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OPTIMIZATION OF MACHINING PARAMETERS OF TITANIUM ALLOY

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***Abstract*— High speed machining of highly reactive material like titanium and its alloys is still far away uncertain. For this reason, it is wiser to study the optimization of Machining parameters under transient cutting speed before advancing to high speed machining. This research work presents the influence of machining parameters like coolant flow rate, cutting speed, feed, Depth of cut on Machinability of Titanium alloy during machining.**

Titanium and its alloys are widely used in aerospace industries due to attractive characteristics of the material, they offers a combination of high strength, light weight, formability and corrosion resistance which have made it a world standard in aerospace applications. However, these materials have been classified as difficult-to machine material because of their high temperature strength, low thermal conductivity, chemical reactivity and relatively low modulus of elasticity. Furthermore these materials can catch fire at temperature 6100 C and the only material can burn in pure nitrogen.

In machining process, most of the mechanical energy used to remove material becomes heat. This heat generates high temperature in the cutting region. The higher the cutting speed, the faster the heat generation and higher temperature resulted. The new challenge in machining is to use high cutting speed in order to increase the productivity. This is the main reason for rapid tool wear. For titanium and its alloy, this problem is more severe due to their low thermal conductivity. 80% of the heat generated in the cutting region goes to the cutting tool and cause wear. So it is convenient to use transient cutting speed for machining the highly reactive material like titanium alloy.

Another Conventional method used to reduce this tool wear is by using cutting fluid. This cutting fluid acts as lubricant and coolant as well during the machining process. Usage of cutting fluid can increase the cutting speed up to 30% without affecting the tool life. However the usage of cutting fluid has negative effect to the economy, environment and health. Total elimination of cutting fluid seems to be not promising due the unsatisfactory tool life and poor surface finish. This rapid tool wears not only gives higher surface roughness value, but also higher micro hardness and major microstructure alteration.

***Index Terms*— Machining parameters, Titanium alloy, cutting fluid, coolant flow rate, cutting speed, feed, Depth of cut.**

I. INTRODUCTION

Machining is the broad term used to describe removal of material from a work piece. It covers several processes, which we usually divide into the following categories. The three principal machining processes are classified as Turning, Drilling and Milling. Other operations falling into miscellaneous categories include Shaping, Planing, Boring, Broaching and Sawing [1].

Turning operations are operations that rotate the work piece as the primary method of moving metal against the cutting tool. Lathes are the principal machine tool used in turning.

Milling operations are operations in which the cutting tool rotates to bring cutting edges to bear against the work piece. Milling machines are the principal machine tool used in milling.

Drilling operations are operations in which holes are produced or refined by bringing a rotating cutter with cutting edges at the lower extremity into contact with the work piece. Drilling operations are done primarily in drill presses but sometimes on lathes or mills.

Miscellaneous operations are operations that strictly speaking may not be machining operations in that they may not be swarf producing operations but these operations are performed at a typical machine tool. Burnishing is an example of a miscellaneous operation. Burnishing produces no swarf but can be performed at a lathe, mill, or drill press.

An unfinished work piece requiring machining will need to have some material cut away to create a finished product. A finished product would be a work piece that meets the specifications set out for that work piece by engineering drawings.

To perform the machining operation, relative motion is required between the tool and the work. This relative motion is achieved in most machining operation by means of a primary motion, called "cutting speed" and a secondary motion called "feed". The shape of the tool and its penetration into the work surface, combined with these motions, produce the desired shape of the resulting work surface [1].

Relative motion is required between the tool and work to perform a machining operation. The primary motion is accomplished at a certain cutting speed. In addition, the tool must be moved laterally across the work. This is a much slower motion, called the feed. The remaining dimension of the cut is the penetration of the cutting tool below the original work surface, called the depth of cut. Collectively, speed, feed, and depth of cut are called the cutting conditions.

A cutting fluid is often applied to the machining operation to cool and lubricate the cutting tool. Determining whether a cutting fluid should be used, and, if so, choosing the proper cutting fluid, is usually included within the scope of cutting condition [5].

A. Work Piece

Titanium and its alloys are widely used in aerospace industries due to attractive characteristics of the material, they offers a combination of high strength, light weight, formability and corrosion resistance which have made it a world standard in aerospace applications. However, these materials have been classified as difficult-to machine material because of their high temperature strength, low thermal conductivity, chemical reactivity and relatively low modulus of elasticity. Furthermore these materials can catch fire at temperature 6100 C and the only material can burn in pure nitrogen [5].

Ti 6Al-4V is known as the "workhorse" of the titanium industry because it is by far the most common Ti alloy, accounting for more than 50% of total titanium usage. It is an alpha+beta alloy that is heat treatable to achieve moderate increases in strength. So Ti-6Al-4V is used for performing these experiment [6].

Titanium alloys are generally classified into three main categories: Alpha alloys, which contain neutral alloying elements (such as Sn) and/or alpha stabilizers (such as Al, O) only and are not heat treatable; Alpha + beta alloys, which generally contain a combination of alpha and beta stabilizers and are heat treatable to various degrees; and Beta alloys, which are metastable and contain sufficient beta stabilizers (such as Mo, V) to completely retain the beta phase upon quenching, and can be solution treated and aged to achieve significant increases in strength. Ti 6Al-4V offers a combination of high strength, light weight, formability and corrosion resistance which have made it a world standard in aerospace applications.

Titanium and its alloys, including Ti 6Al-4V, are susceptible to hydrogen embrittlement. Gaseous or catholic hydrogen can diffuse into the metal, forming brittle hydrides. Thus, it is important to minimize hydrogen pickup during processing, particularly heat treating and acid pickling. Specifications for Ti 6Al-4V mill products typically specify a maximum hydrogen limit of about 150 ppm [4].

II. LITERATURE REVIEW

Antony J (2001), presents a step by step approach to the optimization of production process of retaining a metal ring in a plastic body by a hot forming method through the utilization of Taguchi methods of experimental design. Singh H. And Kumar P. (2006), optimized the multi machining characteristics simultaneously using Taguchi parameter approach and utility concept. They used a single performance index, utility value, as a combined response indicator of several responses. Gusri et al. (2008) applied Taguchi optimization methodology in turning Ti-6Al-4V Ell with coated and uncoated cemented carbide tools to optimize the selected cutting parameters with tool life and surface roughness as response. Lan T. S. (2009) uses the L9 orthogonal array of Taguchi method for optimizing the multi- objective machining in CNC with surface roughness, tool wear and material removal rate are selected as response. Gopalsamy B.M. et al. (2009), applied Taguchi method to find out the optimum machining parameters while hard machining of hard steel and uses L18 orthogonal array, S/N ratio and ANOVA to study the performance characteristics of machining parameters which are cutting speed, feed, depth of cut and width of cut while considering surface finish and tool life as response. [6]

Rajendra Kumar P. (2011), focuses on a Design of experiment approach to obtain optimal setting of process parameters that may yield optimal tool flank wear width and these optimal settings accomplished with Taguchi method.

Ficici F. et al. (2011), uses the Taguchi method to study the wear behavior of boronized AISI 1040 steel. They uses orthogonal array, S/N ratio and ANOVA to investigate the optimum setting parameters Conducting an effective Taguchi Parameter Design study requires review of literature regarding turning parameters and similar studies. Of course, the most readily controlled factors in a turning operation are feed rate, cutting speed, and depth of cut; each of which may have an effect on surface finish.

III. EXPERIMENTAL WORK

A. Preparation of work piece

The Titanium alloy from alpha-beta group Ti-6Al-4V is the most widely used. This material is selected for this experiment. The dimensions of the Ti-6Al-4V test piece are 100x100x160 mm. Each metal piece first cleaned for dust. The composition of titanium alloy Ti-6Al-4V is given in Table 3.1 below.

Table 3. 1 Composition (Weight %) of Work Piece

Serial No.	Content	Weight %
1.	O	0.020
2.	H	0.005
3.	N	0.01
4.	C	0.05
5.	Fe	0.09
6.	V	4.40
7.	Al	6.15
8.	Ti	Balance

Mechanical Properties of titanium alloy Ti-6Al-4V is given in Table 3.2 below

Table 3. 2 Mechanical Properties of Work Piece

Serial No.	Mechanical Property	value
1.	Tensile strength (M Pa)	993
2.	Yield Strength (M Pa)	830
3.	Elongation	14
4.	Modulus of Elasticity (G Pa)	114
5.	Hardness (HRC)	36

B. Milling Operation

A CNC 5-axis vertical milling machine is used for this operation. Fig 3.1 shows the CNC milling machine which is used for performing the required experimental work.

Figure 3. 1 CNC Milling machine

In this CNC machine selecting the best configuration for clamping and locating the work piece can be challenging when it comes to 5-axis setups because we have to consider tool interference and collision avoidance. When we create a tooling strategy for 5-axis and 5- sided machining, we need to consider three things clearance, reach, rigidity. Repeatability and balance of the tool must be maintained to achieve surface finish requirements.

IV. RESULT AND DISCUSSION

A. General

In this chapter we analyses the experimental result obtained in previous chapter 3. The different machining parameters will be optimizing according to Machinability (Tool life, cutting force, and surface roughness). And finally we compile the whole result to a single set of optimum machining parameters.

B. Optimum Machining parameters for Tool life

After finding all the observation in previous chapter, S/N ratio and Means are calculated and various graph for analysis is drawn by using Minitab 15 software. The S/N ratio for tool life is calculated on Minitab 15 Software using Taguchi Method. The steps used are as follows:

The Signal to noise ratio and mean obtained in Minitab 15.0 is shown in Table 4.1. Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The tool life was considered as the quality characteristic with the concept of "the larger-the-better".

The S/N ratio for the larger-the-better is:

$$\mathbf{S/N = -10*log(\Sigma(1/Y2)/n)} \qquad \textbf{Eqn: 4.1}$$

Where n is the number of measurements in a trial/row, in this case, n=1 and y is the measured value in a run/row. The S/N ratio values are calculated by taking into consideration Eqn. 4.1 with the help of software Minitab 15. The tool life values measured from the experiments and their corresponding S/N ratio values are listed in Table 4.1.

Table 4. 1 S/N Ratio for tool life

Serial No.	Coolant Flow Rate (mL/hr)	Cutting Speed (m/min)	Feed Rate (mm/tooth)	Depth of cut (mm)	Tool Life (min)	S/N Ratio
1	0	120	0.100	2.00	8.4	18.4856
2	0	135	0.125	2.25	1.5	3.52183
3	0	150	0.250	2.50	0.4	-7.95880
4	50	120	0.125	2.50	1.5	3.52183
5	50	135	0.250	2.00	2.2	6.84845
6	50	150	0.100	2.25	2.0	6.02060
7	100	120	0.250	2.25	2.5	7.95880
8	100	135	0.100	2.50	2.8	8.94316
9	100	150	0.125	2.00	2.2	6.84845

Analysis and Discussion for tool life

Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the greatest value.

Level	Coolant Flow rate (mL/hr)	Cutting Speed (m/min)	Feed Rate (mm/tooth)	Depth of cut (mm)
1	4.683	9.989	11.150	10.727
2	5.464	6.438	4.631	5.834
3	7.917	1.637	2.283	1.502
Delta	3.234	8.352	8.867	9.225
Rank	4	3	2	1

Figure 4. 7 Response Table by Minitab 15.0 for S/N ratio

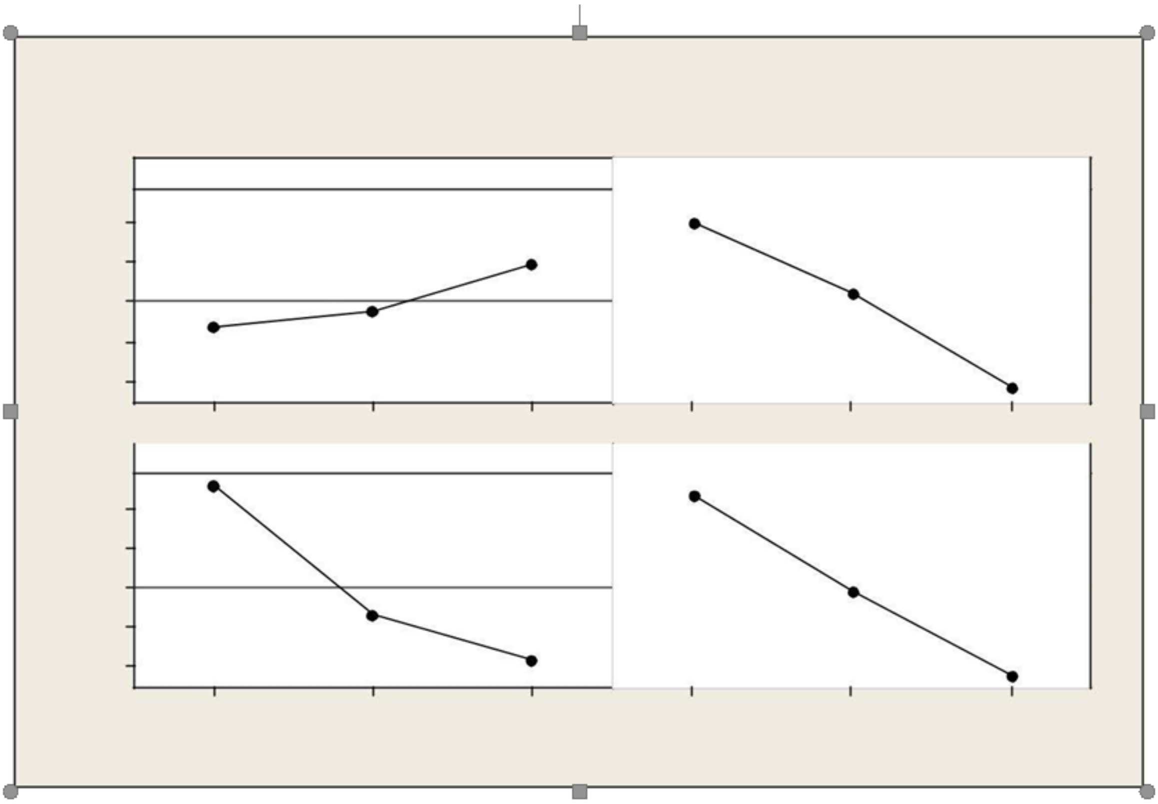

Figure 4. 8 Variation of Machining Parameters with S/N ratio for response as tool life(Larger is better)

It is clear from the fig 4.7 and fig 4.8 that the tool life is maximum affected by Depth of cut, if we increase the Depth of cut then the tool life decreases. Second factor which affect surface roughness is feed rate but this is not as much as effective as Depth of cut. When we increase the feed rate then the tool life will decrease as shown in fig. 4.7 and fig 4.8. Cutting speed and Depth of cut has less effect on tool life. As we increase cutting speed then the tool life decreases and in case of coolant flow rate as we increase coolant flow rate the tool life increases as shown in fig 4.7 and fig 4.8

Coolant Flow Rate

The effect of parameters coolant flow rate on the tool life values is shown in above fig 4.8 for S/N ratio. Its effect is increasing with increase in coolant flow rate. So the optimum coolant flow rate is level 3 i.e. 100mL/hr

Cutting speed

The effect of parameters cutting speed on the tool life values is shown in above fig 4.8 for S/N ratio. Its effect is decreasing with increase in cutting speed. So the optimum cutting speed is level 1 i.e. 120m/min

Feed Rate

The effect of parameters feed rate on the tool life values is shown in above fig 4.8 for S/N ratio. Its effect is decreasing with increase in feed rate. So the optimum feed rate is level 1 i.e. 0.1 mm/tooth

Depth of cut

The effect of parameters depth of cut on the tool life values is shown in above fig 4.8 for S/N ratio. Its effect is decreasing with increase in depth of cut. So the optimum value is level 1 i.e. 2.0 mm.

C. Optimum Machining parameters for Cutting force

After finding all the observation as given in Table 3.13 in previous chapter, S/N ratio and Means are calculated and various graph for analysis is drawn by using Minitab 15 software. The S/N ratio for cutting force is calculated on Minitab 15 Software using Taguchi Method. The steps is already explained above

The Signal to noise ratio and mean obtained in Minitab 15.0 is shown in Table 4.2. Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The cutting force was considered as the quality characteristic with the concept of "the smaller-the-better". The S/N ratio for the smaller- the-better is:

S/N = - 10*log 10[(y2)/ n]   Eqn: 4.2

Where n is the number of measurements in a trial/row, in this case, n=1 and y is the measured value in a run/row. The S/N ratio values are calculated by taking into consideration Eqn. 4.2 with the help of software Minitab 15. The cutting force values measured from the experiments and their corresponding S/N ratio values are listed in Table 4.2.

Table 4. 2 S/N Ratio for Cutting force

Serial No.	Coolant Flow Rate (mL/hr)	Cutting Speed (m/min)	Feed Rate (mm/tooth)	Depth of cut (mm)	Cutting force (N)	S/N Ratio
1	0	120	0.100	2.00	754	-57.5474
2	0	135	0.125	2.25	978	-59.8068
3	0	150	0.250	2.50	1196	-61.5546
4	50	120	0.125	2.50	1046	-60.3906
5	50	135	0.250	2.00	1021	-60.1805
6	50	150	0.100	2.25	826	-58.3396
7	100	120	0.250	2.25	1032	-60.2736
8	100	135	0.100	2.50	832	-58.4025
9	100	150	0.125	2.00	1180	-61.4376

Analysis and Discussion for cutting force

Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the greater value.

Response Table for Signal to Noise Ratios
Smaller is better

[illegible]	Coolant [illegible]	Cutting [illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3	-60.04	-60.44	-60.67	-60.12
Delta	0.40	1.04	2.57	0.64
Rank	4	2	1	3

Figure 4. 9 Response Table by Minitab 15.0 for S/N ratio

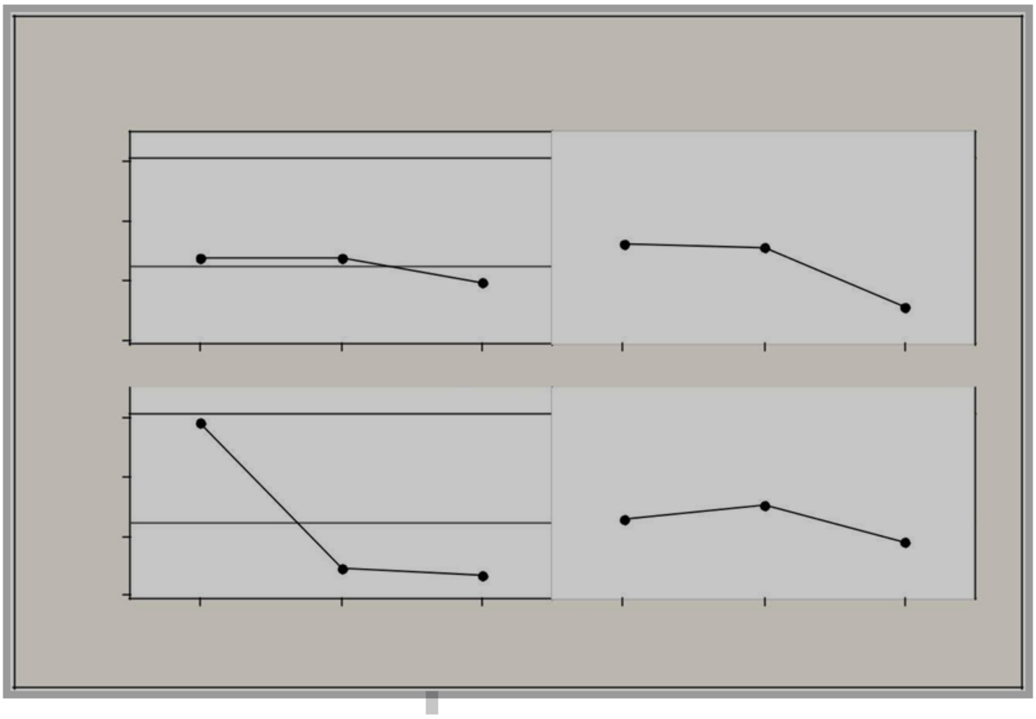

Figure 4. 10 Variation of Machining Parameters with S/N ratio for response as cutting force(Smaller is better)

It is clear from the fig 4.9 and fig 4.10 that the cutting force is maximum affected by feed rate, if we increase the feed rate then the cutting force is also increase. Second factor which affect cutting force is cutting speed but this is not as much as effective then feed rate. When we increase the cutting speed then the cutting force will also increase as shown in fig. 4.9 and fig 4.10. Depth of cut and Coolant flow rate has less effect on cutting force. As we increase Depth of cut then the cutting force first decrease then increase and in case of coolant flow rate as we increase coolant flow rate first the cutting force remains constant then it increase as shown in fig 4.9 and fig 4.10

Coolant Flow Rate

The effect of parameters coolant flow rate on the cutting force is shown above in fig 4.10 for S/N ratio. As we increase coolant flow rate first the cutting force remains constant then it increases and we prefer proper lubrication in the machining process. So the optimum coolant flow rate is level 2 i.e. 50mL/hr

Cutting speed

The effect of parameters cutting speed on the cutting force is shown above in fig 4.10 for S/N ratio. Its effect is increasing with increase in cutting speed. So the optimum cutting speed is level 1 i.e. 120m/min

Feed Rate

The effect of parameters feed rate on the cutting force is shown above in fig 4.10 for S/N ratio. Its effect is increasing with increase in feed rate. So the optimum feed rate is level 1

i.e. 0.1 mm/tooth

Depth of cut

The effect of parameters depth of cut on the cutting force is shown above in fig 4.10 for S/N ratio. Its effect is first decreasing then increasing with increase in depth of cut. So the optimum value is level 2 i.e. 2.25 mm.

D. Optimum Machining parameters for Surface roughness

After finding all the observation as given in Table 3.14 in previous chapter, S/N ratio and Means are calculated and various graph for analysis is drawn by using Minitab 15 software. The S/N ratio for Surface roughness is calculated on Minitab 15 Software using Taguchi Method. The steps are already explained above

The Signal to noise ratio and mean obtained in Minitab 15.0 is shown in Table 4.3. Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The surface roughness was considered as the quality characteristic with the concept of "the smaller-the-better".

The S/N ratio for the smaller- the-better is:

S/N S/N = - 10*log 10[(y2)/ n] **Eqn: 4.2**

Where n is the number of measurements in a trial/row, in this case, n=1 and y is the measured value in a run/row. The S/N ratio values are calculated by taking into consideration Eqn. 4.3 with the help of software Minitab 15. The tool life values measured from the experiments and their corresponding S/N ratio values are listed in Table 4.3.

Table 4. 3 S/N Ratio for Surface finish

Serial No.	Coolant Flow Rate (mL/hr)	Cutting Speed (m/min)	Feed Rate (mm/tooth)	Depth of cut (mm)	Surface roughness (micron)	S/N Ratio
1	0	120	0.100	2.00	0.32	9.897
2	0	135	0.125	2.25	0.48	6.375
3	0	150	0.250	2.50	0.56	5.036
4	50	120	0.125	2.50	0.68	3.350
5	50	135	0.250	2.00	0.58	4.731
6	50	150	0.100	2.25	0.45	6.935
7	100	120	0.250	2.25	0.52	5.679
8	100	135	0.100	2.50	0.38	8.404
9	100	150	0.125	2.00	0.43	7.330

Analysis and Discussion for surface roughness

Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the greater value.

Response Table for Signal to Noise Ratios
Smaller is better

Level	Coolant Flow rate (mL/hr)	Cutting Speed (m/min)	Feed Rate (mm/tooth)	Depth of cut (mm)
1	7.103	6.309	8.412	7.320
2	5.006	6.504	5.665	6.330
3	7.138	6.434	5.149	5.597
Delta	2.133	0.195	3.263	1.723
Rank	2	4	1	3

Figure 4. 11 Response Table by Minitab 15.0 for S/N ratio

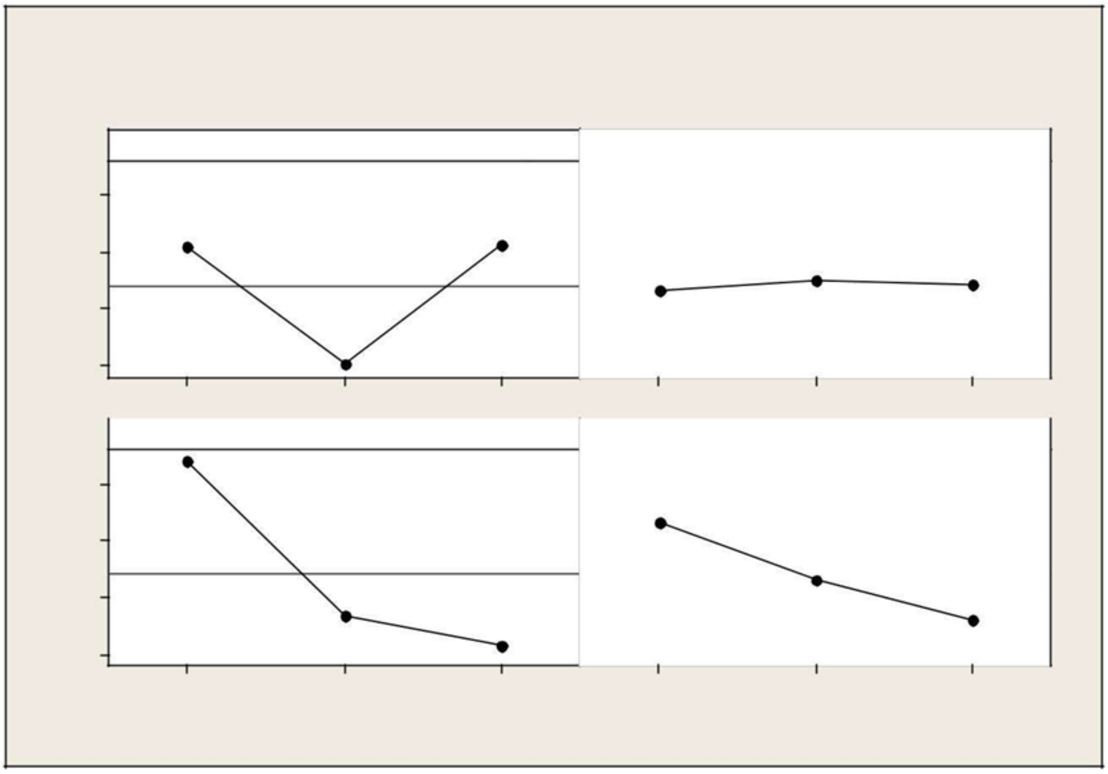

Figure 4. 12 Variation of Machining Parameters with S/N ratio for response as Surface finish (Smaller is better)

It is clear from the fig 4.11 and fig 4.12 that the surface roughness is maximum affected by feed rate, if we increase the feed rate then the surface roughness is also increase. Second factor which affect surface roughness is coolant flow rate but this is not as much as effective then feed rate. When we increase the coolant flow rate then the surface roughness will first increase then decrease as shown in fig. 4.11 and fig 4.12. Depth of cut and cutting speed has less effect on surface roughness. As we increase Depth of cut then the surface roughness increase and in case of cutting speed as we increase cutting speed first the surface roughness decreases then it increase as shown in fig 4.11 and fig 4.12

Coolant Flow Rate

The effect of parameters coolant flow rate on the cutting force is shown above in fig 4.12 for S/N ratio. As we increase coolant flow rate first the surface roughness increases and then it decreases and we prefer proper lubrication in the machining process. So the optimum coolant flow rate is level 3 i.e. 100mL/hr

Cutting speed

The effect of parameters cutting speed on the surface roughness is shown above in fig 4.12 for S/N ratio. Its effect is first decrease then increasing with increase in cutting speed. So the optimum cutting speed is level 2 i.e. 135 m/min.

Feed Rate

The effect of parameters feed rate on the cutting force is shown above in fig 4.12 for S/N ratio. Its effect is increasing with increase in feed rate. So the optimum feed rate is level 1

i.e. 0.1 mm/tooth

Depth of cut

The effect of parameters depth of cut on the cutting force is shown above in fig 4.12 for S/N ratio. Its effect is increasing with increase in depth of cut. So the optimum value is level 1

i.e. 2.00 mm.

V. CONCLUSION AND SCOPE FOR FUTURE

A. Conclusion

On the basis of different experiments the following conclusions are derived:

- Higher cutting speed results in shorter tool life. But at higher feed rate and depth of cut, effect of cutting speed is less significant. This is due to fracture failure and is more important than gradual wear when high feed rate and high depth of cut are applied.

- Longer tool life, when higher amount of coolant is applied, only occurs at cutting speed of 135 m/min. At the speed of 120 m/min, dry machining gives better tool life.

- Shorter tool life under Coolant flow rate 50 mL/H is observed due to the chemical wear. Evidence of chemical wear is shown by fast wear growth after the wear reach 0.2 mm. The wear increase drastically when the coating material had been eliminated.
- Under Coolant flow rate 100 mL/H, the effect of chemical wear is less because sufficient amount of coolant is available to give the cooling effect. Contrary, for cutting speed 150 m/min, Coolant flow rate 100 mL/H is less efficient as compared to Coolant flow rate 50 mL/H. This is due to the bigger size of mist particles that cannot penetrate in to the cutting zone. The penetration of this particle is hindered by the centrifugal force created by the rotating tool.
- The surface roughness depends more on the machine tool rigidity and the geometry of the cutting tool. Beside of that, cutting parameters such as feed rate gives significant effect on surface roughness. This experiment had proved that, higher feed rate results in higher value of surface roughness.
- Low value of surface roughness obtained during this experiment is due the geometry of the cutting tool used. Round shape insert can be considered as large nose radius. Higher the nose radius, lower the value of the surface roughness.
- The vibration or chatter occurred during the machining process can give significant impact on the surface finish. Selection of cutting parameters is very crucial in order to avoid chatter.
- The average value of cutting force obtained at the beginning of the machining for various cutting conditions. At this stage, the cutting tool still sharp. So we can conclude that, there is strong correlation between the cutting force and depth of cut. Moderate correlation exists between cutting force and feed rate.
- Higher the feed rate and the depth of cut result higher cutting force. More energy is required to remove higher volume at shorter time.
- No-linear correlation between cutting force and Coolant flow rate might exist when Coolant flow rate varied. Effect of cutting speed on cutting force seems to be not so significant. This is due to the small variation of cutting speed that was used in this experiment. Bigger variation of cutting speed should be used in order to study the effect of cutting speed on cutting force.
- The variation of cutting force obtained progressively during machining. Higher cutting force was obtained at the end of machining. At this stage, the flank wear reached 0.3 mm. When the tool tip became dull, more contact area between tool tip and work piece was created. This resulted in bigger friction, and thus increased the cutting force. At this stage, effect of Coolant flow rate seemed to be more significant. Dry condition exhibited in higher cutting force, while lower cutting force was obtained when Coolant flow rate was applied.
- At any cutting condition, the cutting speed is the dominant factor in controlling tool life.
- The application of Coolant flow rate is not always effective in term of tool life and surface roughness. Coolant flow rate is only effective at certain cutting speeds. In this experiment Coolant flow rate is most effective at cutting speed of 135 m/min to get better tool life.
- High value Coolant flow rate is less effective at high cutting speed due to the difficulty of the larger particle to penetrate into the cutting zone. Higher pressure is needed to ensure that the mist particle can penetrate into the cutting zone, when higher cutting speed is applied.
- Direct effect of cutting parameter on the surface roughness is not significant. Surface roughness is more dependent on the geometry of the cutting tool and the stability of the machine structure. However, effect of feed rate on surface roughness is more significant as compared to other cutting parameters.
- Although the effect of Coolant flow rate on tool life is not significant, Coolant flow rate seems to be more effective when worn out tool is applied. More contact area between tool and work piece will give better lubrication effect.

B. Scope for Future

- In this present work we select moderate cutting speed for milling machining on titanium alloy but machining with higher cutting speed is still uncertain. In future we use optimization of higher cutting speed.
- In this present work we select non halogen water immiscible cutting fluid in a very small amount. In future we use different cutting fluid in excess for better machinability.

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