Effect of Varying Surface Grinding Parameters on the Surface Roughness of Stainless Steel

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Abstract — Surface grinding is a very complex process to control yet it has very significant role in controlling the performance of the equipments and machine tools. Thus it is very important to analyse the process parameters by performing experiments. This is the purpose my research work in which I have tried to analyse the effect of varying surface grinding parameters on the surface roughness of Stainless Steel using white aluminium oxide grinding wheels. The main input parameters taken into consideration in this study are depth of cut, wheel speed and wheel grain size. Results are tabulated and plotted in form of comparison graphs for ease of analysis.

Keywords — Surface grinding, Surface roughness, Stainless steel, Grinding parameters, Grain size, Depth of cut, Wheel speed.

INTRODUCTION

Surface grinding is a material removal process that involves the interaction of abrasive grits with the workpiece at high cutting speeds and shallow penetration depths. The properties and grain size of these abrasive particles determine the performance of grinding operation. Each individual and irregularly shaped grain acts as a cutting element (single point cutting tool) in every grinding process. It is a mixture of cutting, plowing, and rubbing, with the percentage of each being highly dependent on the geometry of the grit. Surface grinding machines are used primarily to grind flat surfaces as in our analysis. It is a complex process to control because of a number of input parameters required to achieve the desired output of the operation. Most significant desired output parameter in surface grinding is the surface finish followed by other parameters like material removal rate, surface hardness, etc. Many input parameters like abrasive type, grain size, infeed, depth of cut, work speed, coolant used, etc control the surface finish of workpiece. Therefore a analysis is required to study the effect of input parameters on surface finish of various materials in surface grinding operation.

A number of studies have already been done to study the effects of input parameter in grinding process. Vishal Francis et. al. [1], stated that if feed and depth of cut were varied and spindle speed was kept constant to observe their effect on surface roughness then feed rate was found to be the most significant factor in case of cast iron and none of the factor was found be significant for mild steel and stainless steel. H. Adibi et. al. [2], stated that the amount of loading over the wheel surface increases sturdily with increasing depth of cut but is less affected by changes of table speed. Kirankumar R. Jagtap et. al. [3], Stated that the most influencing parameter to surface roughness for AISI 1040 is work speed (Nw) in rpm followed by depth of cut, grinding wheel speed and number of passes. Shih et. al. [6] proposed that, increasing the grinding wheel speed reduces the average chip thickness and increase the effective hardness of the wheel, resulting in more efficient workpiece material removal rates when the workpiece material is ceramic or steel. Hassui et. al. [8], proposed that, the wear of a grinding wheel has a direct effect on the workpiece vibration and both have effect on the workpiece quality. Nathan et al [9], proposed that, in the grinding process, a proper estimate of the life of the grinding wheel is very useful. When this life expires, redressing is necessary. Hardened C60 steel (Rc 40) specimens were ground with an A463 –K5–V10 wheel in a cylindrical grinding machine. The results revealed that the surface quality and in service behaviour of a ground component is affected seriously by the occurrence of grinding burn.

METHODOLOGY

This research takes into account the effect of mainly three process parameters of Surface grinding process i.e. Wheel Speed (rpm), Wheel Grain size and Depth of cut on Surface Roughness with reference to Mild Steel, Die Steel and Stainless Steel as workpiece material. All other process parameters of surface grinding operation are kept constant. Stainless steel is widely used in industry machinery, precision tools, automobiles and household products and these applications require different part surface finish values in order to achieve maximum performance and working life period. Therefore this analysis is done to study the effect of input parameters on surface finish of stainless steel in surface grinding operation. A horizontal spindle and reciprocating table type Surface grinder, White Aluminium Oxide grinding wheels and an average table speed (up grinding) of 0.15 m/s is used throughout the experiment. Synthetic soluble oil (oil to water ratio of 1:25) is used as cutting oil. Material plates are cut into required number of small specimens using Power hacksaw and Chop saw. A Variable frequency drive is used to vary the rpm (wheel speed) of the grinding wheel to three different values. A total of 27 experiments are done on each material by varying wheel grain size, wheel speed (rpm) and depth of cut. Separate mild steel plates of thickness thinner than workpiece specimen are used to hold small workpiece specimen tightly, for stainless steel because of its non ferrous nature. Later surface roughness of each specimen is checked using Mitutoyo Surface roughness tester with cut-off length as 0.25cm. Stainless steel specimen approx. size taken for experiment is 30 x 20 x 6 mm (Length x
Width x Thickness) and material composition is given in Table 3. Process variables and their levels and number of experiments required is formed using N-factorial method as shown in Table 4.

Table 1: Machine Description

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Type</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Working area of grinder</td>
<td>225 x 400 mm</td>
</tr>
<tr>
<td>2.</td>
<td>Maximum height under wheel</td>
<td>250mm</td>
</tr>
<tr>
<td>3.</td>
<td>Vertical feed graduation</td>
<td>0.01 mm</td>
</tr>
<tr>
<td>4.</td>
<td>Cross feed graduation</td>
<td>0.05 mm</td>
</tr>
<tr>
<td>5.</td>
<td>Maximum spindle speed</td>
<td>2800 rpm</td>
</tr>
<tr>
<td>6.</td>
<td>Grinding wheel size (dia x bore x width) (mm)</td>
<td>178 x 31.75 x 13</td>
</tr>
<tr>
<td>7.</td>
<td>Electric Motor</td>
<td>1HP 3 Phase (2800rpm)</td>
</tr>
<tr>
<td>8.</td>
<td>Magnetic chuck</td>
<td>200 x 300 mm</td>
</tr>
<tr>
<td>9.</td>
<td>Dresser with holder</td>
<td>1 CR</td>
</tr>
</tbody>
</table>

Table 2: Wheel Parameters

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Type</th>
<th>Specification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Wheel Material</td>
<td>A</td>
<td>Aluminium Oxide (White)</td>
</tr>
<tr>
<td>2.</td>
<td>Grade</td>
<td>K</td>
<td>Medium</td>
</tr>
<tr>
<td>3.</td>
<td>Structure</td>
<td>5</td>
<td>Dense</td>
</tr>
<tr>
<td>4.</td>
<td>Binder</td>
<td>V8</td>
<td>Vitrified</td>
</tr>
<tr>
<td>5.</td>
<td>Shape</td>
<td>1</td>
<td>Straight</td>
</tr>
<tr>
<td>6.</td>
<td>Dimensions</td>
<td>Dia x Bore x Width (mm)</td>
<td>150 x 31.75 x 13</td>
</tr>
</tbody>
</table>

Table 3: Material Composition

<table>
<thead>
<tr>
<th>Chemical Composition (%)</th>
<th>Stainless Steel T304</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon, C</td>
<td>0.08</td>
</tr>
<tr>
<td>Silicon, Si</td>
<td>1 Max.</td>
</tr>
<tr>
<td>Manganese, Mn</td>
<td>2 Max.</td>
</tr>
<tr>
<td>Phosphorus, P</td>
<td>0.045 Max.</td>
</tr>
<tr>
<td>Nickel, Ni</td>
<td>8 – 10.5</td>
</tr>
<tr>
<td>Sulphur, S</td>
<td>0.03 Max.</td>
</tr>
<tr>
<td>Chromium, Cr</td>
<td>18 – 20</td>
</tr>
<tr>
<td>Iron, Fe</td>
<td>Remaining</td>
</tr>
</tbody>
</table>

Table 4: Process variables and their Levels

<table>
<thead>
<tr>
<th>Levels</th>
<th>Grinding Wheel Grain Size</th>
<th>Grinding Wheel Speed (rpm)</th>
<th>Depth Of Cut (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>46</td>
<td>1300</td>
<td>0.01</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>2000</td>
<td>0.02</td>
</tr>
<tr>
<td>3</td>
<td>120</td>
<td>2700</td>
<td>0.03</td>
</tr>
</tbody>
</table>
RESULTS AND CONCLUSION

3.1 Experimental results: Surface roughness of all 27 specimens is measured using the Mitutoyo Surface Roughness tester and given in Table 5 below.

Table 5: Experimental results for Stainless steel

<table>
<thead>
<tr>
<th>Exp. No.</th>
<th>Material</th>
<th>Grain Size</th>
<th>Wheel Speed</th>
<th>Depth Of Cut</th>
<th>Surface Roughness, Ra μm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stainless Steel</td>
<td>46</td>
<td>1300</td>
<td>0.01</td>
<td>0.177</td>
</tr>
<tr>
<td>2</td>
<td>Stainless Steel</td>
<td>46</td>
<td>1300</td>
<td>0.02</td>
<td>0.185</td>
</tr>
<tr>
<td>3</td>
<td>Stainless Steel</td>
<td>46</td>
<td>1300</td>
<td>0.03</td>
<td>0.219</td>
</tr>
<tr>
<td>4</td>
<td>Stainless Steel</td>
<td>46</td>
<td>2000</td>
<td>0.01</td>
<td>0.140</td>
</tr>
<tr>
<td>5</td>
<td>Stainless Steel</td>
<td>46</td>
<td>2000</td>
<td>0.02</td>
<td>0.142</td>
</tr>
<tr>
<td>6</td>
<td>Stainless Steel</td>
<td>46</td>
<td>2000</td>
<td>0.03</td>
<td>0.155</td>
</tr>
<tr>
<td>7</td>
<td>Stainless Steel</td>
<td>46</td>
<td>2700</td>
<td>0.01</td>
<td>0.128</td>
</tr>
<tr>
<td>8</td>
<td>Stainless Steel</td>
<td>46</td>
<td>2700</td>
<td>0.02</td>
<td>0.134</td>
</tr>
<tr>
<td>9</td>
<td>Stainless Steel</td>
<td>46</td>
<td>2700</td>
<td>0.03</td>
<td>0.144</td>
</tr>
<tr>
<td>10</td>
<td>Stainless Steel</td>
<td>60</td>
<td>1300</td>
<td>0.01</td>
<td>0.138</td>
</tr>
<tr>
<td>11</td>
<td>Stainless Steel</td>
<td>60</td>
<td>1300</td>
<td>0.02</td>
<td>0.107</td>
</tr>
<tr>
<td>12</td>
<td>Stainless Steel</td>
<td>60</td>
<td>1300</td>
<td>0.03</td>
<td>0.109</td>
</tr>
<tr>
<td>13</td>
<td>Stainless Steel</td>
<td>60</td>
<td>2000</td>
<td>0.01</td>
<td>0.099</td>
</tr>
<tr>
<td>14</td>
<td>Stainless Steel</td>
<td>60</td>
<td>2000</td>
<td>0.02</td>
<td>0.096</td>
</tr>
<tr>
<td>15</td>
<td>Stainless Steel</td>
<td>60</td>
<td>2000</td>
<td>0.03</td>
<td>0.103</td>
</tr>
<tr>
<td>16</td>
<td>Stainless Steel</td>
<td>60</td>
<td>2700</td>
<td>0.01</td>
<td>0.111</td>
</tr>
<tr>
<td>17</td>
<td>Stainless Steel</td>
<td>60</td>
<td>2700</td>
<td>0.02</td>
<td>0.092</td>
</tr>
<tr>
<td>18</td>
<td>Stainless Steel</td>
<td>60</td>
<td>2700</td>
<td>0.03</td>
<td>0.095</td>
</tr>
<tr>
<td>19</td>
<td>Stainless Steel</td>
<td>120</td>
<td>1300</td>
<td>0.01</td>
<td>0.147</td>
</tr>
<tr>
<td>20</td>
<td>Stainless Steel</td>
<td>120</td>
<td>1300</td>
<td>0.02</td>
<td>0.134</td>
</tr>
<tr>
<td>21</td>
<td>Stainless Steel</td>
<td>120</td>
<td>1300</td>
<td>0.03</td>
<td>0.100</td>
</tr>
<tr>
<td>22</td>
<td>Stainless Steel</td>
<td>120</td>
<td>2000</td>
<td>0.01</td>
<td>0.185</td>
</tr>
<tr>
<td>23</td>
<td>Stainless Steel</td>
<td>120</td>
<td>2000</td>
<td>0.02</td>
<td>0.175</td>
</tr>
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<td>Stainless Steel</td>
<td>120</td>
<td>2000</td>
<td>0.03</td>
<td>0.169</td>
</tr>
<tr>
<td>25</td>
<td>Stainless Steel</td>
<td>120</td>
<td>2700</td>
<td>0.01</td>
<td>0.206</td>
</tr>
<tr>
<td>26</td>
<td>Stainless Steel</td>
<td>120</td>
<td>2700</td>
<td>0.02</td>
<td>0.202</td>
</tr>
<tr>
<td>27</td>
<td>Stainless Steel</td>
<td>120</td>
<td>2700</td>
<td>0.03</td>
<td>0.153</td>
</tr>
</tbody>
</table>
3.2 Graphs depicting the comparative results of effect of varying wheel grain size for a specific value of wheel speed on surface roughness of Stainless steel:

Surface finish comparison:

<table>
<thead>
<tr>
<th>Wheel Speed(rpm)</th>
<th>Grain size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1300</td>
<td>120 &gt; 60 &gt; 46</td>
</tr>
<tr>
<td>2000</td>
<td>120 &gt; 60 &gt; 46</td>
</tr>
<tr>
<td>2700</td>
<td>60 &gt; 120 &gt; 46</td>
</tr>
</tbody>
</table>

Surface finish of stainless steel decreases with increase in speed of Al₂O₃ wheels. On an average at every speed better surface finish is shown by grain size 120. Only at 2700 rpm, grain size 60 shows better finish as compared to 120 grain size. Surface finish varies largely with small grain size but less with large grain size wheel. Fig. 3.1d shows comparative results for surface finish.

3.3 Graphs depicting the comparative results of effect of varying wheel speed (rpm) for a specific value of wheel grain size on surface roughness of Stainless steel:
Stainless Steel shows better surface finish at lower speeds of Al₂O₃ grinding wheels for almost every grain size at maximum depth of cut. The surface finish is increasing with increase in wheel grain size. Due to good surface toughness value of stainless steel, there is a lot of grain wear and fracture at high wheel speed. But at large depth of cut, the grains are able to shear the surface better thus allowing more cutting action. Fig. 3.1d shows comparative results for surface finish.

CONCLUSION

Out of the three process parameters under study, most significant factor in surface grinding is wheel speed followed by grain size and depth of cut. Increasing wheel speed increases the tangential cutting force on material surface thus allowing more cutting and less of plowing and rubbing of grains. But this also increases stresses on Al₂O₃ wheel grains because of hardness and toughness of stainless steel, thus leading to high grain wear and abnormal fracture. This reduces the cutting action and causes more of plowing and grain rubbing against the metal surface. As all grain size particles fail to provide better surface finish a high wheel speeds, it is clear that Al₂O₃ particles fail to grind stainless steel. Thus should not be used for grinding stainless steel.

With increase in depth of cut, there is a proportional increase in the normal pressure at the point of contact of wheel and workpiece. Very less depth of cut will lead to less cutting and more rubbing or plowing due to small shear pressure or good toughness value of material. Large depth of cut will also lead to less cutting and more rubbing or plowing due to more wear, abnormal fracture and completely break-off of wheel grains. Thus an optimum value needs to be determined depending upon material and machine/process.
parameters.

Considering all the results we can say that in order to achieve minimum surface roughness with Al₂O₃ wheel, we need to choose an optimum value of grain size and depth of cut and a higher wheel speed or lower wheel speed for a certain material. Materials with good machining ability show better surface finish with higher wheel speed and materials with high toughness show poor surface finish with increasing grain sizes.

Studies like these can help to create a relation between independent and dependent variables in surface grinding process thus reducing the errors in design and improving the overall efficiency of the process which can lead to increase in productivity.

REFERENCES:


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