Experimental investigation on the barrelling phenomenon in Turning Process

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Abstract. In the turning process, the quality of the working surface depends on the operating parameters. In this work method was used Taguchi to study the effect of operating transactions on the surface quality of the operator (the barrel). In this study four parameters were used which are sample length (L), sample diameter (D), feed rate (F), and cut depth (T). The objective of this work is to improve the quality of the surface of the machine through the control of the main input parameters for the process of turning aluminum and steel materials. It was selected orthogonal group L9 to study the impact of key factors on the variable response, i.e. barreling. The contribution of key factors and their interaction with the optimal level were determined using ANOVA. The results showed that the cutting depth was 0.5 mm and the feeding rate was 0.5 mm/rotation yields minimum barreling. In addition, ANOVA results indicated that among four major factors, the specimen diameter and cut depth significantly contributed to reducing barreling.

1. Introduction
In the manufacturing industry, surface finishing is a special advantage in reaching the maximum production at the lowest cost, while the quality of the surface and the accuracy of operation depend on several factors in addition to the abuse of the operator itself. On the other hand, the cutting process may take a periodic direction in its development. In the sense that the cutting forces gradually increase until they reach the breaking force of the cut, then the cutting force drops to a small amount and then returns to a second cycle. This is done periodically and continuously, the cutting tool collides with the sample and the operator's surface becomes weak and affects the performance of the mechanical parts. Daniel et. al [1] His study on the effect of procedure parameters (cutting speed, feeding rate and cutting depth) on the material removal rate (MRR) during Melt Carbon Steel CS 1030 conversion using Taguchi experimental design. ANOVA displays that feeding rate needs the most important role in MRR production, followed by cutting speed. The communication between feeding and speed has an important impact on the rate of removal of substances. Dr. C. Rao [2] explain the importance of speed, feeding rate and depth of cut on cutting force and surface roughness during work the results designated that the feeding rate, cutting depth, feed rate have a significant impact on the cutting force. If minimizing energy consumption is the best possible finish of the surface. Yusuf Sahin and Ali Motorcu [3] Development of mathematical models to predict surface roughness through three parameters of cutting speed, cutting depth and feed rate. RSM was used to achieve these equations. It was a steel AISI 1040 material work. The results showed that the feed rate is the main influencing factor. It was observed that the surface roughness increases with the rate of nutrition, but less than increasing the speed of cutting and cutting. Suhail et. al [4] He studied how to improve the cutting
parameters using two measures of performance, surface temperature and surface roughness. The optimal cutting parameters were found for each performance measurement using Taguchi techniques. The use of orthogonal array, signal to noise ratio and change analysis to study the characteristics of performance in the transformation process. The experimental results showed that the workpiece surface temperature can be effectively sensed and used as an indicator to control particle performance and improve the optimization process. Manisekar and Narayanasamy [5] Of the study, we found the radius of curvature of the barrel size to confirm with the calculated value. The calculations on the assumption that the curvature of the barrel follows the arc geometry ring. The establishment of the relationship between the half of the measured diameter of the curvature of the barrel and the parameter of the proportion of stress. Schey et al [6] that the shape of the barrel is Influenced by factors such as engineering h0 / d0 Ratio and the percentage of reduction ratios and diameter. They expressed that the power law could represent Pipe clips samples of steel and aluminium Good conditions for both low and high friction. Tseng et al [7] Find out that the shape of the pipe can be reasonable It characterized as a circle or arc curvature of the circular. Kulkarni and Kalpak Jian [8] showed through his study that the barrel shape in the samples used Al7075 can be well represented by a circular arc during upset forging. Kobayashi [9] Note through experiments that the effect of the pipe is more with increasing friction. Found Mahesh et al [10] that the greater deformation when the contact surfaces, there is an increase in the diameter of the bulge alloys Al-10Si basic compounds.

Contributes to the selection of appropriate parameters such as cutting depth and feed rate and the length of the sample and the sample diameter in the process of improving the quality of the surface and reduce defects caused during operation. The application design method Taguchi, a statistical method, the experiment to get the best results for cutting operations at the lowest cost. In this work, a new input parameter, namely, length and diameter of the specimen were entered. The aim of this work is to improve the key input parameters (F, L, D, and T) for the turning process and thus improve the quality of the machining part through studying the relation between these parameters with the barreling phenomenon for two type of materials.

2. Experimental Work
Specimens of standard length 6000 mm were cut into the following dimensions (500, 750, and 1000) mm, with different diameters of (10, 25, and 40) mm. Four variables were used to enter transactions with three levels for each variable for the formation of steel and aluminium alloy as shown in Table (1). Two types of materials were used in the current work, the first one is alloy steel, which is commercially called as (AISI 4140). Whereas, the other material is aluminium alloy (AA7075-T6). The lathe machine shown in figure 1 was used to machine the specimens. It was kept at fixed speed spindle of 500 rpm, while the use of three levels for other parameters such as F, L, D, and T was done according to the design of experiments (DOE) methods of the most comprehensive in the product using Taguchi method. It provides a simple, effective and systematic way to improve designs in terms of performance, quality and cost. The cutting parameters required are determined based on experience or by the handbook. It was created by the application (Minitab, 17), which will produce as much information as the minimum number of experiments. Using the Taguchi method to design the experiment with the Minitab program. The array has nine experiment runs using parameters are executed by machining and their size levels as shown in Table (2).
**Figure 1.** The picture shows the lathe machine used in the current study.

| Parameter        | Symbol | Unit   | Levels      |
|------------------|--------|--------|-------------|
|                  |        |        | 1    | 2    | 3    |
| Length           | L      | Mm     | 500  | 750  | 1000 |
| Diameter         | D      | Mm     | 10   | 25   | 40   |
| Feed             | F      | mm/rev | 0.5  | 1.0  | 1.5  |
| Depth of cut     | T      | Mm     | 0.5  | 1.0  | 1.5  |

**Table 2.** Using orthogonal array L9 Taguchi with levels of parameters

| Exp. No | L (mm) | D (mm) | F (mm/rev) | T (mm) |
|---------|--------|--------|------------|--------|
| 1       | 50     | 10     | 0.5        | 0.5    |
| 2       | 50     | 25     | 1          | 1      |
| 3       | 50     | 40     | 1.5        | 1.5    |
| 4       | 75     | 10     | 1          | 1.5    |
| 5       | 75     | 25     | 1.5        | 0.5    |
| 6       | 75     | 40     | 0.5        | 1      |
| 7       | 100    | 10     | 1.5        | 1      |
| 8       | 100    | 25     | 0.5        | 1.5    |
| 9       | 100    | 40     | 1          | 0.5    |
The studying model is shown in figure (2) was used to predict the barreling phenomenon under study. It was expected to occur, as it was expected that the length and the diameter has a clear impact on the phenomenon.

The thickness of the layer to be removed from the surface of the specimen is often called as the depth of cutting (T), which can be calculated from the equation (1). Due to the barreling dimension value (B3) is different along the specimen length, the B3 can be calculated from the equation (2), which is derived for this case. The term ((D0-Di) /2) from the equation (2) represents the real depth of cut, which builds up as a result of the deflection in the specimen during the turning process.

\[ T = \frac{D_0 - D_1}{2} \]  \hspace{2cm} (1)

\[ B_i = T - \frac{D_0 - D_i}{2} \]  \hspace{2cm} (2)

Where: Bi is the barreling at i zone (mm); i = 2, 3, and 4; T is the depth of cut (mm); D0 is the diameter of the rod to be machined before machining (mm); D1 is the required diameter of the rod after the machining process (mm); D2 is the diameter of the machined rod at starting zone (mm); D3 is the diameter of the machined rod in the middle of the rod (mm); D4 is the diameter of the machined rod at the end zone (mm).

3. Results and Discussion

The results of the experimental part obtained using the lathe machine and analyze the result using the ANOVA method. The average of at least four values was calculated for each response, such as sample length, sample diameter, feed rate and depth of cut, obtained after taking steps to design the Taguchi methodology. The analysis of the data obtained to determine the optimal levels of parameters that have an important role in determining the quality of the surface. The next step includes a statistical analysis of the results obtained for the parameters of operating using ANOVA to describe the effect of the input parameters on the responses.
The barrel is an indicator of quality in this study. Data were collected during the barrel experiments. Analysis of variance as a result of the four main factors for aluminum alloys are shown in Table (3). The main objective of the statistical analysis ANOVA is the study of design parameters and determine the parameters that significantly affect the quality of the surface of the operator. You can also use the F test to determine the parameter that have the greatest impact on the response. From this preliminary analysis, it is possible to determine the most important factor, which has a value of P is smaller or larger F value. Form of a table (3), it is easy to determine that the most important factor, which affects the construction of the pipe in the center of the sample is D contribution of 42%, followed by T contribution to 38%, while the F and L have less impact on after the pipe. The results of ANOVA show for B3 strong depending on the D and T as the most important factors. It is clear that the diameter and depth of the pieces have a major impact on the value of the pipe. This belongs to the strong relationship between B3 and both D and T according to the equation (2). Figure shows (2) the interaction between the D and T, B3 for bars AL. It is clear that the pipe increases with both D and T, and appears to be 40 mm diameter is more stable and that the amount is relatively small compared to the smaller diameters B3.

![Graph](image)

**Fig. (3)** The plot illustrates the interaction between the cutting depth and specimen diameter vs. B3 Aluminum

| Source | DOF | Seq. SS  | Adj. MS  | F-value | P-value | Percent contribution |
|--------|-----|----------|----------|---------|---------|----------------------|
| L      | 1   | 0.25627  | 0.256267 | 11.21   | 0.029   | 14.84%               |
| D      | 1   | 0.71760  | 0.717604 | 31.39   | 0.005   | 41.57%               |
| F      | 1   | 0.00107  | 0.001067 | 0.05    | 0.840   | 0.06%                |
| T      | 1   | 0.66002  | 0.660017 | 28.87   | 0.006   | 38.23%               |
| Error  | 4   | 0.09145  | 0.022863 | 0.87    | 0.621   | 5.30%                |
| Total  | 8   | 1.72641  |          |         |         | 100.00%              |

**R-Sq. = 94.70%**

*The total error is a: Error/Total = (0.09145/ 1.72641) * 100 = 5.30%*

ANOVA results of barreling in alloy steel shown in the Table (4). It is easy to determine that the most important factor affecting the construction of the pipe in the center of the sample is T with a contribution of 42%, followed by D contribution of 34%, while the F and L for two Less impact on barreled distance. The ANOVA score for B3 shows a strong dependence on T and D as the most
important factors. Obviously, the diameter and depth of the cut have a major influence on the pipe value. Figure 2 shows the interaction between T and D vs. B3 steel bars. The pipe obviously increases with increase in both T and D. 40 mm in diameter appears to be more stable and the amount of B3 is relatively small compared to smaller diameters. This can be attributed to the rigidity of the 40mm diameter rod, and so less deflection may occur, it is clear that the increase of T leads to increase the cutting force and hence leads to increase the deflection. This can give a reasonable explanation of increasing in the barreling with an increase of the T.

![Figure 2](image)

*Fig. (4) Interaction between cutting depth and specimen diameter versus B3 sample alloy steel*

| Table 4. ANOVA for B3(AISI 4140) versus L (mm); D (mm); F (mm); T(mm) |
|-------------|-------|---------|--------|---------|-----------------|
| Source      | DOF   | Seq. SS | Adj. MS | F-value | P-value | Percent contribution |
| L           | 1     | 0.10667 | 0.263935 | 2.30    | 0.204   | 8.59%             |
| D           | 1     | 0.42400 | 0.106667 | 9.16    | 0.039   | 34.16%            |
| F           | 1     | 0.00004 | 0.424004 | 0.00    | 0.979   | 0.00%             |
| T           | 1     | 0.52510 | 0.000038 | 11.34   | 0.028   | 42.31%            |
| Error       | 4     | 0.18524 | 0.525104 |         |         | 14.93%            |
| Total       | 8     | 1.24105 | 0.046309 |         |         | 100.00%           |

R-Sq. = 85.07%

*The total error is a: Error/Total = (0.18524/1.24105) * 100 = 14.93%*
Fig. (5) A chart shows a comparison between the barreling at different measured point.

4. Conclusions

After analysing the results in a process of transformation using 9 experiments were used to cover the design presence of each of the four pieces parameters (diameter sample, the sample length, feed rate, depth of shear) and there were three levels to determine the value of Barrelling using analysis of variance (ANOVA), regression. Analysis and how to improve Taguchi, the following can be inferred from this study:

1. The most important input parameters that affect the size of the barrel is the diameter and depth of the sample followed by cutting the length of the sample, while the feed rate is not important.
2. Can get the best samples for samples of surface quality and composition, with a minimum size of the cylinder (B3) is about 0.17 mm for samples Al and 0.23 mm steel samples using the best settlement cut standards, any pieces of 0.5 mm diameter sample 40 mm depth.
3. The aluminium material results showed that the most important input coefficients affecting the pipe are D (with a contribution of 41.57%) followed by T (with a contribution of 38.23%), while the feed rate has little effect. The same results were performed on steel materials, but with a contribution of 34.16% for D and 42.31% for T.

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