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Milling Parameters Optimization for Better Surface Roughness and Material Removal Rate

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Abstract: ***In this thesis experiments are conducted to determine the process parameters while milling Aluminum alloy using carbide tips for better surface finish quality and higher material removal rate. The machining parameters considered for optimization are Spindle Speed, Cut Feed, Step Over and depth of cut. The milling process is conducted on a CNC Vertical milling machine.***

1. Introduction

Milling is the machining process of using rotary cutters to remove material[1] from a work piece by advancing (or feeding) in a direction at an angle with the axis of the tool.[2][3] It covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes.

CNC Material Removal Rate (MRR)

From month to month or quarter to quarter, as you buy more efficient (and expensive) machines, cutting tools and fixtures, you should be cutting more metal in the same time. How do you ensure that this is happening, and track your progress? The MRR is a single number that enables you to do this. It is a direct indicator of how efficiently you are cutting, and how profitable you are.

Surface Roughness

Surface roughness, often shortened to roughness, is a measure of the texture of a surface. It is quantified by the vertical deviations of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small the surface is smooth. Roughness is typically considered to be the high frequency, short wavelength component of a measured surface (see surface metrology). However, in practice it is often necessary to know both the amplitude and frequency to ensure that a surface is fit for purpose.

2. Literature Review

This paper described by yang yang [1] prediction of surface roughness in end milling with gene expression programming. In this paper, a method based on gene expression programming (gep) has been proposed to construct the prediction model of surface roughness. Gep combines the advantages of the genetic algorithm (ga) and genetic programming (gp). By considering gep as a very successful technique for function mining and formula found, it should be suitable to solve the above problem. On the basis of defining a gep environment for the problem and improving the method of creating constant, the explicit prediction model of surface roughness can been constructed. In this paper done byM.S. Sukumar[2], Taguchi method has been used to identify the optimal combination of influential factors in the milling process. Milling experiment has been performed on al 6061 material, according to taguchi orthogonal array (L16) for various combinations of controllable parameters viz. Speed, feed and depth of cut.

3. Objective And Scope of the Project

The machining parameters used for roughing operation are Spindle Speed – 1000rpm, 1500rpm, 2000rpm, Cut Feed – 2000mm/min, 2500mm/min, 3000mm/min , Step Over – 20mm, 25mm, 30mm and depth of cut – 0.5mm.The machining parameters used for finishing operation are Spindle Speed – 2000rpm, 2200rpm, 2500rpm, Cut Feed – 1000mm/min, 1200mm/min, 1500mm/min , Step Over – 5mm, 10mm, 12mm and depth of cut – 0.3mm.

3.1 Experimental Setup and Procedure

In this project, roughing and finishing operations are done on a work piece made of manganese steel. The cutter used is carbide tool. The surface roughness and MRR are investigated by performing the machining process on 36 pieces. The machining parameters Spindle Speed, Cut Feed and Step over are varied and depth of cut is kept constant.
Size of Component
Length – 600mm
Width – 200mm
Height – 70mm

3.2 Experimental Investigation

a) CNC Machining Data for Roughing

The above table specifies the L9 orthogonal array as per Taguchi method. The following is the table specifying machining types done on the components, machining parameters used and no. of inserts changed in roughing operation.

Component 1

Type of operation		Facing
Cutter		50R6
Material	Work piece	Mn Steel
	Cutter	CARBIDE
Time (hrs)		8.5
No.of inserts changed		7
Spindle speed (rpm)		1000
Feed (mm/min)		2500
Step over (mm)		25
Depth of cut (mm)		0.5

Component 2

Type of operation		Facing
Cutter		50R6
Material	Work piece	Mn Steel
	Cutter	CARBIDE
Time (hrs)		8.5
No.of inserts changed		7
Spindle speed (rpm)		1000
Feed (mm/min)		2500
Step over (mm)		25
Depth of cut (mm)		0.5

Component 3

Type of operation		Facing
Cutter		50r6
Material	Work piece	Mn steel
	Cutter	Carbide
Time (hrs)		8
No.of inserts changed		7
Spindle speed (rpm)		1000
Feed (mm/min)		3000
Step over (mm)		30
Depth of cut (mm)		0.5

b) CNC Machining Data for Finishing

Process parameters	Le vel1	Level2	Level3
Spindle speed(rpm)	2000	2200	2500
Cut feed (mm/min)	1000	1200	1500
Step over (mm)	5	10	12

Component	Spindle speed (rpm)	Feed rate (mm/min)	Step over (mm)
1	2000	1000	5
2	2000	1200	10
3	2000	1500	12
4	2200	1000	10
5	2200	1200	12
6	2200	1500	5
7	2500	1000	12
8	2500	1200	5
9	2500	1500	10

The above table specifies L9 orthogonal array for finishing operations.

The following is the table specifying machining types done on the components, machining parameters used and no. of inserts changed for first 3 components in finishing operation.

Component 1

Type of operation		Facing
Cutter		50r0.8
Material	Work piece	Mn steel
	Cutter	Carbide
Time (hrs)		5
No.of inserts changed		7
Spindle speed (rpm)		2000
Feed (mm/min)		1000
Step over (mm)		5
Depth of cut (mm)		0.3

Component 2

Type of operation		Facing
Cutter		50R0.8
Material	Work piece	Mn Steel
	Cutter	Carbide
Time (hrs)		4.5
No.of inserts changed		6
Spindle speed (rpm)		2000
Feed (mm/min)		1200
Step over (mm)		10
Depth of cut (mm)		0.3

Component 3

Type of operation		Facing
Cutter		50R0.8
Material	Work piece	Mn Steel
	Cutter	Carbide
Time (hrs)		4
No.of inserts changed		6
Spindle speed (rpm)		2000
Feed (mm/min)		1500
Step over (mm)		12
Depth of cut (mm)		0.3

4. Optimization of Machining Parameters

Taguchi Method

Roughing operation

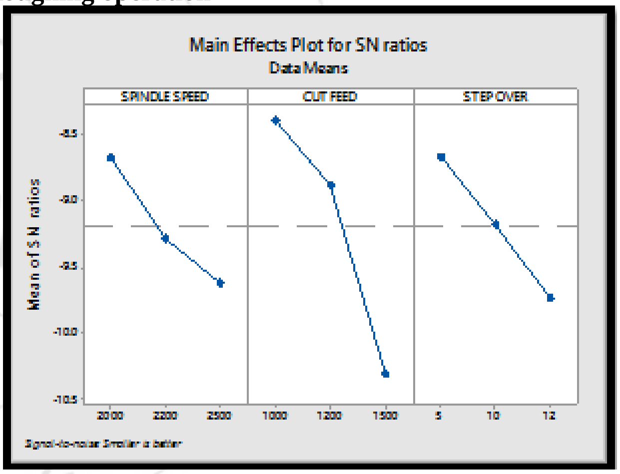

Figure 2: Effect of milling parameters on surface finishfor S/N ratio

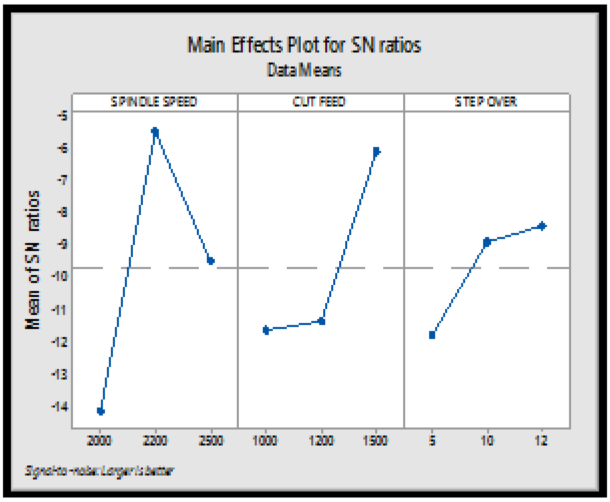

Figure 3: Effect of milling parameters on MRR for S/Nratio

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Regression Analysis

The following graphs determine the optimized spindle speed, cut feed and Step over for minimal Surface Roughness and higher MRR in roughing operations.

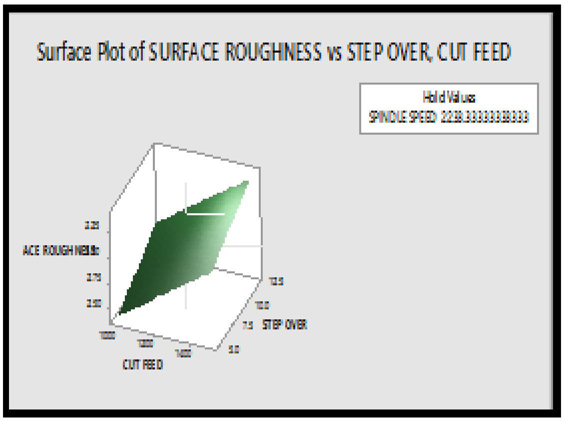

Figure 4: Surface Plot of Surface Roughness vs Step over, Cut Feed

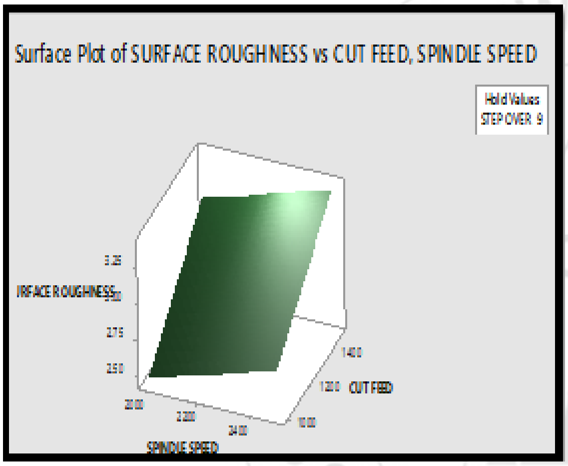

Figure 5: Surface Plot of Surface Roughness vs Cut Feed, Spindle Speed

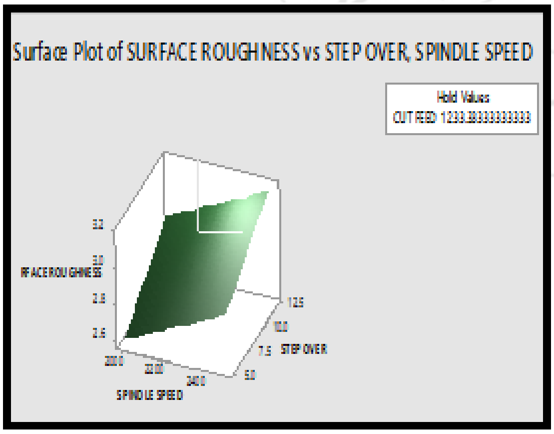

Figure 6: Surface Plot of Surface Roughness vs Step over, Spindle Speed

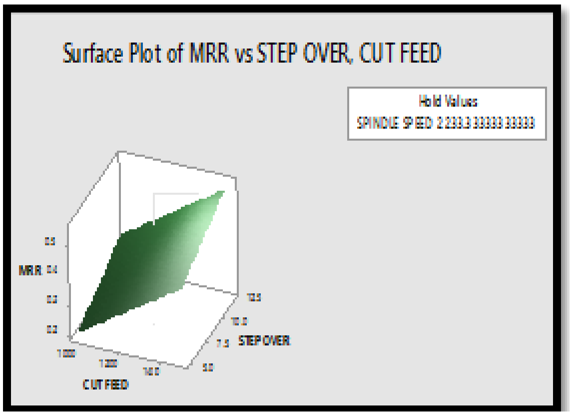

Figure 7: Surface Plot of MRR vs Step over, Cut Feed

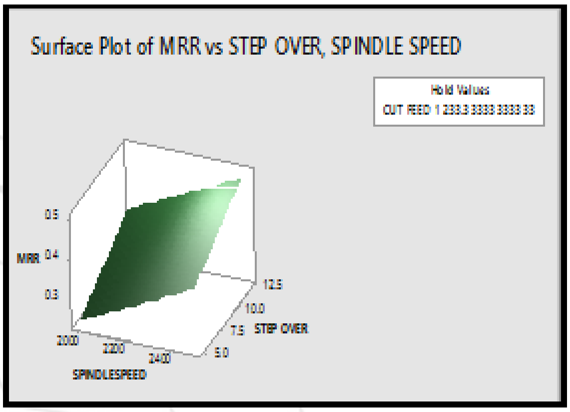

Figure 8: Surface Plot of MRR vs Step over, Spindle Speed

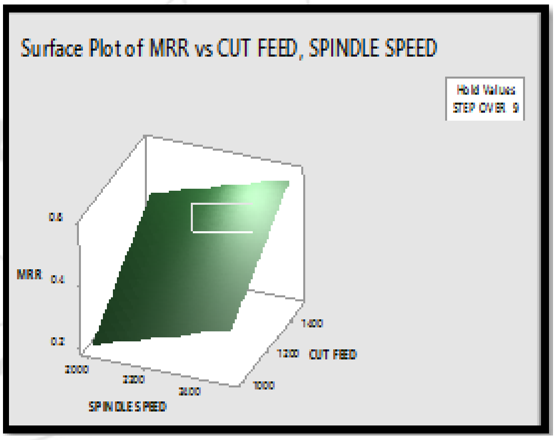

Figure 9: Surface Plot of MRR vs Cut Feed, Spindle Speed

5. Conclusion

From the **Taguchi Method,** the following conclusions can be made:

In roughing operations, the optimized machining parameters, to minimize surface roughness, spindle speed is 1000 rpm, Cut Feed is 2000 mm/min, Step Over is 20 mm. To maximize MRR, spindle speed is 1500 rpm, Cut Feed is 3000 mm/min, Step Over is 25 mm.

In finishing operations, the optimized machining parameters, to minimize surface roughness, spindle speed is 2000 rpm, Cut Feed is 2000 mm/min, Step Over is 5 mm. To maximize MRR, spindle speed is 2200 rpm, Cut Feed is 1500 mm/min, Step Over is 2 mm.

From the **Regression Analysis,** the following conclusions can be made:

In roughing operations, the optimized machining parameters, to minimize surface roughness, spindle speed is 1000 rpm, Cut Feed is 2000 mm/min, Step Over is 20 mm. To maximize MRR, spindle speed is 2000 rpm, Cut Feed is 3000 mm/min, Step Over is 30 mm.

In finishing operations, the optimized machining parameters, to minimize surface roughness, spindle speed is 2000 rpm, Cut Feed is 1000 mm/min, Step Over is 5 mm. To maximize MRR, spindle speed is 2400 rpm, Cut Feed is 1400 mm/min, Step Over is 12.5 mm.

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