MULTI-OBJECTIVE OPTIMIZATION IN MACHINING (TURNING) OF BRASS

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

Bachelor of Technology (B. Tech.)

In

Mechanical Engineering

By

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Certificate of Approval

This is to certify that the thesis entitled **MULTI-OBJECTIVE OPTIMIZATION IN MACHINING (TURNING) OF BRASS** submitted by ***Sri Gyanendra Tripathy*** 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, NIT Rourkela, and this work has not been submitted elsewhere before for any other academic degree/diploma.

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GYANENDRA TRIPATHY

Abstract

The present study highlights a multi-objective optimization problem by applying both TOPSIS and Utility concepts coupled with Taguchi method through a case study in machining (turning) of pure Brass. The study aimed at evaluating the best process environment which could simultaneously satisfy multiple requirements of quality and productivity. In view of the fact, the traditional Taguchi method cannot solve a multi-objective optimization problem; to overcome this limitation, TOPSIS and Utility concepts have been coupled with Taguchi method. The 2 concepts have been adopted to convert a multi-response optimization problem into a single response optimization problem; in which CC (Closeness Coefficient) and U (Utility Index) respectively serve as the representative single objective function for optimization. The study combined TOPSIS/Utility and Taguchi method for predicting optimal setting. Based on Taguchi's Signal-to- Noise ratio (S/N), analysis has been made on the CC/U and optimal process environment has been selected finally which corresponds to highest S/N Ratio of the CC/U. Optimal result has been verified through confirmatory test. The case study indicates application feasibility of the aforesaid methodology proposed for multi-response optimization and off-line control of multiple quality and productivity characteristics in Brass machining.

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CHAPTER-1: Preliminaries

1.1 Turning

Turning is a conventional machining methodology utilized for manufacturing cylindrical shaped surfaces. Ordinarily, the work piece is mounted on the spindle and the tool is sustained into it radially, axially or both the methods all the while to give oblige surfaces. The term turning, all in all sense alludes to era of any cylindrical shaped surface with a single point tool. All the more particularly it is regularly connected to the machining of any cylindrical shaped surfaces situated principally parallel to the work piece axis. In turning, the feed is given axial to the spindle. When the cutting begins, the work piece and the tool are typically in contact until the surface is totally produced. In the meantime, the cutting speed and cut measurements will be consistent when a cylindrical shaped surface is produced.

Turning is a standout amongst the most essential of the machining methodologies. The rotating work piece is followed by a single point cutting tool which moves parallel to the axis of rotation of the job. Turning is regularly done on the outer surface of the job. The initial material for the most case is a work piece which is generated by primary manufacturing processes like casting, extrusion, forging or drawing. Turning can be performed manually, in a conventional lathe, which regularly needs continuous supervision of the operator, or by an automated lathe which does not require much attention. The turning method is of various types like straight turning, taper turning, profiling or external grooving. By turning process we can generate varied shapes of structures like straight, conical, curved, or grooved work pieces. Generally, in turning we use single-point cutting tools. An optimum set of tools angles that have been developed for each group of work piece. In turning process, parameters like speed, feed, and depth of cut, cutting tool shape and materials, number of runs, depth of cut for each run and the use of coolants will affect the cost of production, tool lives, MRRs, cutting forces, and the machining qualities like the surface roughness, the roundness of circular and dimensional accuracy of the product.

The various process parameters that we considered in this optimization process are:-

Cutting Speed : Cutting speed (also called surface speed) may be defined as the rate that the material moves past the cutting edge of tool, irrespective 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.

Feed: Feed rate is the velocity at which the cutter is fed, that is, advanced against the work piece. It is the distance moved by tool per unit movement of the job. It is expressed in mm/revolution.

Depth of Cut: Distance of engagement between tool and job. It is expressed in mm.

Depending on Depth of Cut, machining can be divided into:-

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

1.2 Surface Roughness

Surface roughness is a measure of the texture of a surface. It is quantified by the vertical deviation of a real surface from its ideal form. When the deviations are large, the surface is rough; if otherwise, the surface is smooth. Roughness is typically considered to be the high frequency, short wavelength component of a measured surface. It mainly originates due to feed motion.

Assuming the tool has no curvatures, and has a single sharp point, we can deduce that

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

$$\Rightarrow h_m\ ά\ f, \Phi, \Phi_1$$

1.3 Literature Review

Name of source	**Name of Author**	**Journal of issue**	**Year of issue**	**Deliverables**
Experimental investigation of Material removal rate in CNC turning using Taguchi method	Hassan et al.	International Journal of Engineering Research and Applications, 2(2),1581-1590	2012	The enhancement of MRR is done using 27 trial runs in view of L'27 orthogonal show of the Taguchi methods are performed to focus target capacities which is to be upgraded inside as far as possible. The enhanced estimation of MRR turns out to be 8.91. The perfect levels of procedure parameters for simultaneous advancement of MRR have been recognized.
Optimization of process parameters using Taguchi approach using minimum quantity lubrication for turning	Chaudhari et al.	International Journal of Engineering Research, 1(4), 1268-1273.	2011	The examination of exploratory results demonstrated that the blend of lower levels of “f” and more elevated amounts of N, d is key to accomplish simultaneous boost of MRR and minimization of Ra.
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 turning experiment is held using Tagu L27 OA and an ANN model was developed in Terms of N, f, d and tool nose radius us data from the experiment. By applying th IHSA to the developed ANN surface roughness model optimal cutting parame settings were determined
Parametric Analysis of Copper for Cutting Processes Using Turning Operations Based on Taguchi Method	Singh and Singh	International Journal of Research In Mechanical Engineering & Technology, Vol. 3(2), 202-204.	2013	This study produces the best combination of controlled parameter for the Ra, after experimentally turning a given work piece using an orthogonal array and parameters.
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	The execution attributes in dry turning operation are concentrated on utilizing the orthogonal exhibit, S/N proportion and investigation of change. ANOVA finds that the “d” assumes a huge part in getting higher MRR and insert has its noteworthy part in producing lower surface unpleasantness.
Parametric Analysis and Multi Objective Optimization of Cutting Parameters in Turning Operation of AISI 4340	Adinarayana et al.	International Journal of Research in Engineering and Technology, Vol.-03(02), 449-456	2014	Experiments are composed in view of Taguchi's L27 Orthogonal show outline for turning of AISI 4340 Alloy steel. Taguchi parameter Design and examination are utilized to anticipate and streamline the estimation of Surface Roughness, MRR and Power Consumed amid turning operations

Alloy Steel with CVD Cutting Tool				utilizing CVD Cutting Tool.
Parametric Analysis and Optimization of Turning Operation by Using Taguchi Approach	Sahoo	International Journal of Modern Engineering Research, Vol.3 (4), 2154-2156	2013	Experiments were done by changing any one of the machining parameter like N, f, d and keeping other two fixed so as to obtain the maximum value of each parameter.
Parameter Design Study In A Turning Operation Using The Taguchi Method	Kirbya	The Technology Interface, 1-14	2006	An orthogonal array is utilized to get the optimum turning parameters, along with the noise factor. Machining parameters include N, f, d. The applicability and robustness of the study is increased by including the noise factor. For a given set of parameters a verified combination of a governing equation and controlled factors are obtained.
The Optimization of Machining Parameters Using the Taguchi Method for Surface Roughness of AISI 8660 Hardened Alloy Steel	Motorcu	Journal of Mechanical Engineering, Vol.-56(6), 391-401	2010	An orthogonal design, S/N ratio and ANOVA were used to find out the effective variable and nose radius on the Ra during machining test using PVD coated ceramic tools. The obtained results shows that the “f” is the leading factor on the Ra, then after “d” and tool’s nose radius.
“Optimization of Surface Roughness of AISI 304 Austenitic Stainless Steel in Dry Turning Operation Using Taguchi Design Method	Selvaraj and Chandramohan	Journal of Engineering Science and Technology, Vol.-5(3), 293 – 301	2010	The effect of cutting parameters (N, f, d) on Ra during dry turning is studied. An experiment based on Taguchi’s method was utilised to find the observation. An OA, the ANOVA and the S/N ration are used to find the machining properties of AISI 304 steel bars using TiCN and TiC coated WC cutting tool.

CHAPTER-2: The TOPSIS-based Taguchi Approach

2.1 Taguchi Method

A full factorial design identifies all possible combination for a given set of factors. Given that most industrial experiments usually involve a significant number of factors, a full factorial design leads to a large number of experiments. To reduce the number of experiments in a practical level, Taguchi constructed a speed set of general design guidelines for factorial experiments that cover many applications. Thus method uses a special set of arrays called orthogonal arrays. These arrays stipulate the way of conducting the minimal number of experiments which could give fuel information of all the factors that affect the performance parameter. The curve of the orthogonal arrays method lies in choosing the level combinations of Input Design Variables for early experiment.

While these are many standard orthogonal arrays available, each array is meant for a specific number of independent design variables and levels. Like, if one wants to conduct an experiment to understand the influence of 4 different independent variables with each variable having 3 set(level) values, the a La Orthogonal array might be the right choice. The $_{L9}$ orthogonal array is meant for understanding factors each having 3 factors level values. This array makes the assumption that there is no interaction between any two factors. While in many cases, no interaction model assumption is valid, there are many cases where a clear evidence of interaction is present

In most cases the design of experiments using the orthogonal array is efficient when compared to many other statistical designs, the minimum number of experiments that are required to conduct the Taguchi method can be calculated based on the degrees of Freedom approach.

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

The Design of Experiment involves the following steps:

1) Selection of independent variables.
2) Selection of number of level settings for each independent variable.
3) Selection of Orthogonal Array.
4) Assigning the independent variable to each column.

5) Conducting the experiments.
6) Analysing the data.
7) Inference.

Taguchi also brought about the idea of ‘robust design’, whose objective is to find the Controllable Process parameter for which Noise or Variation has a minimal effect on products or process’s functional characteristics. The influence of Noise on the performance characteristics can be found using the ratio S/N, where ‘S’ is the standard deviation of the Performance Parameter for each inner Array experiment and N is the total number of experiment in the outer orthogonal array. This ration includes the functional vibration due to Noise. Using the result, it is possible to produce robust design control parameter settings will make the process insensitive of noise.

The concepts behind the Taguchi methodology are:

1. Quadratic Loss Functions (or Quality Loss Function) are used to quantify the loss incurred by the user due to deviation from target performance.
2. Signal-to-Noise (S/N) Ratios are used for predicting the field quality through laboratory experiments.
3. Orthogonal Arrays (OA) are used for gathering dependable information about control factors (design parameters) with a reduced number of experiments.

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

1. Nominal-the-Best (NB) or Target-the-Best (TB)
2. Lower-is-Better (LB)
3. Higher-is-Better (HB)

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

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

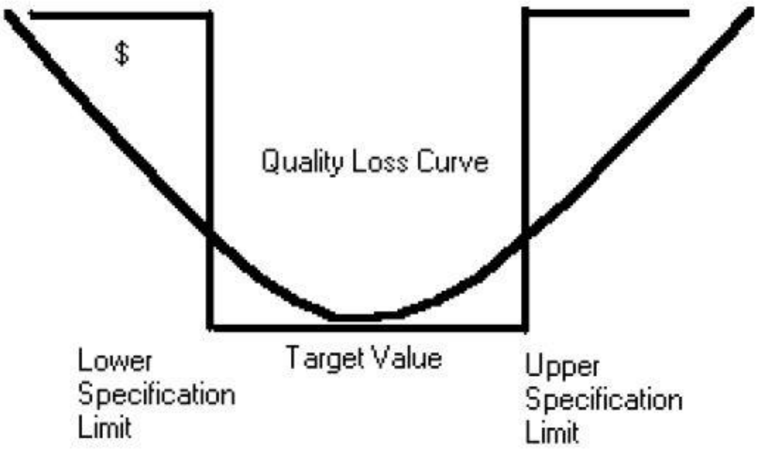

Fig. 2.1: Nominal-the-Best (NB)/ Target-the-Best (TB)

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 these characteristics 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 technique for order of preference by similarity to ideal solution is a multi-criteria decision analysis method, resting on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. It is a method of compulsory aggregation that compares a set of alternatives by identifying weights for each criterion and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in the criterion. But the criterion may differ in type, range and unit; making it difficult to aggregate them. Hence, normalization is generally required in multi-criteria problems. Compensatory methods like TOPSIS allow trade-offs between criteria, where a poor result in one criterion may be neglected by a good result in another criterion, providing a more realistic form of modelling.

<u>Assumptions</u>- 1) Values and stability of each criterion should be linearly increasing or decreasing.

2) Criteria should be independent.

2.2.1 TOPSIS Algorithm

1) Form the Decision Making matrix:

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

where columns are criteria and Rows are alternatives

2) Normalization of Decision Making matrix:

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

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

3) Computation of weighted Normalized Decision Matrix:

Taking weight vector, $W=[w_1, w_2, \ldots\ldots w_n]$, $\sum w_j=1$, where w_i= weight criteria of criteria 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) Determination of Ideal solution and anti ideal Solution:

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

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

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

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

where Ω_b stands for ‘Higher is better’ criteria

Ω_c stands for ‘ Lower is better’ criteria

5) Determine relative closeness 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 is a ‘higher is better’ criteria

6) Final decision making matrix thus reduces to

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

2.3 Experimental Works

In this study, a TOPSIS based Taguchi method is applied to convert the multi objective function into a single characteristics optimization, so the experiments were carried out according to a Taguchi optimization techniques.

2.3.1 Work material and Cutting tool

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

2.3.2 Design of experiments

The 3 process parameters spindle speed, feed rate and depth of cut are set at 3 different levels and experiments are designed as per the Taguchi optimization algorithm. The given set of input parameters are shown in the following table

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

The Optimization Algorithm (OA) is selected based on the number of given factors and its levels. Here there are 3 input parameters which are assigned with 3 different levels, hence Degree of freedom can be calculated by the following equation:

$$DOF = F (L - 1)$$

where, F = number of factors, L = number of levels

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

Here the DOF obtained is 6; hence we select the next higher value of the multiple of 3 that is 9 to obtain the OA. Hence, L_9 orthogonal array is chosen. Nine different combinations of the 3 parameters at 3 levels are obtained in the following table.

Using the smaller-is-better criteria the utility index is obtained and hence the S/N ratio from the given set of L_9 OA.

Table 2.2: L_9 Design Matrix

Expt. No.	N	f	d
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

Experiments were done using an Lathe (HMT NH-26) as per L_9 OA combinations, every experiment was repeated three times for obtaining a genuine observation i.e.9x3 = 27 total experiments were conducted. The Tool tip temperature was measured using Non-Contact Infrared Thermometer of AR882 make, having a temperature range of -18^{0}C to 200^{0}C and Surface roughness was measured by MITUTOYO made Profilometer (Model: SJ-210).

2.4. Experimental Results and Discussion

To analyze the effect of machining parameters on the Surface Roughness and Tool tip temperature, experiments were conducted in Lathe machine using the combination of values from L_9 OA (Table 2). The observations are 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	6.54	6.609	7.416	6.855	31.4
2	7.371	9.881	9.082	8.778	31.1
3	8.609	9.151	10.976	9.578	32.6
4	10.055	8.102	8.131	8.762	31.6
5	8.923	9.228	10.728	9.626	32.4
6	8.644	8.32	8.059	8.341	30.9
7	12.496	15.59	13.443	13.845	32.8
8	14.396	13.179	19.705	15.76	32.3
9	21.7	22.47	26.13	23.433	35.3

From this table, it is observed that Spindle Speed, Feed Rate and Depth of Cut significantly influence both the value of surface roughness and the value of Tool Tip Temperature. The effect of given variables on the desired output are studied by designing an experiment based on Taguchi approach. A Taguchi Design of Experiment was created using MINITAB 16 and corresponding S/N Ratios were calculated for the combination of Surface Roughness and Tool Tip Temperature, utilizing 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	0.915283	-0.7689
2	0.803173	-1.9038
3	0.741117	-2.6023
4	0.791725	-2.0285
5	0.743030	-2.5799
6	0.830452	-1.6137
7	0.610437	-4.2872
8	0.560374	-5.0304
9	0.151278	-16.4045

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

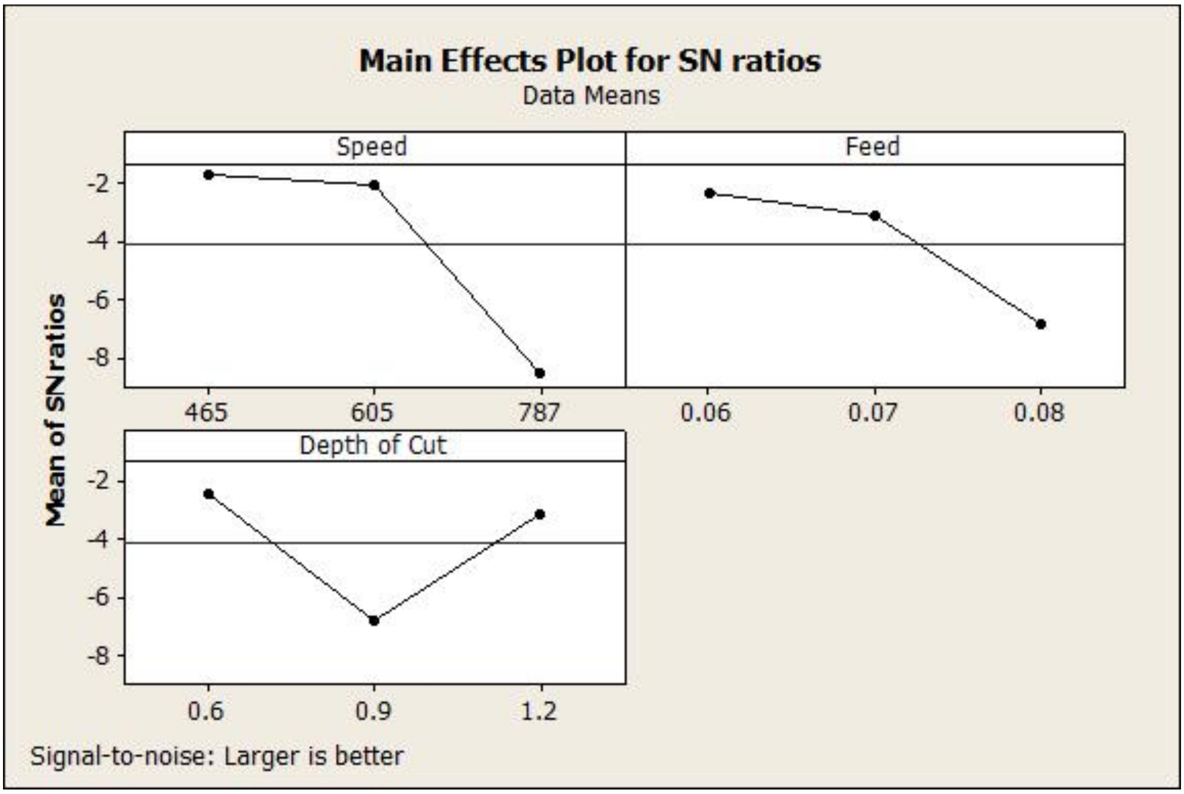

Fig. 2.4: Main Effects Plot for S/N Ratios

The software utilizes 'Smaller-is-Better' criteria for the performance parameters (therefore S/N Ratio would be 'Larger-is-Better' criteria. It can be seen from Figure 3.1, that the first level of Spindle Speed (A1), first level of Feed Rate (B1) and the first level of Depth of Cut (C1) provide the optimum value of Surface Roughness and Tool Tip Temperature. The S/N data analysis proposes the same levels of the variables (A1, B1 and C1) as the best levels.

Hence the optimum parameters were found out to by TOPSIS based Taguchi Approach are Spindle Speed= 465 rpm, Feed Rate= 0.06 mm/rev, Depth of Cut= 0.6mm.

CHAPTER-3: The Utility-based Taguchi Approach

3.1 Introduction

Quality is a key attribute that customers require into the product or services. So the modern quality control and improvement program focuses that their product should be made as per the customer requirements. On the other hand, customer evaluates a product performance based on number of diverse quality characteristics of the product. To be able to make the rational choice, this performance evaluation on different characteristics should be combined to give a composite index. The utility of a product on a particular characteristic measures the usefulness of product/services. It refers to the satisfaction that each attribute provides to the decision maker. Her, we have assumed that the overall utility of the product is the total sum of the utilities of each quality characteristic of the product. Utility function approach provides a methodological framework for the evaluation of alternative attributes made by the individuals, organisations and firms.

Thus, the utility theory assumes that a decision is made on the basis of utility maximization principle, according to which the best choice is the one that provides the highest satisfaction to the decision maker.

3.2 Algorithm for Utility Approach

If X_i is the measure of effectiveness of an attribute (characteristic) 'i' and there are 'n' attributes evaluating the outcome space, then the combined utility functions can be expressed as:

$$U(X_1, X_{2,\dots\dots,}X_n) = f(U_1(X_1), U_2(X_2), \dots\dots, U_n(X_n))$$

The overall Utility function is the sum of individual utilities if the attributes are independent and is given as follows:

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

The overall Utility function after assigning weights to the attributes can be expressed as :

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

The Preference number can be expressed on a logarithmic scale as follows:

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

Here, X_i is the value of any quality characteristic or attribute 'i'

X_{ideal-} is the worst value of quality characteristics or attributes from 'i' to 'n' (Anti-Ideal solution)

A is a constant whose value can be found out by using the condition $X_1 = X_{ideal}$ in the above equation (where X_{ideal} is the best value of quality characteristic from 'i' to 'n' i.e. the Ideal Solution)

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

The overall Utility function can thus be expressed as:

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

Subject to the condition

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

Overall Utility index that has been determined, viewed the problem as optimization using a single objective function. From the various quality characteristic namely Lower-is-better (LB), Nominal-the-best (NB), Higher-is-better (HB) suggested by Taguchi approach, the Utility function uses the Higher-is-better (HB) type. Therefore, for the maximized value of the Quality function, the quality characteristic considered for its evaluation is optimized automatically.

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To analyze the effect of machining parameters on the Surface Roughness and Tool tip temperature, experiments were conducted in Lathe machine using the combination of values from L_9 OA (Table 2). The observations are 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	6.54	6.609	7.416	6.855	31.4
2	7.371	9.881	9.082	8.778	31.1
3	8.609	9.151	10.976	9.578	32.6
4	10.055	8.102	8.131	8.762	31.6
5	8.923	9.228	10.728	9.626	32.4
6	8.644	8.32	8.059	8.341	30.9
7	12.496	15.59	13.443	13.845	32.8
8	14.396	13.179	19.705	15.76	32.3
9	21.7	22.47	26.13	23.433	35.3

From this table, it is observed that Spindle Speed, Feed Rate and Depth of Cut significantly influence both the value of surface roughness and the value of Tool Tip Temperature. The effect of given variables on the desired output are studied by designing an experiment based on Taguchi approach. A Taguchi Design of Experiment was created using MINITAB 16 and corresponding S/N Ratios were calculated for the combination of Surface Roughness and Tool Tip Temperature, utilizing the values of the closeness coefficient. 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	8.45741	18.545
2	7.87667	17.927
3	5.96486	15.512
4	7.34394	17.319
5	6.15470	15.784
6	8.28170	18.362
7	4.40947	12.888
8	4.45443	12.976
9	0.00000	-140.000

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

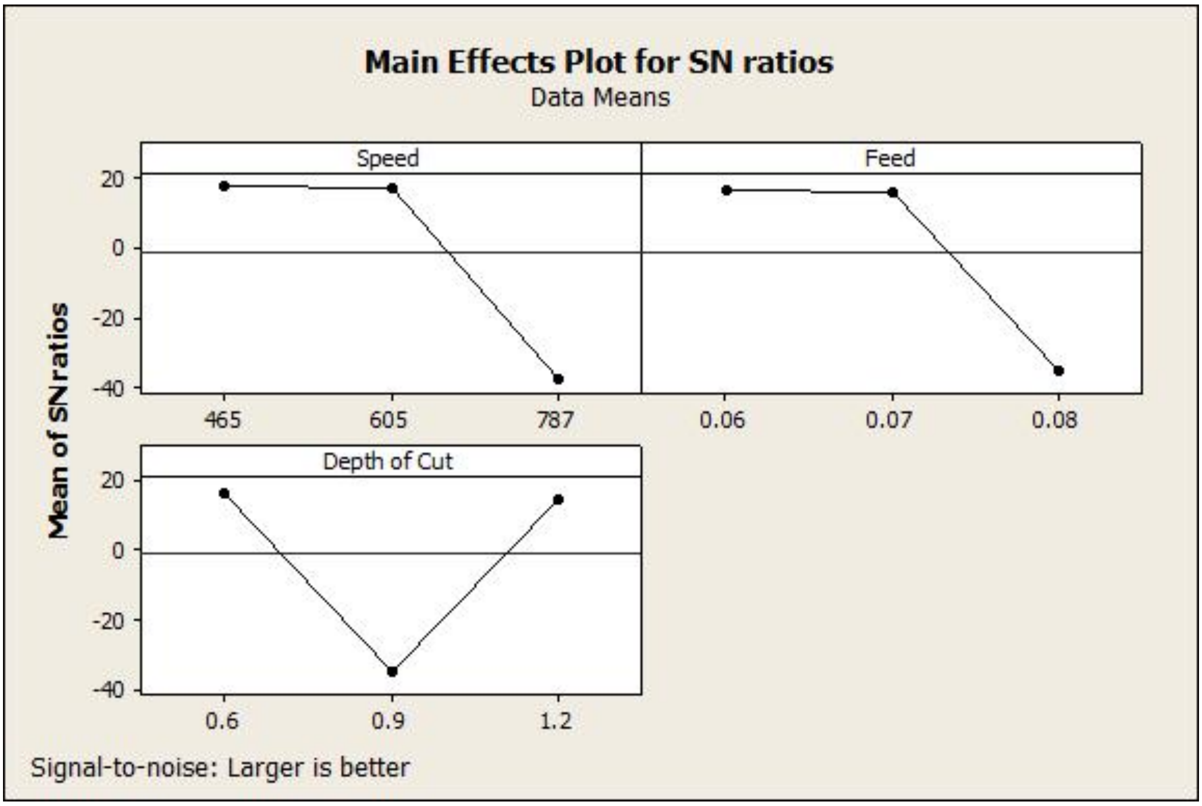

Figure 3.1- Main Effects Plot for S/N Ratios

The software utilizes 'Smaller-is-Better' criteria for the performance parameters (therefore S/N Ratio would be 'Larger-is-Better' criteria. It can be seen from Figure 3.1, that the first level of Spindle Speed (A1), first level of Feed Rate (B1) and the first level of Depth of Cut (C1) provide the optimum value of Surface Roughness and Tool Tip Temperature. The S/N data analysis proposes the same levels of the variables (A1, B1 and C1) as the best levels.

Hence the optimum parameters were found out to by Utility based Taguchi Approach are Spindle Speed= 465 rpm, Feed Rate= 0.06 mm/rev, Depth of Cut= 0.6mm.

CHAPTER-4: Conclusion

The application of multi objective optimization techniques for machining (turning) processes of brass is studied. The TOPSIS-based Taguchi approach and the Utility-based Taguchi approaches are utilized in many disciplines to optimize the single and multi objective functions effectively. In the present study, the conclusion drawn is: for obtaining prime values of Surface Roughness and Tool Tip Temperature for machining of Brass work piece, optimum combination found out was A1, B1 and C1 i.e. Spindle Speed (N) = 465 rpm, Feed Rate (f) = 0.06 mm/rev and Depth of Cut (d) = 0.6 mm, which gives best results.

Future Scope:

The project can be further extended to design of mathematical modeling, structural design and analysis of the tools. The optimization techniques can also be implemented at industries for smooth finishing of the job by minimizing tool wear.

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