Determination of Surface Roughness Throughout CNC Turning of ASTM 316 Steel Expendng Taguchi Method

Shweta Sikta Swain, N. K. Kund

Abstract: Plan of experiment involving Taguchi method got developed and executed to gauge impact of various machining variables (V, F and D) on surface roughness throughout CNC turning of ASTM 316 steel using coated carbide insert. Research findings through different mathematical analyses provided the effective guideline for choosing appropriate machine settings to realize surface roughness within the recommended range during stated turning operation. Ideal machining situations got determined to minimize the surface roughness (here surface roughness factors $R_u$ with $R_s$) in turning of the same. Feed remains observed as paramount momentous variable for workpiece surface roughness. Furthermore, cutting speed remains observed as subsequent paramount momentous variable for workpiece surface roughness. Additionally, depth of cut remains observed as least paramount momentous variable for workpiece surface roughness. $R_u$ only, however, depth of cut got absolutely insignificant impression on $R_s$. Present investigation clearly reveals that multicoated carbide inserts performed splendidly at optimal machining variables combination of $V = 150$ m/min, $F = 0.10$ mm/rev with $D = 0.4$ mm. Calculated ideal limit of sample surface unevenness, $R_u$ and $R_s$ are 0.16 $\mu$m $\leq$ $R_u$ $\leq$ 0.52 $\mu$m and 1.4 $\mu$m $\leq$ $R_s$ $\leq$ 3.1 $\mu$m, respectively. Moreover, surface roughness, $R_u$ is also within stipulated precarious limit of 1.5 $\mu$m (i.e. $R_s$ $< 1.5$ $\mu$m) for turning with coated carbide inserts.

Index Terms: Surface Roughness, CNC Turning, ASTM 316 Steel, Taguchi Method, Machining Variables, Workpiece.

I. INTRODUCTION

Metal cutting remains as the supreme significant practice for removal of undesirable material in manufacturing of any kind of modules. It is a machining practice where finished surface of preferred shape and size gets produced through detachment of superfluous materials stratum in shape of chips using wedge like device termed as cutting tool. Metal cutting practice remains influenced through relative motion between workpiece and cutting tool. Metal cutting remains as forming practice occurring in cutting structural modules through supply power generating determined fracture of stratum actuality detached. Here, fracture happens because of collective/net stress encompassing bending stress. Key objective of machining practices (representative cases as demonstrated in figures 1-3) stand to transform workpiece for getting segment of desired geometry and surface quality using cutting tool through supreme concert throughout its epoch.

In machining practices, the major concern of customer requirements is surface roughness quality. Surface roughness remains primarily an outcome of process parameters like tool parameters/tool geometry (edge geometry, rake angle, nose radius, etc.) and machining variables/cutting conditions (V, F, D, etc.). Numerical or experimental evaluations on materials processing remain extant in collected works [1-7]. Computational and experimental researches stand also described [8-44].

Current research remains as examining the effect of machining variables on surface roughness throughout dry turning of ASTM 316 steel with multicoated carbide tool. Study includes determination of best levels of machining parameters for getting ideal the surface roughness parameters ($R_u$ with $R_s$) using Taguchi method. In addition, machining variables (i.e. V, F and D) got correlated with performance outcomes ($R_u$ with $R_s$).

Figure 1. CNC turning practice

II. EXPERIMENTAL DETAILS

A. Sample Preparation from Work Materials

ASTM 316 steel sample bars of 90 mm length and 50 mm diameter got heated up to appropriate austenizing temperature of 918 °C and kept at that temperature for about 25 minutes to realize desired modifications in crystalline structure. Subsequently, oil quenching of stated sample. Then, tempering by reheating the stated sample up to a pre-calculated temperature of 398 °C (just below lower critical temperature limit) for about 1.5 hours. Thereafter, air cooling for removing residual stresses aimed at structural homogenization.
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B. Cutting Inserts

Multicoated inserts fixed on tool holder got utilized in present practice. Cutting geometry of the same is as stated: clearance angle = 5°, rake angle = −5°, cutting edge inclination = −5°, major cutting edge angle = 92° besides nose radius = 0.7 mm. Overall cases, both back rake and side rake are equal to −6°. All inserts intended for current experimentations got same geometry (with negative rake angle).

III. EXPERIMENTAL PROCEDURES

Experimentations got performed for examining influence of V, F and D on surface unevenness (Rz or Rz). For that Taguchi method is used through above stated parameters at three different levels mentioned in Table 1. CNC turning (with speed limit 3000 rpm and power limit 15 kW) operations got performed for generating investigational data in dry situation. Initially, thin layer from workpiece sample surface got removed and then a hole got drilled on sample face for providing support at tailstock as shown in figure 4.

Surface roughness (Rz or Rz) of turned surface got measured expending a surface roughness tester. Critical surface roughness (Rz < 1.5 µm) is adopted for surface finish in present CNC turning.

Table 1. Machining variables with levels.

<table>
<thead>
<tr>
<th>Machining Variables</th>
<th>Levels</th>
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<tbody>
<tr>
<td>D (mm)</td>
<td>0.3 0.4 0.5</td>
</tr>
<tr>
<td>F (mm/rev)</td>
<td>0.1 0.15 0.2</td>
</tr>
<tr>
<td>V (m/min)</td>
<td>90 120 150</td>
</tr>
</tbody>
</table>

IV. RESULTS AND DISCUSSIONS

A. Demonstration of Experimental Results for Various Machining Process Parameters

The plan of experiment concerning Taguchi method remains developed and executed for evaluating effect of various machining variables like V, F and D on surface roughness throughout CNC turning of ASTM 316 steel using coated carbide insert. Twenty seven trials summarizes the experimental outcomes/observations aimed at surface roughness parameters. Lowest/least magnitudes/levels of surface roughness measures (Rz = 0.4 µm with Rz = 1.8 µm) got observed at F = 0.1 mm/rev, V = 150 m/min with D = 0.4 mm. Highest/uppermost magnitudes/levels of surface roughness measures (Rz = 2.4 µm with Rz = 9.8 µm) got enumerated at F = 0.2 mm/rev, V = 90 m/min with D = 0.4 mm.

B. Prediction of Optimal Design

Main effects plots (as demonstrated in figures 5 and 6) for momentous surface parameters (Rz and Rz) got developed and utilized for evaluating average surface roughness through ideal design situations. Useful levels of momentous surface parameters (Rz and Rz) got established for providing lesser magnitude of roughness. Feed level-1 with cutting speed level-3 (F1V3) usually provides smaller roughness magnitudes. However, practice of evaluating average value rests on additivity existence pertaining to factorial influences meant for accuracy predictions. As no dependency lays between two key parameters the values can remain added for getting lesser roughness magnitude.
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