Optimization of Turning Process Parameters for Hardness in Forged Steel

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Abstract

Turning is one of the common machining methods in manufacturing industry. Hardness of the material is the most significant property in the field of design to satisfy the safety and reliability. The main objective of this investigation is to analyse the changes in the hardness of material on the machined surface due to machining operation (turning) by considering the spindle speed, feed and depth of cut. EN353 forged steel was selected for the analysis to measure the hardness. The hardness was estimated using Rockwell hardness tester by varying the cutting parameters using Taguchi method.

Keywords- Hardness, EN353 forged steel, speed, feed, depth of cut, Taguchi

1. Introduction

Metal cutting is one of the oldest and continued developing processes in industries. The raw material is converted in to required shape by removing excess materials through proper machine tool, technicians, cutting and holding tools by applying proper cutting data. For metal cutting different machine tools like drilling machines, lathes, milling machines, grinding machines are available with different capacities based on requirement of parts.

While considering all machine tools lathe or turning machine is considered as Father of all machine tools since by using lathe different operations can be performed. Normally the customer is satisfied by the supplier through quality, cost and delivery of the part or product. Nowadays quality can be achieved in machined part or product by achieving desired surface roughness mainly. Even though surface roughness is mostly considered as important one the other parameter hardness can also be considered equally along with surface roughness.

In order to ensure the maximum hardness in Metal parts it is important to study about the operating tool parameters such as spindle speed, feed and depth of cut based on work piece materials, cutting tools, type of machine tools whether manual or CNC etc.,

Earlier researchers concentrated mainly on surface roughness and optimized the respective cutting parameters for different materials like ferrous, non-ferrous, alloys and non-metals like plastics, wood etc., not many researchers have been made focussing on work piece hardness.

In this project Material EN353 (forged case hardening steel)selected for experimental set up in a CNC lathe to optimize the cutting parameters to obtain maximum hardness and based on output results and further recommendations for future study. Material forged steel like EN353 plays important role in textile (spindles, gears)and machine tool (spindle, gears, turrets, cams, Geneva mechanisms) industries for sustaining quality throughout life period. Hence this material forged steel is proposed for optimizing the cutting data by sing Taguchi approach in a lathe, focusing not to loose the job's hardness.

2. MATERIAL SELECTION

Here the material EN353 forged steel has been selected for experimental study purpose En353 material is a first choice for heavy duty applications mostly in the areas of automobile, machine tools, textile machineries and military applications for the parts like gears, cams, connecting rods, turrets, indexing plates, spindles, etc. Further EN353 material available at affordable cost.

The most vital factor is to maintain the hardness throughout the minimum life of the product. Due to this material's chemical composition and excellent mechanical properties like tensile strength, ductility, shock résistance, fatigue resistance, low thermal conductivity this material widely selected for the industrial field applications.

2.1. EN353 MATERIAL COMPOSITIONS

A typical material composition of EN 353 is tabulated here, refer table 2.1.

TABLE 2.1 – CHEMICAL COMPOSIION OF EN 353 FORGED STEEL

Element	C	Mn	Si	S	P	Cr	Ni	Mo
%	.20 MAX	.50 - 1.00	.35 MAX	.040	.040	.75 - 1.25	1.00 - 1.50	.08 - .15

Rest = Fe(Iron)

Since most of the required elements present in this type of forged steel to sustain properties of life of product, this material has been chosen for experimental study to optimize the parameter with a aim to maintain the maximum hardness.

3. INTRODUCTION TAGUCHI METHOD

The Taguchi method involves reducing the variation in a process through robust design of experiments. The overall objective of the method is to produce high quality product at low cost to the manufacturer. The Taguchi method was developed by Dr.Genichi Taguchi of Japan who maintained that variation. Taguchi developed a method for designing experiments to investigate how different parameters affect the mean and variance of a process performance characteristic that defines how well the process is functioning. The experimental design proposed by Taguchi involves using orthogonal arrays to organize the parameters affecting the process and the levels at which they should be varies. Instead of having to test all possible combinations like the factorial design, the Taguchi method tests pairs of combinations. This allows for the collection of the necessary data to determine which factors most affect product quality with a minimum amount of experimentation, thus saving time and resources. The Taguchi method is best used when there are an intermediate number of variables (3 to 50), few interactions between variables, and when only a few variables contribute significantly.

Taguchi arrays can be derived or looked up. Small arrays can be drawn out manually; large arrays can be derived from deterministic algorithms. Generally, arrays can be found online. The arrays are selected by the number of parameters (variables) and the number of levels (states). Analysis of variance on the collected data from the Taguchi design of experiments can be used to select new parameter values to optimize the performance characteristic. The data from the arrays can be analyzed by plotting the data and performing a visual analysis, ANOVA, bin yield and Fisher's exact test, or Chi-squared test to test significance.

3.1.DETERMINING PARAMETER DESIGN

The effect of many different parameters on the performance characteristic in a condensed set of experiments can be examined by using the orthogonal array experimental design proposed by Taguchi. Once the parameters affecting a process that can be controlled have been determined, the levels at which these parameters should be varied must be determined. Determining what levels of a variable to test requires an in-depth understanding of the process, including the minimum, maximum, and current value of the parameter. If the difference between the minimum and maximum value of a parameter is large, the values being tested can be further apart or more values can be tested. If the range of a parameter is small, then fewer values can be tested or the values tested can be closer together. For example, if the temperature of a reactor jacket can be varied between 20 and 80 degrees C and it is known that the current operating jacket temperature is 50 degrees C, three levels might be chosen at 20, 50, and 80 degrees C. Also, the cost of conducting experiments must be considered when determining the number of levels of a parameter to include in the experimental design. In the previous example of jacket temperature, it would be cost prohibitive to do 60 levels at 1 degree intervals. Typically, the number of levels for all parameters in the experimental design is chosen to be the same to aid in the selection of the proper orthogonal array.

Knowing the number of parameters and the number of levels, the proper orthogonal array can be selected. Using the array selector table shown below, the name of the appropriate array can be found by looking at the column and row corresponding to the number of parameters and number of levels. Once the name has been determined (the subscript represents the number of experiments that must be completed), the predefined array can be looked up. Links are provided to many of the predefined arrays given in the array selector table. These arrays were created using an algorithm Taguchi developed, and allows for each variable and setting to be tested equally. For example, if we have three parameters (voltage, temperature, pressure) and two levels (high, low), it can be seen the proper array is L4. Clicking on the link L4 to view the L4 array, it can be seen four different experiments are given in the array. The levels designated as 1, 2, 3 etc. should be replaced in the array with the actual level values to be varied and P1, P2, P3 should be replaced with the actual parameters (i.e. voltage, temperature, etc.)

3.2. STEPS IN TAGUCHI PROCESS

A pictorial depiction of these and additional possible steps, depending on the complexity of the analysis provided below.

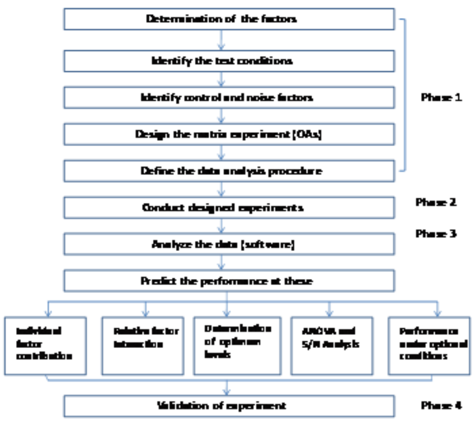


Fig. 3.1 Taguchi process steps

3.3 TAGUCHI L9 ARRAY

Taguchi L9 method of selecting parameters for conducting experimental study is the simplest method to optimize the cutting parameters.

Here 3 parameters like spindle speed(P1), feed(P2) and depth of cut(P3) can be adopted in material tests as per formulated L9 array by Dr Genichi Taguchi and the L9 array table is as per the below table 3.1

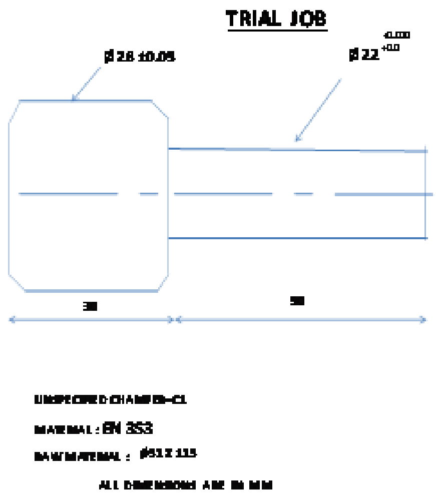
Table 3.1 - Orthogonal L9 Array of Taguchi

Experiment Trail No	P1	P2	P3
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

4. WORK PIECE DETAILS

The Work material for this study is EN 353 forged steel .The raw material size diameter 32 x Length 125 mm and the initial trial conducted with quantity 9 numbers .The dimensions of work piece for investigation made as per figure No 5.1.The machine for trial is a CNC lathe, ACE designers make and trial conducted at M/s ORANGE AUTOMATION, Coimbatore.

Figure – 4.1 Job for Experimental Study



4.1 MACHINING PROCESS

The machining trial conducted on a medium duty CNC lathe JOBBER xl with a through away type carbide coated insert VNMG 150408 made by M/s TAGUETEC. Trials conducted as per Taguchi L9 array first and hardness checked in Rockwell hardness tester Using steel ball and measured in HRB scale.

Figure 4.2 – Experimental Setup To Measure Hardness by Machining

The control cutting parameters for the material is selected and it is given in table 4.1.Trial made as per cutting data's with respect to table 4.2

Table4.1 Factors And Levels For En353 Forged Steel

Level	Spindle speed (rpm) N	Feed rate (mm/rev) F	Depth of cut (mm)
1	1590	0.1	0.75
2	1790	0.2	1.0
3	1990	0.3	1.2

Table 4.2 – Cutting Data for L9 Array

Experiment	Spindle Speed RPM	FEED mm/min	Depth of Cut mm
1	1590	0.1	0.75
2	1590	0.2	1.0
3	1590	0.3	1.2
4	1790	0.1	1.0
5	1790	0.2	1.2
6	1790	0.3	0.75
7	1990	0.1	1.2
8	1990	0.2	0.75
9	1990	0.3	1.0

The machining process carried out as per Table 4.1&4.2 for 9 pieces and after completion the output hardness checked in the work piece diameter (22 mm portion) and recorded .The hardness checked at SITARC testing centre by Rockwell hardness tester and recorded as per table 4.3.

Table 4.3 Observed Hardness Values- Rockwell – HRB Scale

TRIAL No	SPINDLE SPEED RPM	FEED MM/MIN	D.O.C MM	OBSERVED HARDNESS VALUE - HRB
1	1590	0.1	0.75	90.3
2	1590	0.2	1.0	89.1
3	1590	0.3	1.2	91.3
4	1790	0.1	1.0	90.1
5	1790	0.2	1.2	91.5
6	1790	0.3	0.75	91.8
7	1990	0.1	1.2	92.1
8	1990	0.2	0.75	93.1
9	1990	0.3	1.0	93.5

5. RESULT AND DISCUSSION

As per the hardness values tabulated in table No 4.3, it was observed that in turning operation of machining forged steel EN353 the maximum hardness is maintained in 9th trial of Taguchi orthogonal array. That is maximum hardness maintained in the work material (EN 353) while adapting maximum spindle speed, maximum feed and medium depth of cut.

Research may be planned further to carry over further and to find Signal to noise ratio(S/N ratio) and hardness using software techniques for analysing purpose. It may carry over further for experimental study by using L27 orthogonal array to optimize the cutting parameters to more precise level.

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