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STUDY THE MACHINING PERFORMANCE OF EN 36 STEEL UNDER DIFFERENT CUTTING CONDITIONS

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Abstract: High temperatures at the tool - work piece and tool - chip interface affects the surface integrity, quality and the life of the tool strongly. The cooling at tool chip interface becomes very important to improve the properties of the process. An experimental set up was developed to study the effect of cryogenic coolant (Liquid nitrogen) on flank wear of cutting tool, tool forces and workpiece surface roughness in comparison with the traditional cooling condition and dry machining conditions. The experiments were carried out under the three different cutting conditions viz; dry, wet and cryogenics using the uncoated tungsten carbide tool having standard triangular geometry. Experimental results revealed the machining under cryogenic conditions has given the significant improvement as compared with the dry and wet machining. Based on the confirmation runs, the optimal value for the feed force, cutting force, surface roughness and tool flank wear were measured as 7.07Kgf, 18.11 Kgf, 1.037 μm and 0.083 mm respectively.

Keywords**:** Cryogenic coolant, un-coated tungsten carbide, feed force, flank wear

1. INTRODUCTION

The tool life plays a big role to increase the productivity. The metal working industry demands a long tool life as high cutting or spindle speeds and maximum achievable feed rates for maximum achievable quality are required possibly even without lubrication and cooling liquids. It is vital to minimize the heat generated due to high temperatures in the machining zone by selecting the ideal cutting parameters, fluids and tools [1]. Dry machining is the metal removal or cutting process in which there is no use of cutting fluids. The upsides of dry machining include: non-contamination of the air (or water); no build-up on the swarf which will be reflected in decreased transfer and cleaning costs; it offers cost diminishment in machining. Wet machining is the process of the removal of material from the surface of the item to be machined with use of soluble cutting oils/coolants [2]. Cryogenic cooling is the process of the utilization cryogenic liquids as a coolant for the cutting of materials. By infusing a little measure of fluid nitrogen to the chip–tool interface yielded a 67% tool life increase at 3.82 m/s and a 43% increase at the medium velocity of 3.40 m/s when compared with conventional emulsion cooling [3]. Turning of hardened AISI 52100 steel was carried out under dry and cryogenic cooling utilizing CBN tools resulted into improved surface integrity prompting expanded item life and performance [4,5]. Another attempt [6] was made to analyse the tool-wear in the turning of NiTi shape memory alloys (SMAs) with the utilization of liquid nitrogen and then compared it with dry and minimum quantity lubrication. The overall wear and principal cutting forces were found to be decreased in case of the cryogenic cooling. Magadum et al. [7] conducted the experimental tests to study the tool wear and the cutting forces in cryogenic turning of EN 24 steel material with CBN inserts and compared the results with those of turning with conventional flood coolants.

In case of the dry hard turning not much presence of white layer had been found in the microstructure. In another attempt to [8] investigated tool wear and chip formation by turning the Ti-6Al-4V titanium alloy on the CNC lathe with the impact of the cryogenic coolant LN2 with 0.35 l/min at the 4 bar pressure. It had successfully improved the mach inability to turn the titanium alloy by enhancing the tool life and the chip formation and had reduced the friction between the chip and tool interfaces. The temperature in the case of LN2 cryogenic coolant was 200°C less than oil-based coolant. The aim of the present study is to investigate the machining performance of EN36 steel under different cutting conditions.

2. DESIGN OF EXPERIMENTS AND EXPERIMENTATION

In the present study, the design of experiments considered of a total 3 parameters with 3 levels each. Three control factors were considered in order to ascertain the machining characteristics under different cutting conditions. The control factors as shown in Table 1 were the cutting conditions (A), spindle speed (B) and feed (C). The other machine parameters were kept constant. Since there were 3 control factors each with 3 levels in the experiment, a full factorial experimental design methodology was used.

Table I
Machining Parameters

Parameters	*Level 1*	*Level 2*	*Level 3*
Cutting conditions	Dry	Wet	Cryogenic
Spindle speed (RPM)	294	460	720
Feed (mm/rev)	0.063	0.071	0.086

Experiential setup (Fig. 1) was developed on Harrison centre lathe machine. A set up to supply

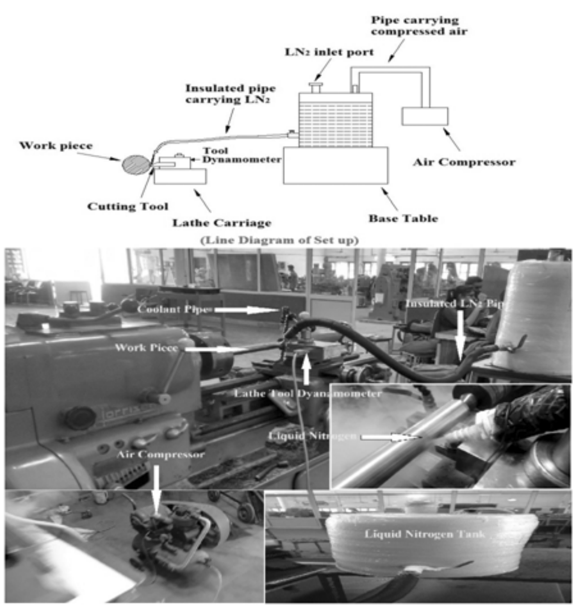

Figure 1: Experimental Setup

the wet coolant was also attached with the machine having supply of 2 liter per minute and a cryogenic cylinder set up was also used in the set up to supply the liquid nitrogen as a coolant through an insulated pipe of diameter of 6mm having 40mm distance from chip tool interface with 4 bar pressure.

A dynamometer set up was also used which consisted of a dynamometer gauge unit and a display unit on which the readings of forces measured during the experiment are shown. The cutting tool holder fitted with uncoated tungsten carbide tool was used for machining the workpiece. The performance characterstics measured are shown in Table 2.

Table 2
Performance Characteristics

Parameters	*Unit*
Surface Roughness	μm
Tool Flank Wear	mm
Tool Forces i.e. Feed Forces(Fx), Cutting Forces(Fy)	Kgf

The composition of the workpiece material is given in Table 3.

Table 3
Chemical Composition of Workpiece

Component	*Composition*
C	0.14
Mn	0.40
Si	0.20
Ni	0.85
Mo	——
Cr	3.75
S	0.05% max
P	0.05% max

The cutting speed was directly measured on the machine. Taguchi Design of experiment according to L9 approach was selected for the experimentation (Table 4).

The surface roughness values of work piece machined with different cutting conditions was measured in terms of R_a value using Surf tester (SUJ 201) with cutoff length of 0.80. The experiments were repeated three times and average value of performance characteristic was taken for better accuracy.

Table 4
Design of Experiment According TO L9 Approach

Exp. No.	*Level 1*	*Level 2*	*Level 3*
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

3. ANALYSIS AND DISCUSSION OF EXPERIMENTAL RESULTS

3.1. Determination Of Tool Force y

Two types of forces viz feed forces and cutting forces and surface roughness value were measured during experimentation.

3.1.1. Determination of Feed Forces

The experimental observations of spindle speed, feed, cutting conditions showing feed force and S/N ratio is shown in Table 5.

Table 5
Observation OF Feed Forces And S/N Ratio

Sr. No.	*Cutting condition*	*Spindle Speed (RPM)*	*Feed (mm/ rev)*	*Mean Feed Forces (Kgf)*	*S/N ratio*
1	Dry	294	0.063	10.0	-20.04
2	Dry	460	0.071	11.5	-21.22
3	Dry	720	0.086	13.5	-22.66
4	Wet	294	0.071	8.0	-18.12
5	Wet	460	0.086	12	-21.61
6	Wet	720	0.063	10.0	-20.04
7	Cryo	294	0.086	7.0	-16.98
8	Cryo	460	0.063	8.0	-18.12
9	Cryo	720	0.071	7	-16.90

The main effect plot for the means of feed forces is shown in Fig. 2.

It is evident that feed forces decreases with the cryogenic cooling condition and increases with the increase in tool feed. The optimal value of feed force can be calculated with the relation

$$\eta_{opt} = m+(m_{A3}-m)+(m_{B1}-m)+(m_{C2}-m)$$

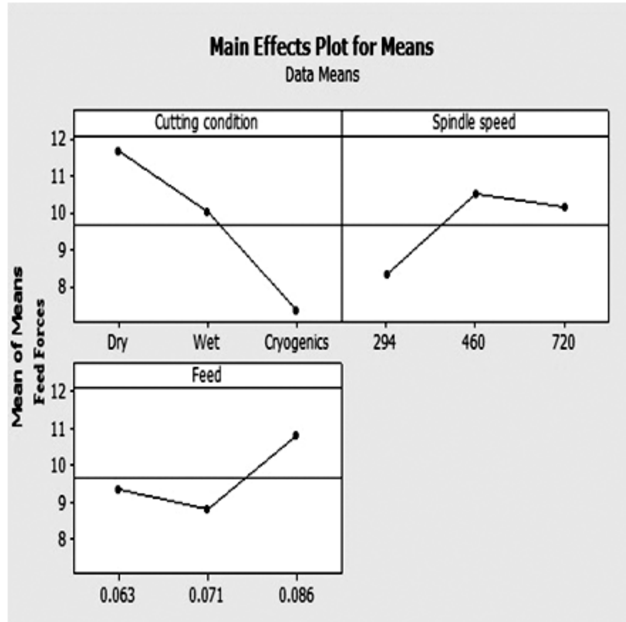

Figure 2: Main Plot oF feed Forces

it comes out to be 7.07kgf.

3.1.2 Determination OF Cutting Force

The experimental observations of spindle speed, feed, cutting conditions showing cutting force and S/N ratio is shown in Table 6.

The main effect plot for the means of cutting forces is shown in Fig. 3.

Table 6
Observation OF Cutting Forces And S/N Ratio

Sr. No.	*Cutting condition*	*Spindle Speed (RPM)*	*Feed (mm/ rev)*	*Mean cutting Forces (Kgf)*	*S/N ratio*
1	Dry	294	0.063	21.0	-26.45
2	Dry	460	0.071	22.0	-26.85
3	Dry	720	0.086	24.5	-27.78
4	Wet	294	0.071	20.0	-26.03
5	Wet	460	0.086	22.5	-27.04
6	Wet	720	0.063	23.5	-27.42
7	Cryo	294	0.086	18.5	-25.34
8	Cryo	460	0.063	20.5	-26.23
9	Cryo	720	0.071	21.0	-26.45

Fig. 3 shows that cutting forces decreases with the cryogenic cooling condition and increases with spindle speed . The optimal value of cutting force can be calculated with the relation

$$\eta_{opt} = m+(m_{A3}-m)+(m_{B1}-m)+(m_{C2}-m)$$

and it comes out to be 18.11 kgf.

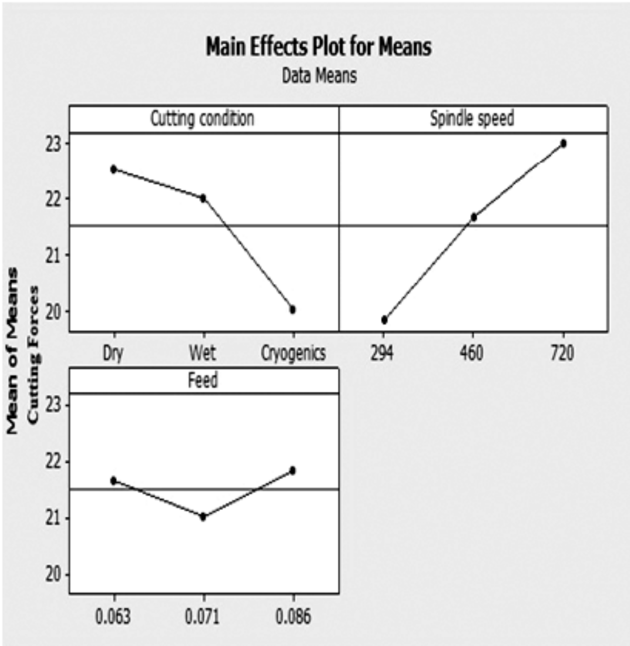

Figure 3: The Main Effect Plot For The Mean OF Cutting Forces

3.1.3. Determination OF Surface Roughness

The experimental observations of spindle speed, feed, cutting conditions showing surface roughness and S/N ratio is shown in Table 7. The main effect plot for the means of surface roughness is shown in Fig. 4. Fig. 4 shows that value of surface roughness decreases with the cryogenic cooling condition and spindle speed. The optimal value of cutting force can be calculated with the relation.

$$\eta_{opt} = m + (m_{A3} - m) + (m_{B1} - m) + (m_{C2} - m)$$

and it comes out to be 1.037,**μ**m.

Table 7
Observation OF Surface Roughness And S/N Ratio

Sr. No.	*Cutting condition*	*Spindle speed RPM*	*Feed (mm / rev)*	*Mean Roughness (μm)*	*S/N ratio*
1.	Dry	294	0.063	4.256	-12.58
2.	Dry	460	0.071	3.546	-10.99
3.	Dry	720	0.086	2.984	-9.49
4.	Wet	294	0.071	2.483	-7.92
5.	Wet	460	0.086	2.685	-8.59
6.	Wet	720	0.063	2.058	-6.39
7.	Cryo	294	0.086	1.602	-4.10
8.	Cryo	460	0.063	1.725	-4.75
9.	Cryo	720	0.071	1.023	-0.22

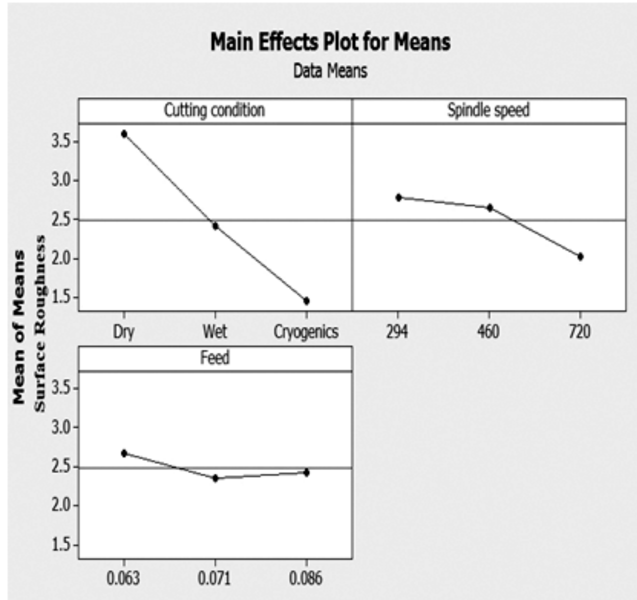

Figure 4: Main Plot OF Surface Roughness

3.2. Determination OF Tool Flank Wear

The experimental observations of spindle speed, feed, cutting conditions showing flank wear and S/N ratio is shown in Table 8.

Table 8
Observation of Flank Wear And S/N Ratio

Sr. No.	*Cutting condition*	*Spindle speed (RPM)*	*Feed (mm / rev)*	*Flank wear (μm)*	*S/N Ratio*
1.	Dry	294	0.063	0.35	9.11
2.	Dry	460	0.071	0.77	2.27
3.	Dry	720	0.086	0.95	0.44
4.	Wet	294	0.071	0.22	13.15
5.	Wet	460	0.086	0.45	6.93
6.	Wet	720	0.063	0.42	7.53
7.	Cryogenic	294	0.086	0.12	18.41
8.	Cryogenic	460	0.063	0.14	17.07
9.	Cryogenic	720	0.071	0.19	14.42

The main effect plot for the means of flank wear is shown in Fig. 4

It is evident for the graph that flank wear decreases with cryogenic conditions and in increases with spindle speed and feed. Tool flank wear is also evident from the pictograph shown in Fig. 6.

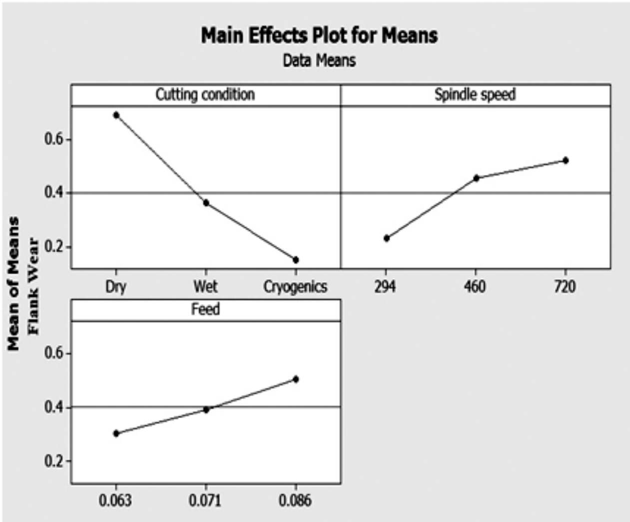

Figure 5: The Main Effect Plot For The Mean OF Flank Wear

The optimal value of flank wear can be calculated with the relation

$$\eta_{opt} = m + (m_{A3} - m) + (m_{B1} - m) + (m_{C2} - m)$$

and it comes out to be .083mm.

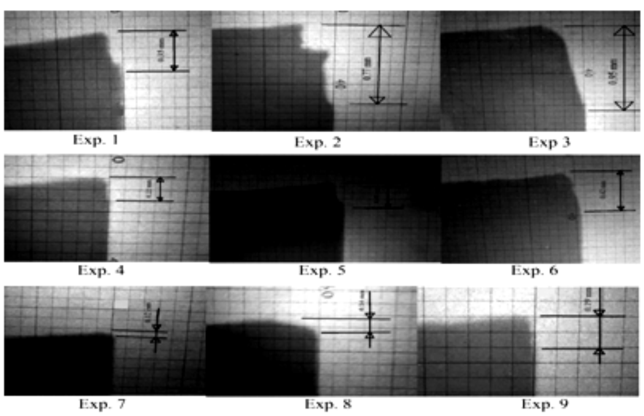

Figure 6: Flank Wear OF Tools AT Different Conditions

4. CONCLUSIONS

From the experiment the following conclusion has been drawn:

1. It has been observed that the cryogenic coolant plays an important role in turning of a material as it has increased the tool life and reduced the forces on tool.
2. For the improvement of flank wear, cutting condition plays much significant role as its percentage contribution was seen 76.83% in flank wear.
3. In the surface roughness improvement, the cutting condition has been seen an important factor as its percentage contribution was 83.36%.
4. The cutting condition has seen again an important factor in the reduction of cutting force as percentage contribution of cutting condition was 39.73% and spindle speed has also an important factor in cutting forces having 56.24% contribution.
5. The feed force having optimum parameters are spindle speed of 720RPM, feed of 0.071mm/rev at the cryogenic condition.

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