of SN ratio is shown in Fig. 4.



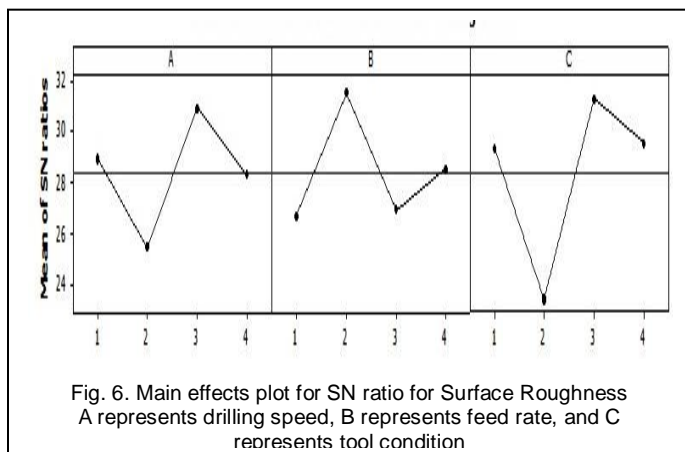
We need to minimize the value of thrust force. Fig. 4, shows the Variation in SN ratio for thrust force.

Hence, the optimal condition is (A2, B4, and C2) for minimum thrust force.

The same procedure is repeated for the calculation of means of SN ratio for Torque and surface roughness and the following Fig. 5. and Fig. 6. are plotted



We need to minimize the value of torque. Fig. 5 shows the Variation in SN ratio for Torque. The optimal condition is (A3, B1, C1) for minimum torque.



We need to minimize the value of surface roughness. Fig. 6, shows the Variation in SN ratio for surface roughness. Hence, the optimal condition is (A2, B1, and C2) for minimum surface roughness.

3 RESULT AND DISCUSSION

THRUST FORCE

The tool condition has the variation of 3.712995, speed has the variation of 1.817923, and feed rate has the variation of 1.54837 in SN ratio for calculated thrust force.

We need to minimize the thrust force. The optimal condition is (A2, B4, and C2) from Fig. 4.

So, it is better to drill with cryogenic treated tool at a speed of 700 rpm and feed rate of 0.08 mm/rev. The value of thrust force at this condition is 65.3333 Kgf minimum.

TORQUE

The tool condition has the variation of 4.798311, speed has the variation of 2.931654, and feed rate has the variation of 1.419755 in SN ratio for calculated torque. We need to minimize the Torque. The optimal condition is (A3, B1, and C1) from Fig. 5.

So, it is better to drill with cryogenic treated tool at a speed of 900 rpm and feed rate of 0.05 mm/rev. The value of torque at this condition is 0.12 Kg-m minimum.

SURFACE ROUGHNESS

The tool condition has the variation of 7.845503, speed has the variation of 5.456697, and feed rate has the variation of 4.82919 in SN ratio for calculated surface roughness.

We need to minimize the surface roughness. The optimal condition is A2, B1, and C2 from Fig. 6.

So, it is better to drill with cryogenic treated tool at a speed of 700 rpm and feed rate of 0.05 mm/rev. The value of surface roughness at this condition is 5.2266 μm minimum

Since, we need to minimize all the factors in one combination; we will optimize these values based on the amount of effect on the thrust force, torque & surface roughness.

The cryogenic treated tool has the largest effect on the thrust force, torque and surface roughness. Feed has the smallest effect on the thrust force, torque & surface roughness (Ra) and, the effect is highest in surface roughness (7.845503) due to tool condition, and lowest in speed (3.712995)

Hence, the final optimum condition for (speed, feed rate, tool condition) is (700, 0.05, CT)

At this optimal condition the value of (thrust force, torque, and surface roughness) is (57.66 Kgf, 0.1166 Kg-m, 5.1466 μm)

This results in minimum value of factors which affects tool wear. The tool becomes more wear resistance and its life increases.

4 CONCLUSION

Drilling exercises were performed using cryogenically treated and non-treated HSS drills to study the tool performance. Based on the study the following conclusions were drawn:

The hardness of the High speed steel drill bit is increased by cryogenic treatment.

Cryogenic treated tool resulted in lesser thrust force, torque and yielded superior surface finish compared to that of non-treated drill bits.

The tool condition had the largest effect on the thrust force, torque and surface roughness. Feed had the smallest effect on the thrust force, torque and the surface roughness.

Based on the results it was concluded that cryogenic treatment can yield significant improvement in both productivity and product quality and hence overall machining economy offsetting the cost of cryogenic cooling.

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