Improvement of Surface Properties in Milling of DRNC (Discontinuously Reinforced Nylon Composite) using Pressurized Steam Jet Approach

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Abstract—A milling machine is a machine tool used to machine solid materials and it is conventional machining process. In the field of material science has been directed towards the development of new lightweight, high performance engineering materials like composites. In this study while milling, efforts are made to improve the surface properties of discontinuously reinforced nylon composite (DRNC) using pressurized steam jet approach. Steam jet act as transportation carriers carrying the heat away from the cutting region, and the efficiency of this cooling method largely depends on the jet pressure. The effect of feed rate, cutting speed, steam pressure and depth of cut on surface properties would be examined. For this study concept of Design of experiment has been used. Results have been evaluated with the help of Minitab software.

Keywords: High Speed End Mill Cutter, Discontinuous reinforced Nylon Composite, Metal Removal Rate, Surface Hardness, Surface Roughness, Taguchi method.

I. INTRODUCTION

Milling is one of the important machining operations. In this operation the work piece is fed against a rotating cylindrical tool. The rotating tool consists of multiple cutting edges (multipoint cutting tool). Normally axis of rotation of feed given to the work piece. Milling operation is distinguished from other machining operations on the basis of orientation between the tool axis and the feed direction; however, in other operations like drilling, turning, etc. the tool is fed in the direction parallel to axis of rotation. The cutting tool used in milling operation is called milling cutter, which consists of multiple edges called teeth. The machine tool that performs the milling operations by producing required relative motion between work piece and tool is called milling machine. It provides the required relative motion under very controlled conditions. These conditions will be discussed later in this unit as milling speed, feed rate and depth of cut. Normally, the milling operation creates plane surfaces. Other geometries can also be created by milling machine. Milling operation is considered an interrupted cutting operation teeth of milling cutter enter and exit the work during each revolution. This interrupted cutting action subjects the teeth to a cycle of impact force and thermal shock on every rotation. The tool material and cutter geometry must be designed to bear the above stated conditions. Depending upon the positioning of the tool and work piece the milling operation can be classified into different types.

II. EXPERIMENTAL SET UP

The experiments have been conducted on Vertical milling machine. Many input parameters like steam pressure, cutting speed, feed and depth of cut has been varied in this experiment. Each factor has its own effect on the output parameters such as Material removal rate (MRR), Surface roughness (SR), and hardness. In all experiments machining time is kept constant of 3 minutes.

For attaining steam jet approach vertical milling machine was equipped with a steam generating cooker. This was capable of producing pressure up to 30 lb/in^2. In experiments only two values of pressure were considered as 15 and 25. The outlet of pressure was with the help of a pipe and nozzle that was located near to the groove made by machining, for the fast removal of material removed. . Steam jet act as transportation carriers carrying the heat away from the cutting region, and the efficiency of this cooling method largely depends on the jet pressure.

Factors	Factors designation	Level1	Level2	Level3
Steam jet pressure (lb/in^2)	A	15	25	
Speed (rpm)	B	450	900	2900
Feed rate (mm/min)	C	20	35	65
Depth of cut (mm)	D	0.5	0.75	1

Table. 1: Factors and their levels of interest

A. *Taguchi method and designs of experiment*

Taguchi method of design provides a simple, efficient and systematic approach for optimization of experimental designs for performance quality and cost. In this, firstly the input factors are selected which are used in experiments and these factors values are entered in Taguchi design .The experimental values are obtained by design of experiment technique.

In Taguchi method the results are analyzed to achieve to one or three following objectives

- To establish the best or optimum condition for product or a process
- To estimate the contribution of individual factors
- To estimate the response under optimum condition.

The optimum condition is identified by studying the main effects of each of the factors. The process involves minor arithmetic manipulation of numerical results and usually can be done by using simple calculator. The main effects indicate the general trend of influence of factors.

Signal-to-noise ratio or the SN number is calculated for each variable to determine the effect on the output. In the equations below, y_i is the mean value and s_i is the variance. y_i is the value of the performance characteristic for a given experiment.

$$SN_i = 10\log \frac{\bar{y_i}^2}{s_i^2} \quad \text{...... (2.1)}$$

where

$$\bar{y}_i = \frac{1}{N_i}\sum_{u=1}^{N_i} y_{i,u}$$

$$s_i^2 = \frac{1}{N_i - 1}\sum_{u=1}^{N_i}(y_{i,u} - \bar{y}_i)$$

i= Experiment number

u= Trial number

N_i= Number of trials for experiment i

For the case of minimizing the performance characteristic, the following definition of the SN ratio should be calculated:

$$SN_i = -10\log\left(\sum_{u=1}^{N_i}\frac{y_u^2}{N_i}\right) \quad \text{.... (2.2)}$$

For the case of maximizing the performance characteristic, the following definition of the SN ratio should be calculated:

$$SN_i = -10\log\left[\frac{1}{N_i}\sum_{u=1}^{N_i}\frac{1}{y_u^2}\right] \quad \text{.... (2.3)}$$

The table-1 indicates the factors and levels for selecting the orthogonal array. For experiment degree of freedom (DOF) is to be calculated. The DOF for orthogonal array should be greater than or at least equal to those for design parameters. In this experiment, L9 orthogonal is used having four columns and nine rows. This array has eight degree of freedom and it can be handle three level design parameter. The surface roughness, Hardness, Material removal rate was analyzed by using this methodology.

III. RESULT AND DISCUSSION

After performing experimentation and machining process details of such parameters of machining i.e. depth of cut (DOC), cutting speed, feed rate, metal removal rate, surface roughness and hardness are obtained. Results are given in tables below:

Experiment No:	Pressure (lb/in^2)	Speed (rpm)	Feed Rate(mm/min)	DOC(mm)	MRR (mm^3/min)	S/N Ratio	Mean
1.	15	450	20	0.50	197.7	45.9201	197.7
2	15	450	35	0.75	369.2	51.3452	369.2
3	15	450	65	1	781	57.8530	781
4	15	900	20	0.50	167.7	44.4907	167.7
5	15	900	35	0.75	409.8	52.2514	409.8
6	15	900	65	1	921.9	59.2937	921.9
7	15	2900	20	0.75	197.8	45.9245	197.8
8	15	2900	35	1	601.5	55.5847	601.5
9	15	2900	65	0.50	717.5	57.1164	717.5
10	25	450	20	1	258.5	48.2492	258.5
11	25	450	35	0.50	238.3	47.5425	238.3
12	25	450	65	0.75	508.1	54.1190	508.1
13	25	900	20	0.75	203.7	46.1798	203.7
14	25	900	35	1	355.4	51.0143	355.4
15	25	900	65	0.50	389.2	51.8035	389.2
16	25	2900	20	1	298.9	49.5105	298.9
17	25	2900	35	0.50	333.2	50.4541	333.2

18	25	2900	65	0.75	898.7	59.0723	898.7

Table. 2: Results for MRR

Trail No.	Pressure (lb/in2)	Speed (rpm)	Feed Rate(mm/min)	DOC(mm)	Surface Roughness(µm)	S/N Ratio	Mean
1.	15	450	20	0.50	0.28	11.0568	0.28
2	15	450	35	0.75	0.49	6.1961	0.49
3	15	450	65	1	0.71	2.9748	0.71
4	15	900	20	0.50	0.29	10.7520	0.29
5	15	900	35	0.75	0.55	5.1927	0.55
6	15	900	65	1	1.23	-1.7981	1.23
7	15	2900	20	0.75	0.49	6.1961	0.49
8	15	2900	35	1	0.81	1.8303	0.81
9	15	2900	65	0.50	1.14	-1.1381	1.14
10	25	450	20	1	0.37	8.6360	0.37
11	25	450	35	0.50	1.05	-0.4238	1.05
12	25	450	65	0.75	1.08	-0.6685	1.08
13	25	900	20	0.75	0.81	1.7237	0.81
14	25	900	35	1	1.14	-1.1381	1.14
15	25	900	65	0.50	1.41	-2.9844	1.41
16	25	2900	20	1	0.99	0.0873	0.99
17	25	2900	35	0.50	1.17	-1.3637	1.17
18	25	2900	65	0.75	1.01	-0.0864	1.01

Table 3: Results for Surface Roughness (Ra)

Trail No.	Pressure (lb/in^2)	Speed (rpm)	Feed Rate(mm/min)	DOC(mm)	Surface Hardness(HRB)	S/N Ratio	Mean
1.	15	450	20	0.50	77.0	37.7298	77.0
2	15	450	35	0.75	77.5	37.7860	77.5
3	15	450	65	1	78.0	37.8419	78.0
4	15	900	20	0.50	77.0	37.7298	77.0
5	15	900	35	0.75	78.0	37.8419	78.0
6	15	900	65	1	78.5	37.8974	78.5
7	15	2900	20	0.75	79.0	37.9525	79.0
8	15	2900	35	1	79.5	38.0073	79.5

9	15	2900	65	0.50	78.0	37.8419	78.0
10	25	450	20	1	79.5	38.0073	79.5
11	25	450	35	0.50	77.0	37.7298	77.0
12	25	450	65	0.75	78.5	37.8974	78.5
13	25	900	20	0.75	79.0	37.9525	79.0
14	25	900	35	1	80.5	38.1159	80.5
15	25	900	65	0.50	80.0	38.0618	80.0
16	25	2900	20	1	80.0	38.0618	80.0
17	25	2900	35	0.50	79.5	38.0073	79.5
18	25	2900	65	0.75	80.0	38.0618	80.0

Table. 4: Results for Hardness

A. MRR

The effect of parameters i.e. steam pressure, cutting speed, feed rate, depth of cut and interaction effect between pressure and cutting speed were evaluated using ANOVA and factorial design analysis. A confidence interval of 95% has been used for the analysis. One repetition for each 18 trails was completed to measure the Signal to Noise ratio (S/N Ratio). ANOVA table shows that feed with F value 35.63, depth of cut with F value 5.68 and pressure with F value 4.25 are the factors that significantly affect the MRR, with % contribution of 67.18%, 8.61% and 2.90% to MRR. The other factor speed and pressure × speed were found to be insignificant. For S/N ratio cutting speed, feed and depth of cut were significant to reduce the variation of MRR. With 95% confidence interval mean value of MRR was found to be 851.8 ± 143.22 mm^3/min.

B. Surface Roughness

The effect of parameters i.e. steam pressure, cutting speed, feed rate, depth of cut and interaction effect between pressure and cutting speed were evaluated using ANOVA and factorial design analysis. A confidence interval of 95% has been used for the analysis. One repetition for each 18 trails was completed to measure the Signal to Noise ratio (S/N Ratio). In this experiment work surface roughness (Ra) has measured at position center. ANOVA table shows that feed with F value 13.93, pressure with F value 15.32 and speed with F value of 3.92 are the factors that significantly affect the surface roughness with % contribution of 43.42 %, 23.93 % and 11.45 % to surface roughness. The other factor depth of cut and pressure •~ speed were found to be insignificant. For S/N ratio pressure, cutting speed and feed were significant to reduce the variation of surface roughness. With 95% confidence interval mean value of surface roughness was found to be 0.2089 □} 0.146 ƒÊm.

C. Surface Hardness

The effect of parameters i.e. steam pressure, cutting speed, feed rate, depth of cut and interaction effect between pressure and cutting speed were evaluated using ANOVA and factorial design analysis. A confidence interval of 95% has been used for the analysis. One repetition for each 18 trails was completed to measure the Signal to Noise ratio (S/N Ratio). Hardness was measured on Rockwell hardness tester on B scale. ANOVA table shows that pressure with F value 24.05, speed with F value 10.14 and depth of cut with F value 7.68 are the factors that significantly affect the surface hardness with % contribution of 31.84 %, 25.17 % and 18.37 % to surface hardness. The other factor feed and pressure •~ speed were found to be insignificant. For S/N ratio pressure, cutting speed and depth of cut were significant to reduce the variation of surface hardness. With 95% confidence interval mean value of surface hardness was found to be 80.61 •} 0.71 HRB

IV. CONCLUSIONS

The present study was carried out to study the effect of input parameters on the MRR, surface roughness and surface hardness. The following conclusions have been drawn from the study:

- MRR is mainly affected by feed rate, depth of cut and pressure.
- Surface roughness is mainly affected by feed rate, steam pressure and cutting speed.
- Surface hardness is mainly affected by steam pressure, cutting speed and depth of cut.

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