Optimization of surface roughness in turning titanium alloy (grade2)

Awdhut Aswale
Student,Mechanical Engineering
Saraswati College of Engineering,
Navi Mumbai, India
awdhutprashant143@gmail.com

Arjun Chauhan
Student,Mechanical Engineering
Saraswati College of Engineering,
Navi Mumbai, India
arjunrchauhan82@gmail.com

Pawan Dukare
Student,Mechanical Engineering
Saraswati College of Engineering,
Navi Mumbai, India
pawan8879d@gmail.com

Saurabh Dubey
Student, Mechanical Engineering
Saraswati College of Engineering,
Navi Mumbai, India
dubeysaurabh0308@gmail.com

Abstract*— In an era of intensive competition, the new challenges faced by industrial manufacturing processes include maximizing productivity, ensuring high product quality, and reducing the production time while minimizing the production cost simultaneously .With the large need of modern engineering products,so the surface roughness control become more vital. These processes work on a particular principle in which we use of certain properties of materials which makes them most suitable for some applications and at the same time put some limitations on their use. In this processes include many process variables (which is known as process parameters) and most suitable parameters setting is too much critical for advanced machining processes which may effect in the performance of process. Due to involvement of large number of process parameters, random selection of these process parameters within the range will not serve the purpose. The situation becomes more severe in case if more number of objectives are involved in the process. Such kind of situations can handle conveniently by use of optimization techniques for the parameters optimization of these processes.

Keywords*—Titanium grade 2, Process Parameter (Speed, Depth of cut, Feed rate), Taguchi Method, S/N ratio.

I. Introduction

Titanium Grade 2 consists higher levels of oxygen and iron than other Commercial Pure grades, which offers extremely good formability and average strength with good corrosion resistance. Commercial Pure Grade 2 titanium is mostly used in heat exchangers. CP2 is the most common titanium grades with properties that makes it a best candidate for aerospace and chemical, marine and medical applications. Titanium alloy is difficult to cut material so machining of such components mainly requires tools which are harder than material being machined. These kind of materials are very costly and if surface roughness occurs then it will cause huge loss in production cost and quality. Hence Surface Roughness monitoring is necessary. Most of the researches have worked on difficult to cut material like Titaniunm-IMI-834, Stainless Steel304 etc. But Surface Roughness monitoring in turning of Titanium grade 2 is not reported till now. Hence in this work, orthogonal array is trained with 9 experimental data to predict the most optimized values of process parameters for the required Surface roughness. The architecture of the network consisted of feed, speed, depth of cut as input and surface roughness as the output. To minimize the power consumption and got the better surface roughness by using Optimization technique (Taguchi method).For Titanium grade 2, very few publication is reported in there Literature. Therefore, in this work, an model is developed to Monitor roughness in lathe machine Titanium grade 2 methodology is as shown in Fig.1.

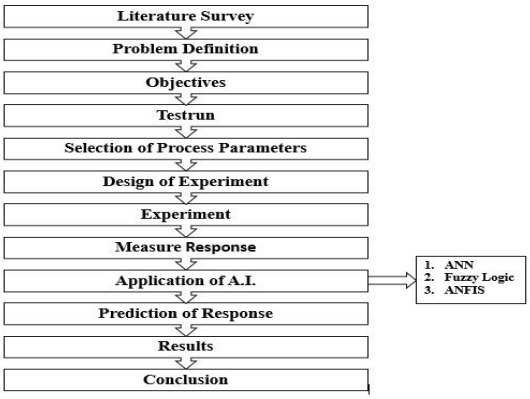

Fig 1. Overall methodology chart

II.SURFACE ROUGHNESS

Quality of roughness play a crucial role in field of manufacturing. Surface roughness is the irregularities produced while turning process on lathe machine.

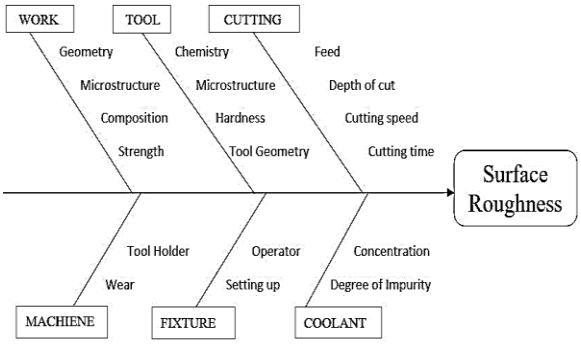

Fig.2. Surface Roughness Affecting Parameters

In fig.2. the parameters which affect the surface roughness are shown, certain change in these parameters can cause change in surface roughness.

III. TAGUCHI METHOD

Taguchi method is a process of evaluation and projection of advances in field of product development and equipment as well as facility sector. These advances enhance the required characteristics and the number of defects are reduced substantially by addressing the key variables which control the process, thus optimizing the procedure and getting best results. A large spectrum of engineering field is covered by this method which ranges from manufacturing materials, products for professional to consumer material. Apart from this, engineering fabrication, computer based design, banking sector are also targeted using this method. Taguchi method is important for 'tuning' a given process for 'best' output results. Taguchi impliments a standard 8-step process for applying his method for optimizing any process.

Step-1: Identify the Main Function, Side Effects, And Failure Mode

Step-2: Identify the Noise Factors, Testing Conditions, And Quality Characteristics

Step-3: Identify the Objective Function To Be Optimized

Step-4: Identify the Control Factors And Their Levels

Step-5: Select the Orthogonal Array Matrix Experiment

Step-6: Conduct the Matrix Experiment

Step-7: Analyze the Data, Predict The Optimum Levels And Performance

Step-8: Perform the Verification Experiment And Plan The Future Action.

IV. EXPERIMENT DETAILS AND MEASUREMENT

In this study, a work piece made of Titanium Grade 2 was used. Its sizes were ϕ 30 x 100 mm of 3 specimens was used for the experimental work.

Fig.3. Titanium Grade 2 (after turning process)

The experimentation was done on Light duty lathe machine. The wet cutting condition was used during experimentation. . The cutting tool material used was tungsten carbide tip tool. The cutting speeds were 220, 350 and 700 rpm. The feed rates used were 0.04, 0.08and 0.15 mm/rev. The depths of cut of 1, 1.5 and 2mm were used. The cutting parameters and their levels were summarized in Table 1. The device used for measuring surface roughness is Mitutoyo surface tester SJ-410 portable device which operates under sample length delta=30mm. Fig.4 shows the experimental arrangement.

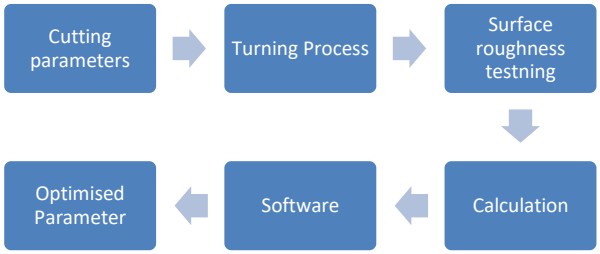

Fig.4. Experimental scheme.

TABLE .I. PARAMETERS & LEVELS.

Level	L1	L2	L3
Speed	220	350	700
Feed	0.04	0.08	0.15
DOC	1	1.5	2

V. TAGUCHI DESIGN OF EXPERIMENT

In order to obtain favourable value of the machining parameters we can use various methods such as trial and error approach, design of experiments, etc. but the result will not be most accurate. We can also use full factorial method for three parameters as taken in our case then the required count of sets of experiment will be 3^3 i.e., 27. This is a very large number of experimental sets for Such an expensive material like titanium grade 2 which makes the method less cost effective. Therefore we can use taguchi method of orthogonal array where we can select the area of our requirement from the set available are L4, L8, L9, L16, L27. For three level of design as in our case L9 and L27 are the arrays that can be used. Therefore we selected orthogonal array L9 for 9 sets of experimentation which will be both cost effective and time saving process.

TABLE .II. L9 ORTHOGONAL ARRAY AND MEASUREMENT

SPEED	DOC	FEED RATE	Ra
220	1	0.04	3.24
220	1.5	0.08	5.24
220	2	0.15	2.70
350	1	0.08	3.14
350	1.5	0.15	4.14
350	2	0.04	3.912
700	1	0.15	2.5
700	1.5	0.08	5.1
700	2	0.04	4.2

In this estimation of surface roughness value by using three parameters i.e depth of cut, speed & feed rate as shown in above table.The TABLE .2. shows a L9 orthogonal array. There are total 9 experiments which we conducted and each experiment is based on the combination of level values as shown in the table. For example, the 3rd experiment is conducted by keeping the design variable 1 at level 1, variable 2 at level 2 and variable 3 at level 3.

TABLE .III. S/N RATIO.

SPEED	DOC	FEED RATE	Ra	S/N ratio
220	1	0.04	3.24	-10.22
220	1.5	0.08	5.24	-14.38
220	2	0.15	2.70	-8.64
350	1	0.08	3.14	-9.94
350	1.5	0.15	4.14	-12.35
350	2	0.04	3.912	-11.84
700	1	0.15	2.5	-7.95
700	1.5	0.08	5.1	-14.15
2700	2	0.04	4.2	-12.46

TABLE .III. shows the calculation of S/N ratio for the roughness value obtained from different set of experimentations. S/N ratio is calculated for the smaller the better criteria with surface roughness as the performance parameter of the calculation. S/N ratio calculation using the equation.

$$\frac{S}{N}\text{=-10 log}(y_1^2+y_2^2+\ldots\ldots) \qquad \text{-eq(1)}$$

From obtaining calculated values of S/N ratio optimal values of variables are obtained from average table.

TABLE .IV. AVERAGE TABLE.

Parameter	Level 1	Level 2	Level 3
Speed (A)	-11.08	-11.3766	-11.52
Feed(B)	-11.50	-12.82	-9.64
DOC (C)	-9.37	-13.62	-10.98

TABLE.IV shows the calculation of average values of S/N ratio divided into three levels where all the three variables are categorised in these three levels. For the 9 sets of experiment Shown above the three levels are designed with three process parameters in each level. Therefore the average taken is shown below

$$\text{Avg=}\frac{P1+P2+P3}{3} \qquad \text{-eq(2)}$$

VI. MAIN EFFECT PLOT

In the plot, the z-axis represent the value of each process parameter on three level & y-axis represent the response value in the main effect plot .The optimal design condition is calculated by using main effect plot to get the low tool wear.

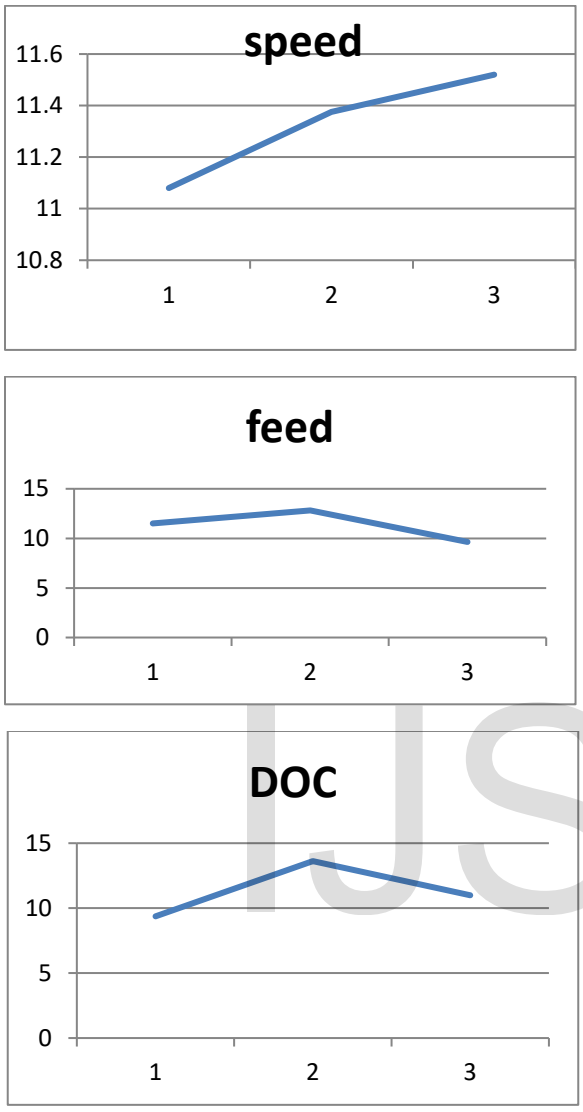

Fig.5. Main effect plot

VII. CONCLUSION

This experimental outcome demonstrate that the taguchi method selected the optimal parameters as Speed (220), depth of cut (2), feed rate(0.15). The surface roughness obtained by this combination is(2.70) which is the best surface finish and when we increase SPEED and DOC while turning on lathe machine then we get poor surface roughness. Also, the main effect plot showed the variation of roughness with the change in the level of parameters. The conducted experiment was on L9 orthogonal array and measurement. Roughness tester (MITUTYA) device is used to calculated minimum and maximum value of surface.The optimization is done by TAGUCHI method. Experimental results outcome demonstrate that the taguchi parameter design is an dominant way of calculate the optimal cutting parameter to obtain the best surface roughness. By this experimentations we get the better surface roughness in low speed on lathe machine.

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