Optimization of Face Milling Parameters Using GA Based Taguchi Method on Inconel 718 alloy

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***Abstract* - Milling machine is one of the important machining operations used for specially those materials which are not axially symmetric. In this operation the work piece is feed against a rotating cylindrical tool. Rotating tool consists of multiple cutting edges. Normally axis of rotation of feed is given to the work piece element. Parametric analysis has been done by conducting a set of experiments on Inconel 718 (100mm×90mm×75mm) with coated cemented carbide in dry conditions. This study focuses on the influence of process parameter such as speed, feed, depth of cut and approach angle on Milling machine and effect of this process parameter on tool life and surface roughness has been studied. Taguchi method used for conducting the experiment and developing empirical models for surface roughness and tool life with the help of Minitab software.**

Keywords* - *Taguchi, GA, Tool Life, Surface Roughness

I. INTRODUCTION

The success of the machining operation depends on the selection of machining process parameters. Proper selection of process parameters play a significant role to ensure quality of product, to reduce the machining cost, to increase productivity in computer controlled machining processes and to assist in computer aided process planning. However, determination of optimum process parameters of any machining process is usually a difficult task where the following aspects are required knowledge of manufacturing process, empirical equations to develop realistic constraints, specification of machine tool capabilities, development of effective optimization criteria, and knowledge of mathematical and numerical optimization techniques [1]. Face milling is currently the most effective and productive manufacturing method for roughing and finishing large surfaces of metallic parts. Milling data, such as surface topomorphy, surface roughness, non-deformed chip dimensions, cutting force components and dynamic cutting behavior, are very helpful, especially if they can be accurately produced by means of a simulation program[2].

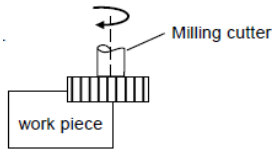

Fig. 1

Surasit Rawangwong et al.[3] investigate the effect of main factors of the surface roughness in aluminum 7075-T6 face milling. The results could be applied in the manufacture of automotive components and mold industry. The purpose of the study of investigating the surface roughness in aluminium 7075-T6 face milling process by CNC milling machine and using face mill cutting tool with twin edges type was to identify the means of the surface roughness of aluminum 7075-T6 face milling process. Şeref Aykut et al.[4] proposed a new multiobjective optimization approach for the selection of the optimal values for cutting environment in the face milling of cobalt-based alloys. This approach aims to handle the possible manufacturing errors in the design stage. It is believed that the used method provides a robust way of looking at the optimum parameter selection problems. Prof. H. R. Ghan and S.D.Ambekar [5] investigate the effect of the various parameters like cutting tools material, machine tools, , tool geometry and cutting parameters. In production system, the variations in input process parameters such as speed, feed and depth of cut affects the surface roughness, machining time and metal removal rate of the Aluminium LM-26 alloy which affect the performance of manufacturing process. The purpose of this research is to find out the optimized parameter levels of milling and turning which give optimize parameters by using Taguchi Design of Experiment.

In this work, the study is focused on the Milling machine using Inconel 718 as work piece material. Consequently, an analysis of the influence of process parameters such as Speed, feed, depth of cut and approach angle over response variables such as tool life and surface roughness was performed. This was done using the Taguchi Method and optimized by Genetic Algorithm using mat lab software.

II. EXPERIMENTAL DETAIL

In this section, there will be brief description of equipment used to carry out the Milling operation. Also the design factors used in this work will be outlined.

Fig. 2 Milling Machine

A. Equipment Used In the Experiments

The equipment used for experiment is milling machine using Inconel 718. In this operation the work piece is feed against a rotating cylindrical tool. Rotating tool consists of multiple cutting edges. Cutting tool used in milling operation is called milling cutter, it consists of multiple edges called teeth. fig. 2 shows the photograph of this equipment.

Surface roughness is measure of the texture of the surface in µm. Roughness is fine irregularities that are produced during a machining process. Surface roughness measurement was carried out using a surtronic 3+. fig. 3 show the figure surtronic 3+.

Fig. 3 Surtronic 3+

B. Material Used In the Experiments

Work piece material used for experiments was Inconel 718. Inconel 718 is a nickel based super alloy which is widely used in aerospace industry due to their exceptional thermal resistance and ability to retain mechanical properties at elevated service temperatures over 700°C[6]. The difficulty of machining Inconel 718 results into shorter tool life and severe surface abuse of machined surfaces [7]. Table-1 shows the description of chemical composition Inconel 718.

TABLE – I
CHEMICAL COMPOSITION OF INCONEL 718 (%)[8]

Elements	C	Si	Mn	Ti	Co	Cr	Fe	Mo	Nb	Al	Ni
Wt (%)	0.08	0.35	0.35	0.6	1	19	17	3	5	0.8	52.8

TABLE - II
MECHANICAL PROPERTIES OF INCONEL 718 [8]

Property	Value
Tensile strength (MPa)	1310
Yield strength (MPa)	1110
Elastic modulus (GPa)	206
Hardness (HRC)	38
Density (g/cm3)	8.19
Thermal conductivity(W/m K)	11.4

C. Process Parameters and Their Levels

TABLE –III
PROCESS PARAMETERS AND THEIR LEVELS

Factor	Level-1	Level-2	Level-3
SPEED(RPM)	40	60	80
FEED(mm/rev)	0.16	0.22	0.28
Depth of cut(mm)	0.1	0.15	0.20
Approach angle	35	45	55

There are various process parameters to be considered, but in this work we have considered four process parameters such as speed feed, depth of cut and approach angle. The tool life and surface roughness selected as response variables.

Tool Life

Tool wear is a time dependent process. Tool life generally indicates the amount of performance done by a fresh cutting tool till it is declared failed. Tool wear is measured by using Mitutoyo Toolmaker's Microscope TM-500 with a magnification of 15x fitted with digital micrometer XY table with the resolution of 0.001 mm. The Tools were examined at regular intervals of cutting time until the tool failed. Tool rejection criteria 0.35mm flank wear was used in accordance with ISO standard 3685 for tool life [8].

D. Methodology

Design of experiment: Experiments were designed by using Minitab software. Genetic Algorithm was used as a tool for development of a prediction model of tool life and surface roughness.

Taguchi Method

Traditional experimental design methods are very complicated and difficult to use. Also, these methods require a large number of experiments when the number of process parameters increases. In order to reduce the number of tests required, Taguchi experimental design technique, a powerful tool for designing high-quality system, was developed by prof. Taguchi. This method uses a design of orthogonal arrays to study the entire parameter space with small number of experiments only. Orthogonal array is a method of designing experiments that usually requires only a fraction of the full factorial combinations. Orthogonal array means design is balanced so that factor levels are weighted equally.

TABLE - 4

ORTHOGONAL ARRAY L9 OF THE EXPERIMENTAL RUNS AND RESULTS

S. No.	Speed (R.P.M)	Feed (mm/rev)	Depth of cut(mm)	Approach Angle	Tool Life (min)	Surface roughness (µm)
1.	40	0.16	0.10	35	23.86	1.11
2.	40	0.22	0.15	45	18.65	1.46
3.	40	0.28	0.20	55	9.37	3.93
4.	60	0.16	0.15	55	6.22	1.24
5.	60	0.22	0.20	35	3.75	1.48
6.	60	0.28	0.10	45	7.88	1.78
7.	80	0.16	0.20	45	1.83	1.05
8.	80	0.22	0.10	55	3.87	1.72
9.	80	0.28	0.15	35	2.07	2.54

III. DATA OPTIMIZATION

It is the process of finding the minimum or maximum of a function by systematically choosing the values of the variables from within set which allowed. Objective functions are those functions which have to be optimized and the variables on which the objective function depends are called the input variable [9]. Data are optimized through genetic algorithm with the help of regression analysis using Mat lab software.

Genetic algorithm

Genetic algorithm (GA) is a subclass of population based stochastic search procedure which is closely modelled on the natural process of evolution with emphasis on the survival of the fittest and breeding. The algorithm starts in spite of starting with a single point with a set of initial solutions. In spite of deterministic result at each iteration, GA operators produce probabilistic results leading to stochasticity. Suitable search direction can be provided to the GA by simulating the natural evolution's process [9].

Optimization of tool life

Regression equation

TL = 56.4–0.36*x(1)-35*x(2)-68.9*x(3)-0.17*x(4)

TABLE - 5

OPTIMUM VALUE FOR TOOL LIFE

Input Parameter	**Value**
1.Speed	40 rpm
2.Feed	0.16 mm/rev
3.Depth of Cut	0.1 mm
4.Approach Angle	35°
Response Variable	
Tool Life	23.56 min

This table shows optimum value of tool life 23.56 mm which is obtained from 40 rpm of speed , 0.16 mm/rev of feed , 0.1 mm of depth of cut and 35° of approach angle.

Optimization of Surface Roughness

Regression equation

Ra = -2.8-0.01*x(1)+13.5*x(2)+6.17*x(3)+0.03*x(4)

TABLE - 6
OPTIMUM VALUE FOR SURFACE ROUGHNESS

Input Parameter	Value
1.Speed	72.225 rpm
2.Feed	0.16 mm/rev
3.Depth	0.101 mm
4.Approach Angle	39.338°
Response Variable	
Surface Roughness	0.44 µm

This table shows optimum value of Surface roughness 0.44 µm which is obtained from 72.225 rpm of speed , 0.16 mm/rev of feed, 0.101 mm of depth of cut and 39.338° of approach angle.

IV. COMPARISON BETWEEN EXPERIMENTAL VALUE AND OPTIMIZED VALUE

Higher tool life is good for cutting tools. Higher tool life which is obtained from experimental result is 23.86 min while the optimized value which came from genetic algorithm is 23.56 min which is lesser than the maximum experimental value but in the case of surface roughness optimized value which is came from the genetic algorithm is much lesser than the minimum value of experimental result.

Optimized value of Surface roughness is best because I want to minimum surface roughness but optimized value of tool life is not good in this case, because I want to maximum tool life.

V. CONCLUISION

Using Taguchi based Genetic algorithm i got the optimized value of tool life 23.56 min and surface roughness 0.44 µm but experimental value of tool life is 23.86 min and surface roughness 1.05 µm. Value which is good for me is experimental value of tool life 23.86 min and optimized value of surface roughness 0.44 µm.

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