# MULTI-OBJECTIVE OPTIMIZATION IN MACHINING (TURNING) OF COPPER

Thesis submitted in partial fulfilment of the requirements for the Degree of

**Bachelor of Technology (B. Tech.)**

In

**Mechanical Engineering**

By

**SIDDHARTH DAS**

**Roll No. 111ME0290**

Under the Guidance of

**Prof. SAURAV DATTA**

**NATIONAL INSTITUTE OF TECHNOLOGY(NIT)**
**ROURKELA 769008, INDIA**

## NATIONAL INSTITUTE OF TECHNOLOGY
## ROURKELA 769008, INDIA

Certificate of Approval

This is to certify that the thesis entitled **MULTI-OBJECTIVE OPTIMIZATION IN MACHINING (TURNING) OF COPPER** submitted by ***Sri Siddharth Das*** has been carried out under my supervision in partial fulfilment of the requirements for the Degree of ***Bachelor of Technology*** in ***Mechanical Engineering*** at National Institute of Technology, Rourkela, and this work has not been submitted elsewhere before for any other academic degree/diploma.

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**Dr. Saurav Datta**
Assistant Professor
Department of Mechanical Engineering
National Institute of Technology, Rourkela-769008

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**SIDDHARTH DAS**

# Abstract

A multi-objective optimization problem has been showcased in this work, which involves the use of both the TOPSIS and Utility in the case study in machining of copper. The machining process turning is being studied with the aim of identifying the best possible environmental parameters, so that the present day need of quality and productivity can be satisfied simultaneously. The conventional Taguchi method has the drawback of failing to solve multi-objective optimization cases. Hence we use TOPSIS and Utility model to get rid of this constraint. These two, when coupled with concept of Taguchi creates a single response optimization environment from a multi-response optimization case. The closeness and Utility Index are the governing single objective function that assist the optimization process. This merger of Taguchi concept with TOPSIS/Utility process gives the best]/optimal setting. The data from closeness coefficient and utility index are in turn used to find the S/N ratio based on Taguchi concept. The process environment corresponding to maximum value of S/N ratio of closeness coefficient and utility index is considered as the optimum solution.

The verification has been made by other conformity test. The above study gives us an insight for feasible application of the above methodology as multi-response optimization of copper machining process and its off-line control are being studied to improve the productivity as well as the quality.

# Contents

# CHAPTER-1: Preliminaries

## 1.1 Turning

Cylindrical surfaces are being generated by the process of turning .Normally, the rotary motion is given to the work piece is on the spindle and the feed of tool is radially, axially or combined simultaneously to create desired surface. The term turning, in layman's language highlights surface generation of any cylindrical surface with tool of single point type. To be precise, it is generally applied for surface generation of any cylindrical surfaces directed parallel in axis of work piece. In this, the feed motion is directed specifically axial with respect to the spindle of the machine. Once the machining begins, the work piece and the tool piece are generally in contact as long as the surface generation is complete. Meanwhile, the constancy of cut dimensions and cutting speed and cut dimensions is maintained during the generation of cylindrical surface in turning.

The most basic of any machining operation is turning .The rotating part is being machined by a single point cutting tool by its parallel movement with respect to the axis of rotation. Normally, the external surface of the part is turned similarly as internally (boring). The elementary material is normally a work piece that is being created by other processes like extrusion, casting, forging or drawing. Manually, turning is done in a conventional form of lathe, which regularly needs continuous operator guidance, or by assigning an automated lathe and Computer-controlled and which is independent of much supervision. This type of machine tools are known as computer numerical control, commonly known as CNC and are normally several different format of machine tools are used, keeping the lathe apart. The various varieties of turning method are profiling, taper turning, straight turning or external grooving. Various shapes are being generated during the turning process like curved, straight, or grooved work pieces. Normally, simple single-point cutting tools are being used in turning. The optimum set of desired tool angle has been set for each group of work piece that have been studied along the years. In this operation, parameters like materials and cutting tool geometry and , number of passes, the feed rate ,depth of cut, , Spindle speed and the application of cutting fluids will affect the tool costs, MRR, production costs, cutting forces, and the machining qualities like the dimensional accuracies and surface roughness, of the product.

The parameters (Process parameters) that we have studied in this optimization process are:-

*Feed*: Feed rate is the velocity at which the feeding is done to the cutter, that is, towards the work piece. It is expressed in mm/revolution.

*Cutting Speed:* Cutting speed (also called spindle speed) is defined as the rate of movement of material past the cutting edge of tool, independent of the machining operation used. It is expressed in m/min.

$$Vc = \frac{\pi DN}{1000} \ m/min$$

$$2D = D1 + D2 \text{ mm}$$

N is in rpm.

*Depth of Cut:* Initial Engagement distance between tool and job. It is expressed in mm. Depth of Cut can classify the machining into:-

- Roughing (0.6-2 mm)
- Semi-finishing (0.2-0.6 mm)
- Finishing (<0.2 mm)

## 1.2 Surface Roughness

Surface roughness is used to measure and study the surface texture. It is calculated by the vertical deviation from its ideal surface form. For large deviations, the surface is rough; else, the smooth surface is observed. Roughness is generally characterized by the short wavelength, high frequency, component of a surface studied. It is affected mostly by feed motion.

With the assumption of no curvature of the tool i.e. it has a single sharp point, the following formula is being found-

$$h_m = f / (\cot \Phi + \cot \Phi_1)$$

$$\Rightarrow h_m = F(f, \Phi, \Phi_1)$$

## 1.3 Literature Review

| Name of source | Name of Author | Journal of issue | Year of issue | Deliverables | Area of interest |
|---|---|---|---|---|---|
| Parametric analysis and optimization of turning operation by using Taguchi approach | Sahoo | International Journal of Modern Engineering Research, Vol.3 (4), 2154-2156 | 2013 | Speed, Feed and Depth of cut were studied intensively such that at each experiment, two values were set constant and one was varied | The machining process was optimized by the use of Taguchi method and the effect of these three parameters were also studied |
| Application of surface roughness when turning polyamide using ANN-IHSA approach | Madic et al. | International Journal of Engineering and Technology, Vol.1 (4), 432-443. | 2012 | A surface model for roughness was studied with parameters cutting speed, feed rate depth of cut, and nose radius The IHSA was applied to the developed ANN surface and the surface roughness was studied | (ANN) was coupled harmony was made better to use algorithm (IHSA). The optimum parameters were determined considering the range and limit of the experiment |
| Optimization of process parameters using Taguchi approach with minimum quantity lubrication for turning | Chaudhari et al. | International Journal of Engineering Research, Vol.1 (4), 1268-1273. | 2011 | The experiment provided that to achieve higher MRR and low surface roughness a synergetic combination of lower level of feed rate and upper/ higher level of depth of cut as well as cutting speed is required. | Taguchi Technique was used for optimization of the process parameters by single response optimization method. |
| Enhancement of surface finish for CNC turning cutting parameters by using Taguchi method | Tanaji. Jadhav | Indian Journal Of Research, Vol.3 (5), 88-91 | 2013 | CNC turning was used for machining experiments in which the material of work piece was varied and tool insert types for the given parameters. The optimization was done using the Taguchi method in which one set of value was kept constant and other repeated. | Taguchi method was applied to optimize the process of turning using variable work piece materials and variation of cutting tool inserts. |
| Application of Taguchi method in optimization of tool flank wear width in turning operation of AISI 1045 Steel | Mishra, Gangele | Industrial Engineering Letters, Vol. 11-18. | 2012 | S/N ratios and ANOVA were used to study the machining performance like N, f, d as turning to check response of tool flank wear. These parameters have considerable effect on the tool flank wear width of Tungsten Carbide tool while AISI 1045 steel machining and shows that cutting speed is the most affecting parameter. | The tool flank wear width of AISI 1045 Steel was studied and optimized using Taguchi techniques. |
| Parametric analysis of | Sodhi , Singh | International Journal of | 2013 | The optimum combination of controlled parameter was | Control parameters being consider in this |

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|---|---|---|---|---|---|
| copper for cutting processes using turning operations based on Taguchi method | | Research In Mechanical Engineering & Technology, Vol. 3(2), 2 204. | | studied on the turned sample work piece using the appropriate orthogonal array. | paper are cutting speed, feed rate and depth of cut are the controlled parameters studied and Taguchi design was used to optimize surface roughness in traditional lathe. |
| Effect of machining conditions on MRR and surface roughness during CNC Turning of different materials Using TiN coated cutting tools – A Taguchi approach | Dave et al. | International Journal of Industrial Engineering Computations, Vol.-3, 925–930 | 2012 | Taguchi method was employed to find out the optimum performance characteristics. The S/N noise ratio and variance analysis were performed for performance characteristics study in turning in dry state operation. The depth of cut is dominant and has maximum effect on MRR and insert affect surface roughness | Study of the machining characteristics of EN materials and its grades in CNC turning process of tools of TiN coating cutting tools. The analysis is focussed on maximum MRR and minimum surface roughness and employs the Taguchi method. |
| Optimization by Taguchi method and in-process monitoring of cutting parameters using acoustic emission for EN8 | Dhale , Khan | International Journal of Application or Innovation in Engineering & Management, Vol.2 (11), 465-471 | 2013 | Three parameters cutting with water as coolant , dry cut and simple coolant were observed. EN8 is the material used in study. optimal value of Ra i.e. surface roughness in turning was optimized using Taguchi. Various models of Regression were validated and developed for signal values of AE | AE is being proposed as non-contact as well as indirect technique simultaneous surface roughness measurement during machining |

# CHAPTER-2: The TOPSIS-based Taguchi Approach

## 2.1 Taguchi Method

All possible combination are created for a full factorial design for a given factor set The number of factors are involved are usually significant in majority of the industrial experiment, a full factorial design meets the need for a large number of experiments and more. The reduction in number of experiments was done in a practical level. Taguchi constructed a set of general design guidelines for factorial experiments that deals with many processes. Orthogonal arrays, a special set of arrays, were being used. The way of conducting the least number of experiments was found out which is able to provide information of every factors that affects the performance parameter in a complete way.

Along with these, many standard orthogonal arrays are also possible, number of independent design variables were specified and assignment of array was done to each individual array. An assumption is being taken of interaction independence between any two factors. While in majority of cases, a clear evidence of interaction is there, there are some in which interaction model assumption is invalid.

Design of Experiment efficiency using the Orthogonal Array is higher as compared to varieties of other statistical designs, the least number of experiments to conduct the Taguchi method is being calculated depending on the degrees of Freedom (DOF) approach.

$$N_{Taguchi} = 1 + \sum(L_i - 1)$$

The Design of Experiment involves the following steps:

1) Independent variables selection
2) Number of possible level settings selection for each independent variable.
3) Choosing Orthogonal Array.
4) Independent variable positioning to each column.

5) The experiments conduct.

6) Data analysis.

7) Conclusion.

The concepts behind the Taguchi methodology are:

1. Quality Loss Functions (or Quadratic Loss Function) quantifies the loss incurred due to deviation by user from target performance.
2. Signal-to-Noise (S/N) Ratios for predicts the field quality through various experiments.
3. Orthogonal Arrays (OA) gathers dependable information related to control factors so that number of experiments are reduced.

The different S/N ratio characteristics have been given below:

1. Nominal-the-Best (NB) or Target-is-Best (TB)

2. Lower-is-Better (LB)

3. Higher-is-Better (HB)

**Nominal-the-Best (NB) or Target-is-Best (TB)**

In this approach, the closer to the target value, the better. It does not matter whether thedeviation is above or below the target value (example: diameter of a shaft). Under thisapproach the deviation is quadratic.

$$\eta_j^i = -10\log_{10}\left[\frac{1}{l}\sum_{k=1}^{l}\frac{\overline{y}_j^{i\,2}}{S_j^{i\,2}}\right]$$

The following graph portrays Nominal-the-Best (NB) characteristics.

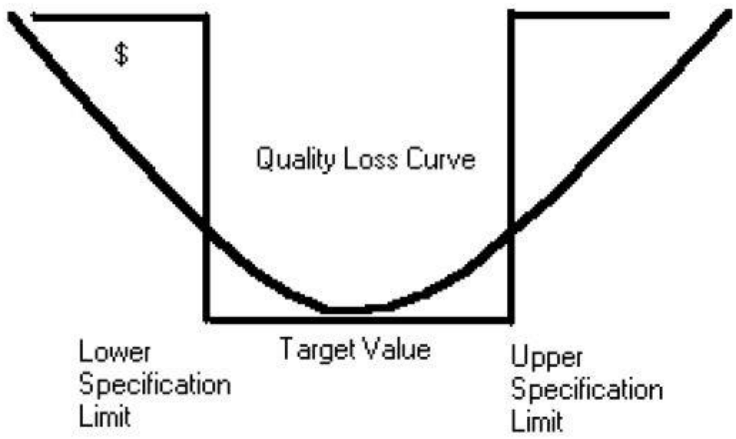



Fig. 2.1: Nominal-the-Best (NB)/ Target-is-Best (TB)

**Lower-is-Better (LB)**

Lower-is-Better criteria for S/N ratio always predict values pessimistically. It includes quality characteristic which has the undesired output such as defects in product like surface roughness, pin holes or unwanted by-product. The formula for these characteristics is:

$$\eta_j^i = -10\log_{10}\left[\frac{1}{l}\sum_{k=1}^{l} y_{jk}^{i\ 2}\right]$$

The following graph (Fig. 2.2) portrays Lower-is-Better (LB) characteristics.

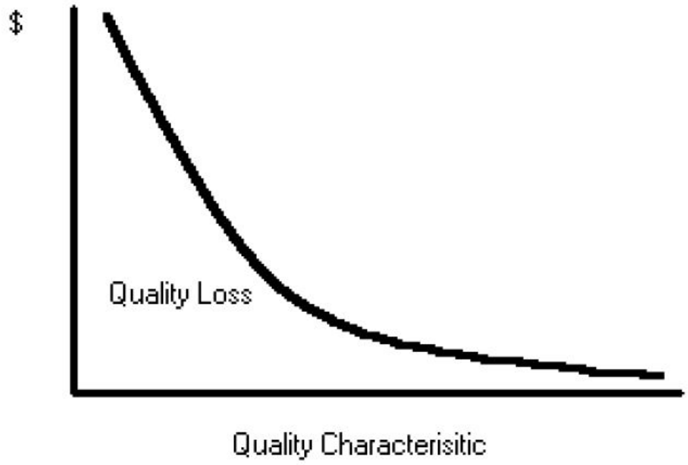
Fig. 2.2: Lower-is-Better (LB)

**Higher-is-Better (HB)**

Larger the better characteristic includes the desired output such as bond strength, material removal rate, employee participation and the customer acceptance rate. The formula for thesecharacteristics is:

$$\eta_j^i = -10\log_{10}\left[\frac{1}{l}\sum_{k=1}^{l}\frac{1}{{y_{jk}^i}^2}\right]$$

The following graph (Fig. 2.3) portrays Higher-is-Better (HB)




characteristics

Fig. 2.3**:** Higher-is-Better (HB)

## 2.2 TOPSIS

The TOPSIS is a tool for multi-criteria decision analysis and formulation, working on the concept which says that the geometric distance from the positive ideal solution should be the shortest and the geometric distance from the point of the negative ideal solution should be longest for a given chosen alternative. This is a method of aggregation which is used to compare a set of alternatives by identifications of weights for each criterion and calculation of the each alternative and the ideal alternative, the best score in the criterion is given by this geometric distance. The criterion has variations in type, unit and range; making it hard to accumulate them. So, normalization is a must require part in solving a multi-criteria problems. TOPSIS allow inter criteria trade-offs, where a non-optimum result in one criterion may be assumed void by a better or optimum result from another criterion, Hence a more realistic form of modelling is achieved.

<u>Assumptions</u>- 1) Each criterion should be stable either by linearly decreasing or increasing.

2) Independency of criteria.

*2.2.1 TOPSIS Algorithm*

1) Decision Making matrix is formed:

$$X=(x_{ij})_{n*m}=\begin{bmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{bmatrix}$$

Criteria are denoted by columns and alternatives by rows.

2) Normalization of Decision Making matrix or Normalization:

$$R=(r_{ij})_{n*m}=\begin{bmatrix} r_{11} & \cdots & r_{1m} \\ \vdots & \ddots & \vdots \\ r_{n1} & \cdots & r_{nm} \end{bmatrix}$$

where $r_{ij}= x_{ij}/(\sum x_{ij}^2)^{1/2}$

3) Weighted Normalized Decision Matrix Calculation:

Using weight vector, $W=[w_1, w_2, \ldots\ldots w_n]$, $\sum w_j=1$, where $w_i=$ criteria of criteria(weight) $c_i$

$$V= (v_{ij})_{n*m} = \begin{bmatrix} v_{11} & \cdots & v_{1m} \\ \vdots & \ddots & \vdots \\ v_{n1} & \cdots & v_{nm} \end{bmatrix}$$

Where ,$V_{ij}=(r_{ij}*w_j)$

4) Ideal solution and anti-ideal Solution determination:

$A^*$= Ideal Alternative=$[v_1^* \ldots\ldots v_n^*]$

A =Anti ideal alternative=$[v_1 \ldots\ldots vn]$

where, $v_i^*=\{\max v_{ij} |_{j \in \Omega b}, \min v_{ij} |_{j \in \Omega c}\}$

$v_i=\{ \min v_{ij} |_{j \in \Omega b}, \max v_{ij} |_{j \in \Omega c}\}$

Here, $\Omega_b$ refers for 'Higher is better' criteria

$\Omega_c$ refers for 'Lower is better' criteria

5) Relative closeness determination of each alternative with respect to ideal solution:

$D_i^*$=distance between $A^k$and $A_i$ = $(\sum(v_{ij}-v_j^*)^2)^{1/2}$, i=1,2,…..n

$D_i^-$ =distance between $A^-$ and $A_i$ =$(\sum(v_{ij}-v_j)^2)^{1/2}$, i=1,2….n

Closeness coefficient $C_{ci}=D_i^-/(D_i^*+D_i^-)$, which uses a 'higher is better' criteria

6) Final decision making matrix thus converts to

$$X^* = [\ C_{c1} \quad C_{c2} \quad \ldots\ldots \quad C_{cn}]^T$$

## 2.3 Experimental Works

In this experiment, Taguchi method is being applied for optimization of single characteristics and is being used to establish relationship between the independent variables, hence the experimentation was done as per Taguchi design of experiments.

### *2.3.1 Work material and cutting tool*

A readily available single point HSS (High Speed Steel) tool was used as cutting tool material and was used to machine a cylindrical copper bar of diameter 20 mm.

*2.3.2 Design of experiments*

Taguchi method was used to design experiments, which uses an Optimization Algorithm to utilize the complete parametric space with a finite number of experiments. In this study three process parameters (factors) are chosen, Spindle Speed, Feed Rate and Depth of Cut. Three different levels were set for each of them. (See table 2.1)

Table 2.1: Level values of input parameters

| S.No | Parameter | Unit | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|---|
| 1 | Spindle Speed | rpm | 465 | 605 | 787 |
| 2 | Feed Rate | mm/rev | 0.06 | 0.07 | 0.08 |
| 3 | Depth of Cut | mm | 0.6 | 0.9 | 1.2 |

A particular Optimization Algorithm (OA) is selected depending on the number of levels of all factors. Here, 3 levels are there with three parameters each, therefore Degree of Freedom (DOF) required can be calculated as, Eq.1 [17]

$$(DOF)_R = P\,(L - 1) \qquad (1)$$

Where , P = number of factors, L = number of levels

Here, $(DOF)_R = 3\,(3 - 1) = 6$

Total DOF of OA must be greater than or equal to the DOF required for the experiment. Here 9 > 6, hence, $L_9$ $(3^2)$ OA is selected (See Table 3.2). Each machining parameter is assigned to a column of OA and 9 possible machining parameter combinations are, thus, designed. The performance parameter being studied in the present experimentation is Surface Roughness. The “smaller-the-better” quality characteristic is being used for the calculation purpose of the signal to noise (S/N) ratio of the performance parameter.

Table 2.2: $L_9$ Design Matrix

| Expt. No. | N(rpm) | f (mm/rev) | d(mm) |
|---|---|---|---|
| 1 | 465 | 0.06 | 0.6 |
| 2 | 465 | 0.07 | 0.9 |
| 3 | 465 | 0.08 | 1.2 |
| 4 | 605 | 0.06 | 0.9 |
| 5 | 605 | 0.07 | 1.2 |
| 6 | 605 | 0.08 | 0.6 |
| 7 | 787 | 0.06 | 1.2 |
| 8 | 787 | 0.07 | 0.6 |
| 9 | 787 | 0.08 | 0.9 |

### *2.3.3 Experimental planning*

A lathe machine was used to conduct the experiments as per $L_9$ DOA combinations & each time it was iterated for three times for getting a precise database i.e. 9x3 = 27 total experiments were being conducted. MITUTOYO made Profilometer (Model: SJ-210) was used to measure surface roughness and the Non-Contact Infrared Thermometer of AR882 make was used to measure tool tip temperature, with a temperature range of -18$^0$C to 200$^0$C.

## 2.4 .Experimental Results and Discussion

In order to observe the effect of process parameters on the Surface Roughness and Tool tip temperature, experiments were being conducted using $L_9$ DOA. The experimental data and S/N ratios is given in Table 2.3

Table 2.3: Experimental Data

| **Expt. No.** | **Surface Roughness (μm)** | | | | **Tool Tip Temp. (°C)** |
|---|---|---|---|---|---|
| | **Trial 1** | **Trail 2** | **Trail 3** | **Average** | |
| 1 | 33.549 | 27.148 | 32.264 | 30.987 | 31.2 |
| 2 | 19.236 | 21.481 | 14.409 | 18.375 | 31.5 |
| 3 | 18.051 | 27.292 | 19.391 | 21.570 | 32.2 |
| 4 | 17.111 | 19.318 | 18.492 | 18.366 | 30.8 |
| 5 | 12.503 | 16.577 | 13.997 | 14.590 | 31.9 |
| 6 | 17.942 | 16.192 | 13.490 | 15.870 | 32 |
| 7 | 14.869 | 16.546 | 18.326 | 16.581 | 34 |
| 8 | 19.358 | 22.796 | 22.255 | 21.469 | 34.1 |
| 9 | 24.737 | 26.411 | 27.595 | 26.247 | 31 |

From the above tabulation, it is clear that Spindle Speed, Feed Rate and Depth of Cut have considerable effect on both the surface roughness value and Tool Tip Temperature value. The significance of the process variables is studied towards Surface Roughness and Tool Tip Temperature. A Taguchi Design of Experiment was created using MINITAB 16 and corresponding values of S/N Ratios were being calculated for the combination of Surface Roughness and Tool Tip Temperature, by the values of the closeness coefficient. The S/N Ratios are given below in Table 2.4.

Table 2.4: S/N ratios of observed results

| Expt. No. | Closeness Co-efficient | S/N Ratio |
|---|---|---|
| 1 | 0.245 | -12.185 |
| 2 | 0.682 | -3.314 |
| 3 | 0.576 | -4.791 |
| 4 | 0.702 | -.3.071 |
| 5 | 0.840 | -1.514 |
| 6 | 0.750 | -2.406 |
| 7 | 0.676 | -3.398 |
| 8 | 0.545 | -5.265 |
| 9 | 0.490 | -6.720 |

The MINITAB 16 gives the output of Main effects plot for S/N Ratios which is plotted below in Figure 2.4

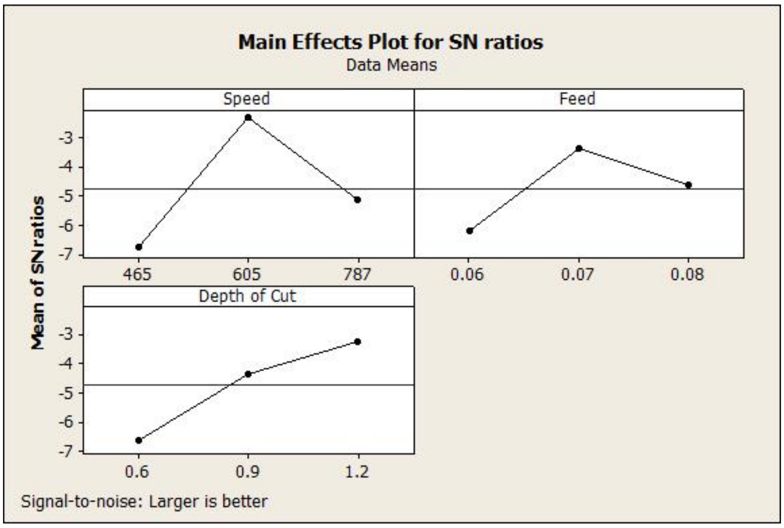



Fig. 2.4: Main Effects Plot for S/N Ratios

The software works on the principle of 'Smaller-is-Better' criteria for evaluating performance parameters (therefore S/N Ratio will evaluate with the principle of ‘Larger-is-Better' criteria. As shown in Figure 3.1 that **the second level of Speed (A2), second level of Feed (B2) and the third level of Depth of Cut (C3)** provides the optimum value of Surface Roughness and Tool Tip Temperature by evaluating the performance parameters. The S/N data analysis and validates the same levels of the variables **(A2, B2 and C3)** as the optimum levels.

# CHAPTER-3: The Utility-based Taguchi Approach

## 3.1 Introduction

The key attribute that a customer requires for choosing a product or services is undoubtedly quality. The modern quality improvement and control program focuses so that the product is being made as per the customer requirement. Looking into the other hand, a product performance is solely based on number of diversified quality characteristics of the product, as per the customer's point of view.

The utility theory works on the assumption that as a decision is being taken on the basis of maximizing the utility principle, the best choice is the one which meets the decision maker's satisfaction to the maximum extent.

## 3.2 Algorithm for Utility Approach

The measure of effectiveness of an attribute or characteristic is given by $X_i$, where for 'i' and 'n' attributes evaluating are there in the space, the combined utility functions is then suitably expressed as:

$$U(X_1,X_2,\ldots,X_n) = f(U_1(X_1), U_2(X_2),\ldots\ldots, U_n(X_n))$$

Utility function as overall is the summation of individual utilities assuming that the attributes have independency the same can be given as follows:

$$U(X_1,X_2,\ldots X_n) = \sum_{i=1}^{n}(U_i(X_i))$$

After assignment of weights to overall utility functions to the attributes can be expressed as :

$$U(X_1,X_2,\ldots X_n) = \sum_{i=1}^{n}(w_i U_i(X_i))$$

The Preference number is described on a logarithmic scale (base 10) as follows:

$$P_i = A^* \log ( X_i / X_{ideal-} )$$

Here, $X_i$ is defined as value of quality characteristic or attribute of 'i'

The worst value of quality characteristics is defined as $X_{ideal-}$ or Anti-Ideal solution

Here A is a constant whose value is calculated from the condition $X_1 = X_{ideal}$ in the above equation (where $X_{ideal}$ is defined as the best value of quality characteristic part from 'i' to 'n' , also called as the Ideal Solution)

Therefore, $$A = 9 / (\log( X_{ideal} / X_{ideal-} ))$$

The Utility function can thus overally be expressed as:

$$U = \sum_{i=1}^{n} (w_i P_i)$$

With the condition

$$\sum_{i=1}^{n} (w_i) = 1$$

The determined Overall Utility index, sees the problem as a case of single objective function rather than multi-objective one for optimization. Various quality characteristic types like Nominal-the-best (NB), Lower-is-Better (LB), Higher-is-Better (HB), defined by Taguchi, guides the Utility function that works on the principle of Higher-is-Better (HB). Therefore, the maximum value of quality function is the quality characteristic that is considered automatically for optimization.

### 3.3 Experimental Works

In this experimentation, a Utility-based-Taguchi method is being used for single characteristics optimization and has been used to establish relationship among the independent variables, hence the experiment was carried out as per Taguchi design of experiments.

*3.3.1 Work material and cutting tool*

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| 9 | 787 | 0.08 | 0.9 |

### *3.3.3 Experimental planning*

A lathe machine was used to conduct the experiments as per $L_9$ DOA combinations & each time it was iterated for three times for getting a precise database i.e. 9x3 = 27 total experiments were being conducted. MITUTOYO made Profilometer (Model: SJ-210) was used to measure surface roughness and the Non-Contact Infrared Thermometer of AR882 make was used to measure tool tip temperature, with a temperature range of $-18^0$C to $200^0$C

## 3.3. Experimental Results and Discussion

In order to observe the effect of process parameters on the Surface Roughness and Tool tip temperature, experiments were being conducted using $L_9$ DOA. The experimental data and S/N ratios is given in Table 3.3**.**

Table 3.3: Experimental Data

| Expt. No. | Surface Roughness (μm) | | | | Tool Tip Temp. (°C) |
|---|---|---|---|---|---|
| | Trial 1 | Trail 2 | Trail 3 | Average | |
| 1 | 33.549 | 27.148 | 32.264 | 30.987 | 31.2 |
| 2 | 19.236 | 21.481 | 14.409 | 18.375 | 31.5 |
| 3 | 18.051 | 27.292 | 19.391 | 21.570 | 32.2 |
| 4 | 17.111 | 19.318 | 18.492 | 18.366 | 30.8 |
| 5 | 12.503 | 16.577 | 13.997 | 14.590 | 31.9 |
| 6 | 17.942 | 16.192 | 13.490 | 15.870 | 32 |
| 7 | 14.869 | 16.546 | 18.326 | 16.581 | 34 |
| 8 | 19.358 | 22.796 | 22.255 | 21.469 | 34.1 |
| 9 | 24.737 | 26.411 | 27.595 | 26.247 | 31 |

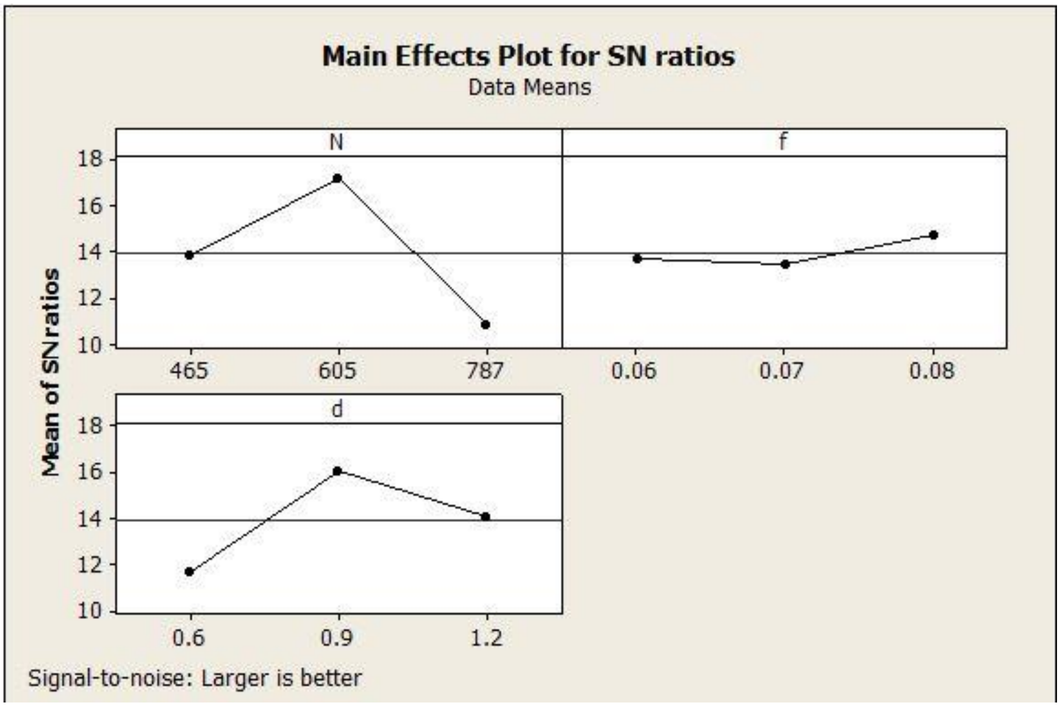
From the above tabulation, it is clear that Spindle Speed, Feed Rate and Depth of Cut have considerable effect on both the surface roughness value and Tool Tip Temperature value. The significance of the process variables is studied towards Surface Roughness and Tool Tip Temperature. A Taguchi Design of Experiment was created using MINITAB 16 and corresponding values of S/N Ratios were being calculated for the combination of Surface Roughness and Tool Tip Temperature, by the values of the Utility Index. The S/N Ratios are given below in Table 3.4.

Table 3.4: S/N ratios of observed results

| Expt. No. | Utility Index | S/N Ratio |
|---|---|---|
| 1 | 3.921 | 11.886 |
| 2 | 6.563 | 16.342 |
| 3 | 4.651 | 13.352 |
| 4 | 7.579 | 17.591 |
| 5 | 7.448 | 17.441 |
| 6 | 6.720 | 16.551 |
| 7 | 3.781 | 11.569 |
| 8 | 2.141 | 06.635 |
| 9 | 5.184 | 14.294 |

The MINITAB 16 gives the output of Main effects plot for S/N Ratios which is plotted below in Figure 3.1

Figure 3.1- Main Effects Plot for S/N Ratios




The software works on the principle of 'Smaller-is-Better' criteria for evaluating performance parameters (therefore S/N Ratio will evaluate with the principle of ‘Larger-is-Better' criteria. As shown in Figure 3.1 that **the second level of Speed (A2), third level of Feed (B3) and the second level of Depth of Cut (C2)** provides the optimum value of Surface Roughness and Tool Tip Temperature by evaluating the performance parameters. The S/N data analysis and validates the same levels of the variables **(A2, B3 and C2)** as the optimum levels.

# CHAPTER-4: Conclusion

This study is focussed at single characteristics optimization approaches for turning processes. The TOPSIS-based Taguchi approach and the Utility-based Taguchi approaches are applied in many field for optimization the multi and single performance characteristics. The most elementary machining processes in Conventional manufacturing processes is turning. In this study, the conclusion drawn are:

1. For obtaining optimum values of Surface Roughness and Tool Tip Temperature for machining of Copper work piece, optimum combination found out was **A2, B2 and C3 i.e. Speed= 605 rpm, Feed= 0.07 mm/rev and Depth of Cut= 1.2 mm**, which gives best results for TOPSIS-based Taguchi
2. For obtaining optimum values of Surface Roughness and Tool Tip Temperature for machining of Copper work piece in the Utility-based Taguchi, optimum combination found out was **A2, B3 and C2 i.e. Speed= 605 rpm, Feed= 0.08 mm/rev and Depth of Cut= 0.9 mm**, which gives best results.
3. In both the optimization processes, the second level of spindle speed is preferable which gives the dominant value of spindle speed in the given set of performance parameter as 605 rpm.
4. In the above two process, one is having a higher value of feed and lower value of depth of cut while the other is having the inverse. Since both feed rate and depth of cut have considerable effect on surface roughness the effect is cancelling out each other, providing us with two feasible and distinct solution.
5. Hence, the TOPSIS-based Taguchi approach and the Utility-based Taguchi approaches are applied and the optimum value are found out.

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