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OPTIMIZATION OF MICRO MILLING PROCESS USING GRAY TAGUCHI METHOD

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***Abstract*— Recently the need of micro technologies is growing rapidly. Demand of microscale miniaturized parts are increasing in industries like electronics, aerospace, optics, telecommunication, medical, automobile etc. where quality is the most significant element. Micro-machining, micro‑molds and micro‑system are modern engineering science for mass production of the 3D micro-components with an accuracy of microns in a wide range of workpiece material. Mechanical micromachining is an important method in micro-machining process which includes micro-drilling, micro turning and the most efficient micro-milling. IN this project we will perform a micro milling process on Inconel aerospace alloy workpiece using a High Speed Steel tool of 1mm diameter on the CNC machine available in our workshop. Our main objective is to determine the optimal value of the process parameter commonly used in the micro milling process which are Feed Rate, Spindle Speed and Depth of cut so as to reduce the output parameter such as cutting force, cutting time and cutting torque.**

***Index Terms*— Mechanical Micromachining, Micro milling, Inconel Aerospace Alloy.**

I. INTRODUCTION

Recently the requirement of small technologies is growing quickly. Demand of micro scale miniaturized components are increasing in industries like physics, aerospace, optics, telecommunication, medical, automobile etc. wherever quality is that the most vital component. Micro-machining, micro‑molds associated micro‑system are trendy field of study for production of the 3D micro-components with an accuracy of microns during a wide selection of piece of work material. Mechanical micromachining is a very important technique in micro-machining method which incorporates micro-drilling, small turning and also the best micro-milling. Micromachining could be a diminish edition of standard machining method, however the quantitative relation of feed per tooth to tool radius is significantly higher compared with standard finish edge [1] and enormous a part of the warmth generated is channeled dead set the encompassing through the chips generated throughout machining thence low cutting force required, temperature of the piece of work became low and provides less straining in work piece[5].One major vantage of micromachining is it will machine components of various form and size with an outsized vary of piece of work material. Material removal rate of edge is bigger than the other material removal method offered in our industries. Conjointly its surface end is nice. Material removal rates will increase by increasing the feed rate and spindle speed and decreasing the depth of cut [5]. currently a day’s laptop numerically controlled (CNC) machine tools are used wide as a result of it enhances the surface quality of the piece of work, permit automatic machining and enhances the productivity of the lineman and also the machining method [1]. Chip generation in micro-milling is extremely completely different from that of standard edge owing to high negative rack angle. Terribly little tool run-out conjointly affects the process [1]. Feed rate, spindle speed, tool diameter, depth of cut, material of the piece of work, etc. are the foremost parameter that affects the cutting force, torque, surface roughness, cutting time and power wear[1]. Here we tend to are considering the output variable as cutting force, cutting time and force needed by variable feed rate, spindle speed and depth of cut. Through the information of cutting force we are able to ascertain the productivity, the facility consumption of the cutting method and power wear that is kind of tough to grasp just in case of small machining owing to its little tool size [1].

II. LITERATURE SURVEY

EmelKuram, Babur Ozcelik[1] investigated on small edge of AL 7075 with a vicker hardness of 139 mistreatment Taguchi primarily based gray relative optimization methodology by taking spindle speed, feed per tooth and depth as method parameter and also the response variables were tool wear, force and surface roughness. They used 800 small meter diameter ball finish mill tool. SEM results show the buildup of plastically distorted work piece. They found the optimized price to minimize: (A) tool wear were depth of cut of 50 µm, feed per tooth of 0.5 µm/tooth and spindle speed of 10,000 rpm. (B) Fx were spindle speed of 10,000 rpm, feed per tooth of 0.5 µm/tooth and depth of cut of one 100 µm. (C) Fy were spindle speed of 10,000 rpm, feed per tooth of 0.5 µm/tooth and depth of cut of seventy 5 µm. (D) Ra spindle speed of 12,000 rpm, feed per tooth of 0.5 µm/tooth and depth of cut 50 µm. They used Multi- objective optimization methodology to seek out out the optimized values for minimizing the tool wear, Fx, Fy and surface roughness, were spindle speed of 10,000 rpm, feed per tooth of 0.5 µm/tooth and depth of cut of 50 µm.

Mao-yong LIN, Chung-chen TSAO[2], investigated The small edge discharge machining (EDM) method of alloy 718 alloy mistreatment W inorganic compound tool conductor of diameter of 200 µm by taking peak current, pulse on-time, pulse off-time and spark gap as method parameter whereas the response variables are as such: conductor wear (EW), material removal rate(MRR) and dealing gap(WG) by the Grey-Taguchi methodology. They found the optimized price to (A) minimize electronic warfare were peak current 0.5 A, pulse on-time 6 µs, pulse off-time 25 µs and spark gap 6 V. (B) higher MRR were peak current 1.5 A, pulse on-time 1 µs, pulse off-time 3 µs and spark gap 45 V (C) lower operating gap were peak current 0.5 A, pulse on-time 1 µs, pulse off-time 25 µs and spark gap 60 V. (D) get smart multiple performance characteristics in small edge EDM of alloy 718 were 0.5 A peak current, 3 µs pulse on-time, 3 µs pulse off-time and 60 V spark gap. They terminated that we are able to bring home the bacon low electronic warfare by increasing pulse off-time and spark gap, and decreasing peak current. Beneath the best obtained parameters the conductor wear decreases from 5.6×10-9 to 5.2×10-9 mm3/min, the fabric removal rate will increase from 0.47×10-8 to 1.68×10-8 mm3/min, and also the operating gap decreases from 1.27 to 1.19 µm.

III. Experimental Setup

In this experiment, 2mm thick Inconel sheet was taken as a work-piece, with dimension of-length X breadth (80 mm X 30 mm). The milling cutter which is used in the experiment is High Speed Steel milling cutter with a dimension of 1mm diameter. The work piece is mounted on the dynamometer with the help of nut and bolt. Dynamometer is mounted on the saddle of the CNC machine. Dynamometer is connected with the amplifier which shows the force component and torque in the digital screen. The micro-milling experiment is conducted in the central workshop of CIPET Lucknow, India. 9272A type 4 component dynamometer measures:- force and torque. Stop watch measured: - time.

Some Specifications:

1) Milling Cutter:

Type -------------------------High Speed Steel milling cutter

Diameter--------------------1mm

2) Work- Piece:

Type : INCONEL (AEROSPACE MATERIAL)

Density : 8.19 g/cm^3

Composition : Ni 72

: Cr14-17

: Fe 6-10

: Mn 1

: Cu 0.5

: Si 0.5

: C 0.15

: S 0.015

3) Amplifier:

Type ----------------------------5070A

Company------------------------Kistler Corporation

4) CNC Specifications:

Company name : Ralliwolf Limited, Bombay (400080)

Type : WDH

Serial No : B913238

Power rating : 415V, 3ϕ, 15KVA

Axes motor : Fanuc Servo motor β 4i series

Spindle motor : Fanuc spindle motor β 3i series

F/L amps : 2.55A

N/L RPM : 560 rpm

AC/DC volts : 235V

5) CNC Program:

```
G28 G91 Z0;
G00 G40 G80 G90 G54 X0 Y0;
M03 S2000;
G00 Z2;
# =0.045;
N1 G01 Z-#1 F2;
#1 +#1+0.045;
G01 G04 X25 Y0 F15;
G01 G40 X0 Y0;
IF [#1 LT 0.09] THEN GOTO1;
G00 Z5;
G28 G91 Z0;
G28 G91 Y0;
M30;
```

6) Dynamometer:

The Kistler Dynamometer 9272 A with Charge Amplifier 5070 A measures the three perpendicular components of the force **(Fx, Fy, Fz)** acting on the workpiece as well as the moment. The dynamometer has high rigidity and hence high natural frequency. The high resolution enables very small dynamic changes to be measured in large forces. The dynamometer measures the active cutting force regardless of its application point. Both the average value of the force and the dynamic force increase may be measured. The usual frequency range depends mainly on the resonance frequency of the entire measuring rig [17].

The passive force is denoted as Fc (Fz),the feed force as Fs (Fx) and the normal feed force as Ft (Fy). The dynamometer is mounted on the saddle of the CNC. These three component of the cutting forces are displayed by the charged amplifier.

Type : 9272A
Company : Kistler Corporation

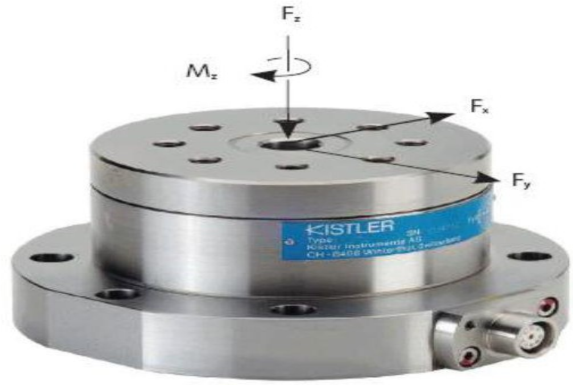

Figure No. 1: Tool dynamometer

Table No. 1: Dynamometer specifications

Specifications	**Unit of measures** **Metric | Imperial**	**Type 9272**
Measuring range (Fx)	kN	-5.00 ... 5.00
Measuring range (Fy)	kN	-5.00 ... 5.00
Measuring range (Fz)	Kn	-5.00 ... 20.00
Measuring range (Mz)	kN·m	-0.200 ... 0.200
Design		Force Plate / Dynamometer
Number of axes		4
Measuring mode		Direct
Operating temperature range	°C	0 ... 70
Height	Mm	70.0
Outside diameter	Mm	100.0
Inside diameter	Mm	15.0
Degree of protection	IP	67
Cable is replaceable		Yes
Connector / cable		Plug

IV. PROCEDURE

Firstly, the work-piece was cut according to above mentioned dimension i.e. 80*50*5 mm by cutter. Then two holes of 8mm and 12mm diameter are made by heavy duty driller to hold the work-piece tightly by the nuts and bolts. After drilled hole in work piece, Kistler model 9272A piezoelectric drilling dynamometer is to be mounted on T-slot bed with T-type bolts. The above said PMMA strip is settled above the dynamometer by the help of two bolts and washers. With the aid of G-coding program in a CNC drilling machine, the spindle speed and feed are to be inserted as a input parameters in the micro-drilling operation. The output parameters of thrust force and torque are measured simultaneously which were displayed on monitor of amplifier monitor. The machining time is measured with the care of stop watch. After the micro-drilling process, the images of total 10 holes were to be measured by JEOL SEM machine at acceleration voltage of 15KV and magnification of X50.

A. Analysis of Experiments

Design Of Experiment the branch of applied statistics that deals with planning, conducting, analyzing and interpreting controlled tests to evaluate the factors that control the value of a parameter or group of parameters.[15]an orthogonal array is a "table" (array) whose entries come from a fixed finite set of symbols (typically, {1,2,...,n}), arranged in such a way that there is an integer t so that for every selection of t columns of the table, all ordered t-tuples of the symbols, formed by taking the entries in each row restricted to these columns, appear the same number of times. The number t is called the strength of the orthogonal array [16]. Here we use L9 orthogonal array with 3 levels.

B. Gray Rational Analysis

Grey Relational analysis is as follows:

- Generating the experimental data tables through Design of Experiment.
- following formula is used to Normalize the output variables:

$$Nij = \frac{(Xij)\ max - Xij}{(Xij)\ max - (Xij)\ min}$$

Here,

Nij= Normalized value after grey relational generation

(Xij) max= Maximum value of response parameter

(Xij) min= Minimum value of response parameter and

Xij= Value of response in it column and threw of design matrix.

Here i:{1,2,3,4} and j:{1,2,…..,9}

- Calculation of the grey relation co-efficient.

$$\gamma\ (x0j,Xij) = \frac{\Delta min + \xi \Delta max}{\Delta ij + \xi \Delta max}$$

Here,

Δij= |x0j – Xij|

ξ= Distinguishing coefficient lies between 0 to 1. Here ξ is 0.5

V. Result and Discussion

After the completion of the experiment and the theoretical investigation for the optimization of micro milling process parameters we reached to the following results:

1. The optimal condition of the machining parameters are 15mm/min feed rate, 209.43 rpm spindle speed and 45 µm depth of cut.

2. From the signal to noise ratio graph the optimum value occurred at 1.01513.

3. Optimum value for SN ratio occurred for feed rate in 3rd level, for spindle speed in 3rd level and depth of cut in 2nd level.

4. Total mean grey relational grade is 0.672.

5. Depth of cut is additional vital than the spindle speed and Feed rate as it has the minimum value of P i.e. 0.077 in the ANOVA table of means.

6. The points on the residual vs. fitted value graph do not produce any pattern therefore it has zero error.

7. SN ratio at optimum value is increased by 0.466568 i.e 45.96% whereas mean value is decreased by 0.0382333 i.e. 4.29%.

8. From the response table it is clear that Depth of cut is the most substantial Characteristics as its rank is 1

9. Our investigation is unto the mark as we get the normally distributed graph.

10. Maximum width of the slot as seen by the SEM machine is 1.05mm and the total Mean average width of the slot is 1.009mm.

11. From the SEM images we have seen that the width of the slots are nearly same as that of the cutter diameter but there are some burr formation takes place.

VI. Conclusion

Our investigation of micro milling of Inconel aerospace alloy with High Speed Steel tool of 1mm diameter is conducted successfully on the CNC machine. Our main objective was to determine the optimal value of the process parameter commonly used in the micro milling process which are Feed Rate, Spindle Speed and Depth of cut so as to reduce the output parameter such as cutting force, cutting time and cutting torque. And we conclude our investigation as follows:

1. As the parameter depth of cut increases the output variables force, time and torque decreases. Hence to get low value of cutting force, cutting time and torque it required high depth of cut value.
2. While in case of other machining parameter like feed rate and spindle speed, low value of these parameters are preferable
3. The optimal condition of the machining parameters are 15mm/min feed rate, 209.43 rpm spindle speed and 45 µm depth of cut.

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