Experimental Investigation To Determine The Effect of Cryogenic Treatment on Milling Tool Life

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Abstract

In this paper an attempt has been made to determine the effect of sub-zero temperature on the milling tool life. For this purpose three main parameters are selected for analysis such as depth of cut, cutting speed and feed rate. The main aim of this study is to predict the effect of these parameters in order to lower down the wear rate for the improvement in tool life by using taguchi experimentation. Machining was performed on different levels with a combination of factors. From the results, it was found that spindle speed and depth of cut play a vital role in improving the tool life.

Keywords- cryogenic treatment, end mill, DOE, cutting velocity, ANNOVA.

I. Introduction

Machining of materials in the field of manufacturing is one of the constituting arenas of the subject which involves study of various kinds of mechanics and physics. With the passage of time the methods and mechanisms related to machining have changed and evolved to suit the needs of industry thereby achieving the desired product. However with much work progress conveniently desired results were achieved but only through costlier set up; and coupled with this was the non-feasibility of the process with the super low temperatures of the coolant being involved in the process thereby posing a problem. Thus another way that was thought of was to machine with help cryogenically treated tool. The tool to be used in machining was first treated cryogenically which imparted increased hardness, very crucial factor for higher rate of material removal in cases of hard to machine materials.

The process of treating work pieces to cryogenic temperature i.e. below temperatures like -190ºC in order to achieve the desired results in form of changes in mechanical properties is called as cryogenic treatment. Notwithstanding looking for upgraded adjustment and stress help or wear opposition, cryogenic treatment is likewise looked for its capacity to improve erosion obstruction by hastening miniaturized scale fine estimated time of arrival carbide particles which can be estimated previously or after in a section utilizing a quantimet [1].

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Hollis et al. [2] was concentrating the impacts of cryogenic cooling on tip of carbide instruments while machining titanium. The creators at that point acquainted fluid CO_2 with the base of carbide embed through slender cylinders in order to bring down the encompassing temperature and along these lines expanding the temperature angle in the instrument's cross-segment. It was discovered that the presentation of CO_2 had impeded the pit wear and the welding and culling activity had likewise decreased. Evans and Bryans [3] concentrated the impacts of machining forms on precious stone instrument while machining treated steel in cryogenic and non-cryogenic cooling conditions in order to accomplish brings about a near scale. Precious stone instrument wear systems were inspected and it was seen that both break and substance components might be significant. Surface completion toward the finish of procedure with cryogenic help was additionally seen as superior to the next one. Paul and Chattopadhyay [4] discovered the impact of cryogenic cooling by fluid nitrogen stream on powers, temperature and surface lingering worries in crushing steels and contrasted them and the outcomes from dry pounding and granulating with dissolvable oil. It was accounted for that cryogenic cooling had the edge over different coolants regarding controlling the temperature, remaining anxieties and granulating powers, and it is likewise condition well disposed.

Kumar and Choudhury [5] led trial concentrate to watch the impact of cryogenic cooling on instrument wear and high recurrence dynamic cutting powers produced during fast machining of treated steel. Analyses were completed both in dry and cryogenic conditions in a similar report premise to comprehend the relative favourable position offered by cryogenic cooling. It was found from the trial results that cryogenic chilling was powerful in bringing off the cutting temperatures that credited for the generous decrease of the flank wear (37.39%). Khan and Ahmed [6] set up thinks about keeping in my mind goals of machining like high material evacuation rate, great work surface completion and low apparatus wear, the last being the most significant of all. To achieve these destinations the chief move to be made ought to be one which diminishes apparatus wear for which we require a productive cooling framework during the machining procedure. Coubon et al. [7] improved the comprehension of cryogenic help with machining Ti6Al4V and Inconel 718 with carbide devices. It particularly plans to examine the cooling as well as oil abilities of a nitrogen stream under outrageous contact conditions utilizing a devoted tribometer. Sunil et al. [8] did machining of EN24 steel which is solidified to 45 HRC and it was done on machine to assess device life and cutting powers affected by impact of regular flood coolant and cryogenic coolant. Tests were completed at cutting velocities of 125, 160, 200 m/min and the feed rate, profundity of cut were kept steady at 0.1 mm/fire up and 1 mm individually. Sun et al. [9] concentrated the impact of cryogenic packed air cooling on instrument wear and cutting powers during cutting Ti–6Al–4V alloy at two cutting velocities at which cutting apparatus bombs as the aftereffect of continuous flank wear and disastrous plastic distortion of the front line, individually, during dry machining. It is discovered that the use of cryogenic compacted air drastically expanded instrument life contrasted and dry machining, and the expansion in device life was increasingly huge at higher cutting pace as the plastic twisting of

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bleeding edge that happened during dry machining was smothered during machining with cryogenic packed air cooling.

II. Experimental details

a) Cutting tool

For machining purpose an end mill cutter has been used with the following specification.

Table 1: ‘n’ value of carbide used as cutting tool material for Taylor’s tool life equation.

Tool material	Typical 'n' value
Carbides	0.2-0.5

b) Machine Used

Experiments were carried out on a vertical milling machine as shown on figure 1.

Figure 1- Vertical Milling Centre

Tool used was solid carbide end mill with a diameter of 10 mm as shown in figure 2. The grade specification of the tool are EM10 mm×25×70 4 FLT TA. The work piece used during experimentation was AISI 1045.

Figure 2- Solid Carbide End Mill

c) Cryogenic treatment

The cryogenic treatment was performed on end mill at a temperature of -193^0 C followed by tempering at 150^0 C for two times.

The following treatment process has been followed for the tool:

(i) The temperature was descended from room temperature to -193^0 C

(ii) Soak at -193^0 C

(iii)The temperature was then ascended from -193^0 C to room temperature.

(iv) It was then subjected to tempering for two times at 150^0 C.

d) Design of experimentation

In order to find the best combination of parameters for machining by using cryo treated end mill defined in table 2 taguchi approach has been used. L9 orthogonal array was generated by using Minitab 16 with different levels shown in table 3.

Table 2- Factors and their levels

Factor	1	2	3
Cutting speed (m/min)	240	260	280
Feed (mm/tooth)	0.20	0.25	0.30
Depth of Cut (mm)	1	2	3

Table 3- L9 Orthogonal Array

Cutting Speed	Feed	Depth of Cut
240	0.20	1
240	0.25	2
240	0.30	3
260	0.20	2
260	0.25	3
260	0.30	1
280	0.20	3
280	0.25	1
280	0.30	2

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III. Result and Discussion

a) Analysis for tool life for cryogenic treated tool

Tool life of the cryogenic treated carbide milling tool was determined by calculating the time interval between the successive regrinding. The value for tool life and its corresponding signal to noise ratio is tabulated in the table 4 below.

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Table 4- Tool life and S/N ratio (Cryogenic Treated Tool)

Cutting Speed	Feed	Depth of Cut	Tool Life (min)	S/N ratio
240	0.20	1	123.96	41.8656
240	0.25	2	65.99	36.3896
240	0.30	3	51.66	34.2631
260	0.20	2	62.64	35.9370
260	0.25	3	35.95	31.1140
260	0.30	1	55.95	34.9560
280	0.20	3	33.13	30.4044
280	0.25	1	52.62	34.4230
280	0.30	2	27.61	28.8213

From the analysis of S/N ratio shown in figure 3 it has been found that in order to improve the tool life the best combination of the given parameters were- are cutting velocity, feed rate and depth of cut are 240, 0.20 and 1 respectively.

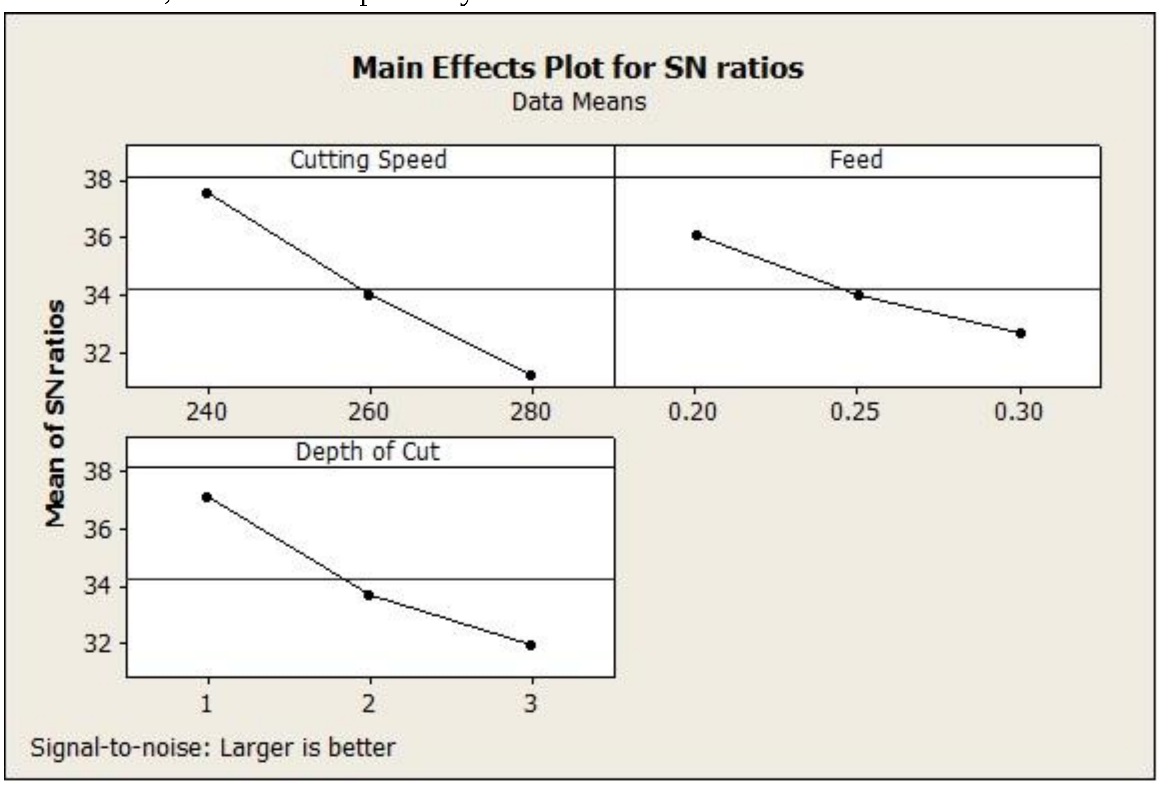

Figure 3- S/N ratio for Cryo treated tool

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b) Analysis of variance for cryogenic treated tool

The analysis of variance results for S/N ratio are shown in table 5 and this table specifies that the cutting velocity and depth of cut are the significant parameters in order to obtain an improved tool life at 95% confidence level. This table indicates that the most important parameter is the cutting speed followed by depth of cut and the least significant parameters is feed.

Table 5- Analysis of Variance for SNRA1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cutting Speed	2	59.601	59.601	29.800	33.07	0.029
Feed	2	17.545	17.545	8.773	9.73	0.093
Depth of Cut	2	41.095	41.095	20.547	22.80	0.042
Error	2	1.802	1.802	0.901		
Total	8	120.043				

S = 0.949339   R-Sq = 98.50%   R-Sq(adj) = 93.99%

c) Analysis for tool life for without treatment tool

Tool life of the simple carbide milling tool was determined by calculating the time interval between the successive regrinding. The value for tool life and its corresponding signal to noise ratio is tabulated in the table 6.

Table 6- Tool life and S/N ratio (Simple Carbide Tool)

Cutting Speed	Feed	Depth of Cut	Tool Life	S/N ratio
240	0.20	1	110.32	40.8531
240	0.25	2	56.63	35.0609
240	0.30	3	49.63	33.9149
260	0.20	2	55.21	34.8404
260	0.25	3	32.62	30.2697
260	0.30	1	51.26	34.1956
280	0.20	3	30.14	29.5829
280	0.25	1	47.95	33.6158
280	0.30	2	23.85	27.5498

From the analysis of S/N ratio shown in figure 4 it has been found that in order to improve the tool life the best combination of the given parameters were are cutting velocity, feed rate and depth of cut are 240, 0.20 and 1 respectively.

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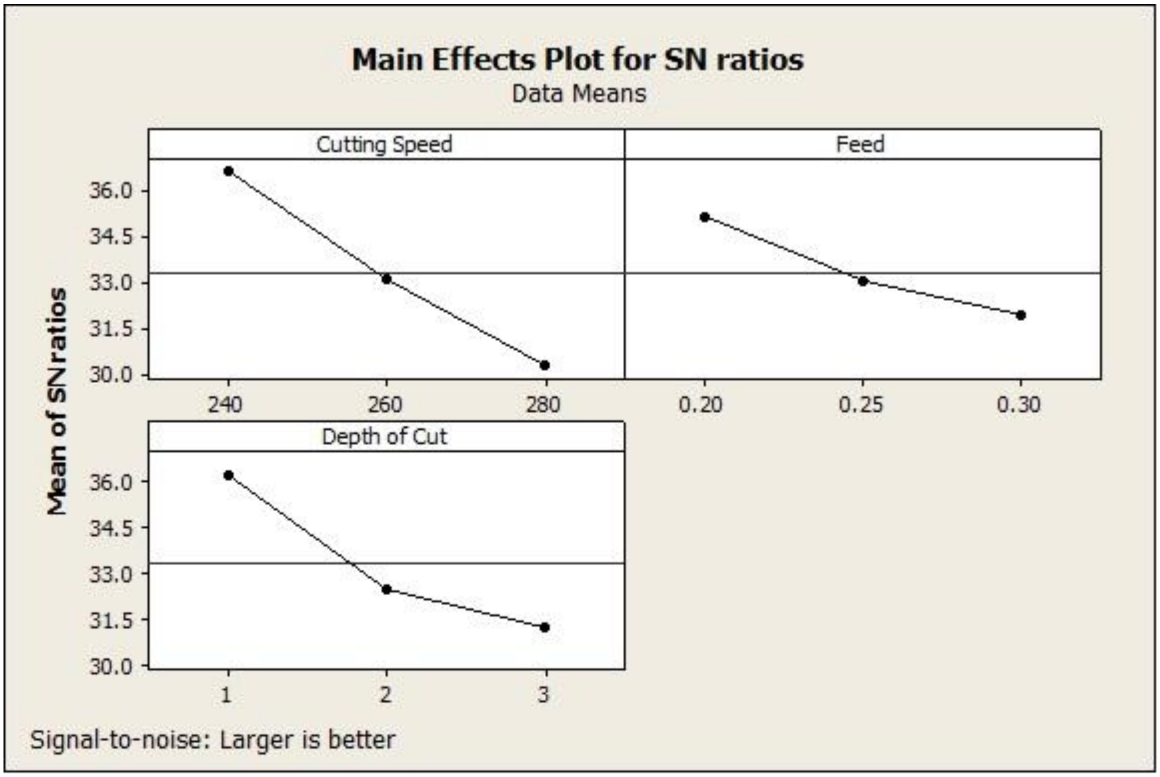

Figure 4- S/N ratio for simple carbide tool

d) Analysis of Variance for cryogenic treated tool

The analysis of variance results for S/N ratio for simple carbide tool is shown in table 7 and this table specifies that the cutting velocity is the most significant factor in order to obtain an improved tool life at 95% confidence level. After that depth of cut and the least significant parameters is feed.

Table 7- Analysis of Variance for SNRA2, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cutting Speed	2	60.892	60.892	30.446	20.93	0.046
Feed	2	15.926	15.926	7.963	5.48	0.154
Depth of Cut	2	40.137	40.137	20.068	13.80	0.068
Error	2	2.909	2.909	1.454		
Total	8	119.864				

S = 1.20598   R-Sq = 97.57%   R-Sq(adj) = 90.29%

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e) Comparison of Treated and Non Treated tool

Further after doing the analysis of variance for both treated and non-treated tool the comparison of both these tool life was done and it was found (table 8) that the tool with cryogenic treatment shows significant improvement in the tool life as compared to non-treated tool.

Table 8- Comparison of Treated and Non Treated Tool

S.No.	Cryo Treated Tool Life	Non Treated Tool Life	Deviation
1	123.96	110.32	13.64
2	65.99	56.63	9.36
3	51.66	49.63	2.03
4	62.64	55.21	7.43
5	35.95	32.62	3.33
6	55.95	51.26	4.69
7	33.13	30.14	2.99
8	52.62	47.95	4.67
9	27.61	23.85	3.76

IV. Conclusion

From the above experimental results it is evident that:

1. Cryogenic treatment has a significant effect on the tool life as compared to non-treated tool and maximum was 13.64%.
2. From the S/N ratio of cryogenic treated tool, the optimum parameters for machining AISI 1045 are cutting velocity; feed rate and depth of cut are 240, 0.20 and 1 respectively.
3. From the ANNOVA analysis for cryo treated tool, cutting velocity and depth of cut are the significant factors in order to obtain an improved tool life at 95% confidence level.
4. From the ANNOVA analysis for non-treated tool, cutting speed is the most influential factor in order to obtain an improved tool life at 95% confidence level.

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