

# Comparison of Teaching Learning Based Optimization method and Taguchi Method by Analysing Force in Turning by single point cutting tool

Gaurav Dixit<sup>1</sup> Santosh Kumar Mishra<sup>2</sup>

<sup>1</sup>M.E. Scholar <sup>2</sup>Assistant professor

<sup>1,2</sup>Department of Mechanical Engineering

<sup>1,2</sup>Bhilai Institute of Technology, Durg, Chhattisgarh India

**Abstract**— The purpose of this paper is to obtain a comparison between Teaching Learning Based Optimization Technique and Taguchi Method in order to achieve optimal setting of turning process parameters (cutting velocity, depth of cut and feed rate) resulting in an optimal value of the Resultant force when machining Aluminum 6061(AI 61S) with single point cutting tool. The effects of the selected turning process parameters on Resultant force and the subsequent optimal settings of the parameters have been analyzed by using Teaching Learning Based Optimization method and Taguchi Method. The results indicate that the selected process parameters are more optimized in Teaching Learning Based Optimization Method than Taguchi.

**Key words:** Cutting parameters; turning process; Resultant force; Teaching Learning Based Optimization method; Taguchi method; Aluminum 6061(AI 61S); single point cutting tool

## I. INTRODUCTION

Turning is one of the most basic machining processes. The part is rotated while a single point cutting tool is moved parallel to the axis of rotation. Turning can be done on the external surface of the part as well as internally (boring). The starting material is generally a work piece generated by other processes such as casting, forging, extrusion, or drawing. Turning can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using a Computer-controlled and automated lathe which does not. Turning process can produce various shapes of materials such as straight, conical, curved, or grooved work pieces. In general, turning uses simple single-point cutting tools. Each group of work piece materials has an optimum set of tools angles which have been developed through the years. In turning process, parameters such as cutting tool geometry and materials, number of passes, depth of cut for each pass, the depth of cut, feed rates, cutting speeds as well as the use of cutting fluids will impact the production costs, MRRs, tool lives, cutting forces, and the machining qualities like the surface roughness, the roundness of circular and dimensional deviations of the product.[1]

### A. Turning Operation:

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a predefined diameter, and to produce a smooth surface of work piece. Many a times a single work piece is turned in a way that it consist of cross sectional area of varied diameters. Basically turning operation is used to make cylindrical parts. When outer diameter is machined the process is called turning and when inner diameter is machined the process is called

boring. The basic process of turning can be understood as follows:

- Work piece which is to be machined is fixed at the center of the chuck of lathe rigidly.
- Now for turning operation a single point cutting tool is used. The feed motion of the tool is axial i.e. parallel to the work piece axis.
- The tool is held at a very small distance from the work piece. When the feed motion is given to the tool it starts removing metal in form of chips.
- The tool remains stationary for a particular revolution. While during this revolution the work piece rotates about its central axis.
- When one revolution completes the tool shifts in the direction of feed to a new level.
- The turning process is depicted with the help of below figure 1.1

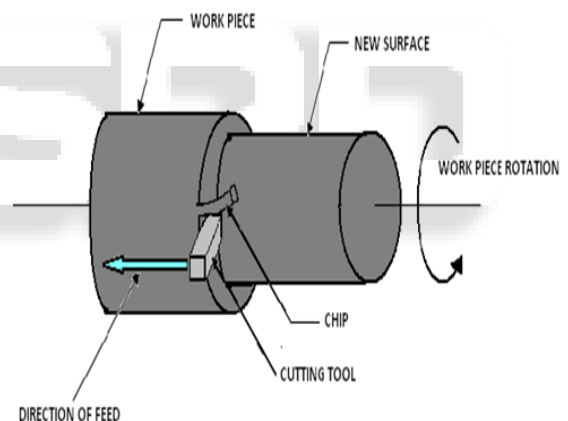


Fig. 1.1: Turning Operation

If the feed motion is radial i.e. normal to the axis of rotation an end face or shoulder is produced. All turning operations are done in lathe. The major types of turning operations are

- (1) turning of cylindrical and stepped cylindrical surfaces (fig 1.1),
- (2) turning of tapered and curved surfaces of revolution,
- (3) turning of screw threads and
- (4) face turning and parting.

### B. Cutting Factors in Turning:

The three primary factors in any basic turning process are cutting velocity ( $v$ ), feed ( $f$ ), and depth of cut ( $d$ ). Other factors such as type of tool and material to be cut, have a large influence on the process but the above mentioned factors are the ones that can be changed as per requirement.

## II. METHODOLOGY

### A. Taguchi Method:

The Taguchi Method is a powerful problem solving technique for improving process performance, yield and productivity. Developed by Dr. Genichi Taguchi, a Japanese quality management consultant. It reduces scrap rates, rework costs and manufacturing costs due to excessive variability in processes. Taguchi recommends a three stage process to achieve desirable product quality by design-system design, parameter design and tolerance design. System design helps to identify working levels of design parameters, parameter design seeks to determine parameter levels that provide the best performance of the product or process under study. The optimum condition is selected so that the influence of uncontrollable factors (noise factors) cause minimum variations to system or process performance. Variables that are suspected to have some effect on the quality characteristic of interest are known as factors. At this point any expert knowledge of the subject matter should be applied in the selection of variables to include as factors. Those variables suspected to have the largest effects on the quality characteristic are generally considered first. Taguchi has envisaged a new method of conducting the design of experiments which are based on well defined guidelines. This method uses a special set of arrays called orthogonal arrays. These standard arrays stipulates the way of conducting the minimal number of experiments which could give the full information of all the factors that affect the performance parameter. The crux of the orthogonal arrays method lies in choosing the level combinations of the input design variables for each experiment.[2]

#### 1) Designing An Experiment:

The design of an 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 variables to each column
- (5) Conducting the experiments
- (6) Analyzing the data
- (7) Inference

### B. Teaching Learning Based Algorithm (TLBO):

A new and efficient technique of optimization known as "Teaching Learning Based Optimization" is developed by Dr. R.VenkataRao, Professor, Department of Mechanical Engineering, NIT Surat, Gujarat, India. This method works on the effect of teacher on learners. The population is considered as a group of learners or a class of learners. TLBO is a two stage technique. The first stage is known as "Teacher's phase" and second stage is known as "Learner phase". Teacher phase means learning from the teacher and Learner phase means learning by the interaction between learners. The TLBO method is based on the effect of the influence of a teacher on the output of learners in a class. Here, output is considered in terms of results or grades. The teacher is considered as a highly learned person who shares his or her knowledge with the learners. It is obvious that a

good teacher trains learners such that they can have better results in terms of their marks or grades.

Teaching-learning-based optimization is based on teaching-learning process in which every learner tries to learn something from other individuals to improve themselves. This algorithm simulates the traditional teaching-learning phenomenon of a class room . Here, two different teachers, T1 and T2 are assumed teaching same subject to the same merit level students in two different classes. The distribution of marks obtained by the learners of two different classes as shown in the Figure 2.1 is evaluated by the teachers.

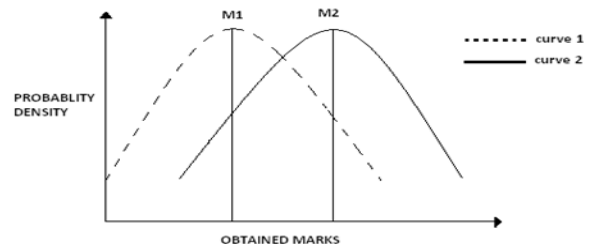


Fig. 2.1: Distribution of marks obtained by learners taught by two different teachers.[3]

Curves 1 and 2 shown in Figure 2.2 represent the marks obtained by the learners taught by teacher T1 and T2 respectively. Generally a normal distribution is assumed for the obtained marks. The normal distribution is defined as

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

Where  $\sigma^2$  is the variance,  $\mu$  is the mean and  $x$  is any value for which the normal distribution function is required.[3]

As represented in the Figure 2.2 below, let us assume that the teacher T2 is better than teacher T1 in terms of teaching. The main difference between both the results is their mean (M2 for Curve-2 and M1 for Curve-1), i.e. a good teacher produces a better mean for the results of the learners. Learners also learn from the interaction among themselves, which helps in the improvement of their results. Considering this teaching learning process Rao et al. developed a mathematical model and implemented it for the optimization of unconstrained non-linear continuous function, thereby developing a optimization technique called Teaching-Learning-Based Optimization (TLBO). Let the marks obtained by the learners in a class with curve-A be mean MA as shown in the Figure 2.2. As the teacher is considered as the most knowledgeable person in the society, so the best learner imitate as a teacher, which is shown by TA in Figure 2.2.

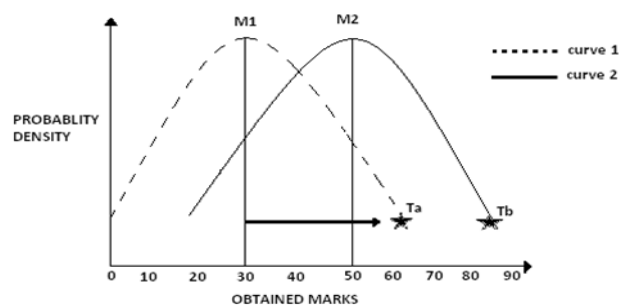


Fig. 2.2: Model for distribution of marks obtained for a group of learners[4]

The teacher tries to spread knowledge among learners, which will in turn enhance the knowledge level of the entire class and facilitate learners to get good marks or grades. Hence, the teacher increases the mean of the class according to his or her capability. The teacher TA will try to move mean MA towards their own level according to his or her capability, thereby increasing the learner's level to a new mean MB. Teacher TA will put maximum effort for teaching their students, but students will gain knowledge according to the quality of teaching delivered by a teacher and the quality of students present in the class. The quality of the students is judged from the mean value of the population. Teacher TA puts effort in so as to increase the quality of the students from MA to MB, at which stage the students require a new teacher, of superior quality than themselves, i.e. in this case the new teacher is TB. After which, there will be a new curve-B with new teacher TB. Like other nature-inspired algorithm, TLBO is also a population-based algorithm, where a group of students (i.e. learners) is considered the population of solutions to proceed to the global solution. The different design variables in the optimization problem are analogous to different subjects offered to the learners. The fitness value of the optimization problem is analogous to the results of the learners in the optimization problem. The best solution in the entire population is considered as the teacher. The next teacher is considered as the best teacher obtained. This algorithm is divided into two levels of learning phase i.e. through the teacher (known as the teacher phase) and interacting with other learners (known as the learner phase).[4]

1) *Teacher Phase:*

In this phase the learning is through the teacher. During the learning process the teacher spread knowledge among the learners and tries to increase the mean results of the class. At any iteration 'i', let, there are 'm' number of subjects (i.e design variables) offered to 'n' number of students (i.e. population of solutions i.e. k = 1, 2, ..., n) and  $M_{j,i}$  is the mean results of the students in a particular subject (j = 1, 2, ..., m) As the teacher is considered as the most knowledgeable person in each subject, the best learner in the whole population is considered a teacher in the algorithm. The best overall result is  $X_{total-kbest,i}$ , obtained in the whole population of learners considering all the subjects together can be considered as a the result of best learner  $K_{best}$ . However, as the teacher is usually considered as a highly learned person who trains learners so that they can have better results, the best learner identified is considered as the teacher. The difference between the existing mean result of each subject and the corresponding result of the teacher for each subject is given by:

$$\text{Difference\_Mean}_{j,k,i} = r_i (K_{j,k \text{ best},i} - TF M_{j,i})$$

Where  $X_{j,kbest,i}$  is the result of the best learner (i.e., teacher) in subject j, TF is the teaching factor which decides the value of mean to be changed, and  $r_i$  is the random number in the range [0,1]. The value of TF is decided randomly with equal probability as:

$$TF = \text{round} [1 + \text{rand} (0, 1) \{2-1\}]$$

TF is not a parameter of the TLBO algorithm. The value of TF is not given as an input to the algorithm and its value is randomly decided by the algorithm using Equation (11). Rao et al. have conducted a number of experiments on

many benchmark functions and it is concluded that the algorithm performs better if the value is between 1 and 2. However, the algorithm is found to perform much better if the value of TF is either 1 or 2 and hence to simplify the algorithm, the teaching factor is suggested to take either 1 or 2 depending on the rounding up criteria given by Equation (11). However, one can take any value of TF in between 1 and 2. Based on the  $\text{Difference\_Mean}_{j,k,i}$  the existing solution is updated in the teacher phase according to the following expression.

$$X'_{j,k,i} = X_{j,k,i} + \text{Difference\_Mean}_{j,k,i}$$

Where  $X'_{j,k,i}$  is the updated value of  $X_{j,k,i}$ .  $X'_{j,k,i}$  is accepted if it gives a better function value. At the end of teacher phase all the accepted values are maintained and these values become the input to the learner phase.[4]

2) *Learner Phase:*

Learners increase their knowledge by interacting themselves in this second section of this algorithm. A learner interacts randomly with other learners for enhancing their knowledge and experience. A learner learns new things or ideas if the other learner has more knowledge than him or her. Considering a population size of 'n', the learning phenomenon of this phase is expressed below.

Two learners P and Q are randomly selected such that

$$X'_{total-P,i} \neq X'_{total-Q,i}$$

(where,  $X'_{total-P,i}$  and  $X'_{total-Q,i}$  are the updated values of  $X_{total-P,i}$  and  $X_{total-Q,i}$  respectively at the end of teacher phase).

$$X''_{j,P,i} = X'_{j,P,i} + r_i (X'_{j,Q,i} - X'_{j,P,i}), \text{ if } X'_{total-P,i} < X'_{total-Q,i}$$

$$X''_{j,P,i} = X'_{j,P,i} + r_i (X'_{j,P,i} - X'_{j,Q,i}), \text{ if } X'_{total-Q,i} < X'_{total-P,i}$$

Accept  $X''_{j,P,i}$  , if it gives a better function value.

All the accepted function values at the end of the learner phase are maintained and these values become the input to the teacher phase of the next iteration. The values of  $r_i$  used in above equations can be different. Repeat the procedure of teacher phase and learner phase till the termination criterion is met.[4]

III. CALCULATION

The workpiece of length of 3 feet(914mm approx) centered and fixed on headstock of lathe. Workpiece was divided into 9 equal parts of length 25 mm each. Taking different parameters readings were taken into analysis. The analysis was focused on three vital parameters in turning process. These parameters are Cutting Velocity "v", Depth of Cut "d", Feed "f". Design of Experiment was used to decide the parameter variation.

Machining of workpiece was carried out. The readings obtained are tabulated in Observation Table- 3.1

Operation Performed -Turning of Aluminum 6061(Al 61S)

Composition of Material - Aluminum = 97.9% ; Silicon = 0.60% ; Copper = 0.28% ; Magnesium = 1.0% ; Chromium = 0.20%

Cutting Velocity v (m/min)	Depth of Cut d (mm)	Feed Rate f (mm/rev)	New Value of Resultant force $R_{f1}$
11.86	0.5	0.044	8.52329
11.86	0.75	0.089	16.53448

11.86	1	0.178	29.85551
18.65	0.5	0.089	12.83295
18.65	0.75	0.178	24.57743
18.65	1	0.044	11.52157
30.52	0.5	0.178	18.99037
30.52	0.75	0.044	9.44246
30.52	1	0.089	17.17450

Table 3.1: Observation Table

A. Taguchi Method Application:

Before application of Taguchi method it is important to define the domain of experiment. Following table depicts the domain of experiment.

Factors	Symbol & Unit	Code assigned	Levels of factors		
			I	II	III
Cutting Velocity	v (m/mm)	A	11.86	18.65	30.52
Depth of Cut	d (mm)	B	0.5	0.75	1
Feed Rate	f (mm/rev.)	C	0.044	0.089	0.178

Table 3.2: Domain Of Experiment

1) Lower The Better Criteria:

Sound to Noise ratio or SNR is an important tool for analyzing the factors which have great impact on process performance. Lower the better SNR is given as

$$SNR = -10 * \log \left\{ \frac{\sum y^2}{n} \right\}$$

Here, y = each observed value

n = number of values at each trial condition (in present analysis n = 1) average SNR values for factors at each level. The values are tabulated in following table.

Parameters	A	B	C
SNR-1	-23.1567	-21.1129	-18.7779
SNR-2	-23.7358	-23.8934	-23.7439
SNR-3	-23.1021	-25.1427	-27.6272
DIFFERENCE	-0.6337	-4.0298	-8.8493

Table 3.3: Average SNR For Parameters at three levels

B. TLBO Application:

Cutting Velocity v (m/min)	Depth of Cut d (mm)	Feed Rate f (mm/rev)	Resultant force R <sub>f3</sub> (N)
22.04	0.25	0.029	4.27328
15.28	0.25	0.014	2.78346
30.52	0.25	0.029	4.12029
16.96	0.25	0.014	2.75113
30.52	0.25	0.029	4.12029

33.92	0.25	0.029	4.07183
33.92	0.25	0.029	4.07183
57.66	0.25	0.029	3.83692
40.7	0.25	0.014	2.49420

IV. CONCLUSION

A. Taguchi Method:

- As table 3.3 of average Sound-to-Noise Ratio (SNR) values clearly shows that for parameter 'A'(cutting velocity), the least value in that column is SNR-3 = -23.1021. This value indicates that the process is least affected by this value of parameter 'A'.
- SNR-3 = -23.1021, corresponds to value of cutting velocity at level III, in table 3.2, that is v = A3 = 30.52
- From table 3.3, we can see that for parameter 'B' (depth of cut) the least value is give by SNR-1 in that column.
- SNR-1 = -21.1129, corresponds to value of depth of cut, at level I in table 3.2, that is d = B1 = 0.5
- The average SNR value for parameter 'C' (feed rate) from table 3.3 shows, the least value is at SNR-1 of that column.
- SNR-1 = -18.7779, corresponds to value of feed rate at level I in table 3.2, that is f = C3 = 0.044
- The value of resultant force associated with above parameter value set is R<sub>f</sub> = 7.6671 which is lowest as compared with table 3.1
- Taguchi method effectively highlights the best parameterical set of values, amongst the observed values or given set of values.
- Taguchi method shows the effect of different parameters on the process with the help of SNR-plots and helps to find the most dominant parameter.

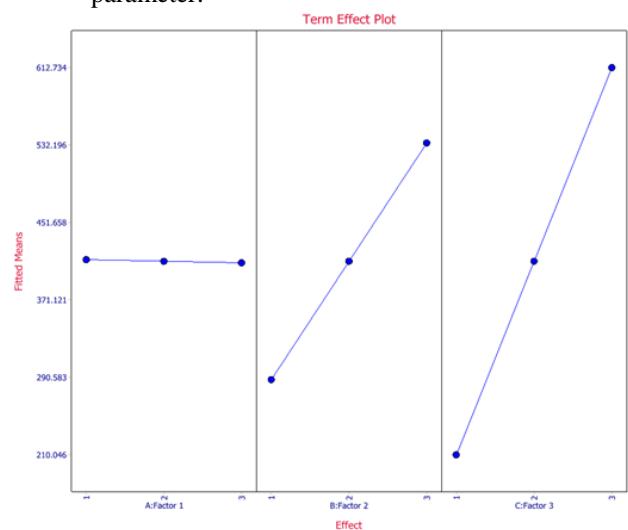


Fig. 4.1: Term Effect Plot

- Taguchi method finds the better combination of values for a given set of values according to the need of objective function.

The difference calculated at the end of each column in table 3.3 shows the effect of that parameter on the process. Irrespective of sign, the higher value means that parameter effects more in increasing the resultant force.

**B. TLBO Method:**

- At the end of Learner phase, the value of objective function that is resultant force '  $R_{f_3}$  ', decreased to another level for all the values as compared with value in table 3.4
- All the new calculated values of parameters at the end of learner phase are tabulated in table 3.4
- The minimum value of parameters according to the minimum value of objective function, at the end of Learner phase  
Minimum objective function value  $R_{f_3} = 2.49420$   
Parameter values-  $v = 40.7$ ,  $d = 0.25$ ,  $f = 0.014$
- TLBO uses the same set of values which were taken in Taguchi. The end values of parameter, obtained after design of experiment(in Taguchi Method) are used as initial population in TLBO, which gives more specific results.
- TLBO further refines the parameter values in two phases of its operation, namely Teacher phase and Learner phase.
- The objective function that is resultant force is minimized to a appreciably low level in both phases of TLBO.
- In present case it's been found that, the feed rate is the most dominant parameter, having a very strong effect on the process, followed by depth of cut. The cutting velocity is having very less effect on the resultant force.

REFERENCES

- [1] R.Venkata Rao, 2011, Advanced modeling and optimization of manufacturing process, Springer Verlag London limited.
- [2] Jiju Antony and Frennie Jiju Antony,2001,Teaching the Taguchi method to Industrial Engineers,Work Study
- [3] Rao R.V., Savsani V.J. and Vakharia D.P. 2011, Teaching-learning-based optimization: A novel method for constrained mechanical design optimization problems, Computer-Aided Design.
- [4] P. J. Pawar & R. Venkata Rao2012Parameter optimization of machining processes using teaching learning-based optimization algorithm.