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An expeirmental investigation for the effect of surface grinding parameters on the produced sureface roughness

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Abstract

Surface grinding in industry is used as finishing process. The quality of the finished surface is largely dependent on the selected machining parameters. There is many other factors contribute in the surface quality, but the major contribution to improve the surface quality can be achieved by controlling the machining parameters.

Grinding concept is very complex random cutting process between many cutting edges on the wheel circumference and the workpiece. The functional behavior of machined components can be enhanced by the grinding process, so proper selection of the grinding parameters can result in improving the surface integrity. So that, understanding the surface integrity imparted by grinding is very important.

This paper introduced an experimental investigation to study the relation between some selected input parameters on the surface quality; the behavior of the grain along with the machining time is also investigated.

It is concluded that the surface roughness is influenced by changing the depth of cut and the feed rate. Increasing feed rate and depth of cut increase the normal and tangential forces; leading to higher surface roughness.

The depth of cut is the most significant parameter that affecting surface roughness.

The machining time affect the quality of the machined surfaces.

Keywords: Surface grinding parameters, Surface Roughness, ANOVA, SNR, Grain Condition.

1. Introduction

Workpiece accuracy and surface integrity are critical qualities which affecting the performance of machined components. Manufacturing companies confront the problem of meeting high-quality product requirements in terms of high strength, superior surface finishes, cheap prices, and decreased environmental consequences [1]. Surface roughness is a critical metric in many sectors since it indicates the quality of machined products' surfaces [2]. Selecting of machining parameters such as cutting speed, cutting depth, and feed rate may make manufacturing operations more efficient and optimal. Furthermore, surface roughness is a critical factor in determining the process accuracy [3-5]. The impacts of machining factors on the surface roughness of metals, alloys, and composites have been explored by several researchers.

Grinding is used as the last shaping procedure to achieve the appropriate surface roughness and accuracy of form features. A huge massive number of abrasive grains, dispersed on the outer circumference surface of the grinding wheel, serve as cutting tools and remove materials in this operation. The interaction of the workpiece with those grains during chip generation identifies the mechanical behavior of the workpiece. When grain is introduced into a machined material on a regular basis, it causes active workpiece and tool behavior, which can degrade surface quality and machining precision. Because each grain cuts the surface produced by the preceding grain, emerging vibration has forced vibration mechanism and a regeneration mechanism [6]. Vibration analysis necessitates evaluating the cutting forces under defined cutting circumstances.

Excessive cutting edge wear increases the contact area, which leads to increased heat output. Thermal distortions will occur on both the machine tool and the workpiece as a result of the increased heat, reducing the workpiece precision that can be achieved. One of the most limiting issues in grinding is heat damage. The use of lubricants, such as cutting fluids, can help to reduce the occurrence of thermal damage by removing the heat created in the cutting zone. Because cutting fluids operate as both lubricants and coolants, heat created by friction between the workpiece and the tool is reduced, reducing grinding forces and residual stress [7- 9].

Process parameters are often chosen based on the data book or operator expertise, however the drawback is that productivity suffers as a result. Thus more investigations for the effect of surface grinding parameters on the cutting forces and the produced surface roughness are required in the industry field.

[10] looked into the impact of different grinding settings on geometric error and the best grinding conditions.

[11–13] used the MQL approach to study the impact of different grinding settings on ABNT 4340 steel.

The Taguchi experimental design technique was used by [14] to investigate the impact of process parameters and dressing mode on force components and surface roughness.

This investigation focus on the feed rate and depth of cut as the variable machining parameters and revel there influence on the cutting forces generated and the produced surface roughness.

In this research analysis of variance (ANOVA) which is a statistical tool was employed for analyzing and process optimization.

Composition	C	Cu	Mn	P	S	Fe
%	0.2	0.18	1.03	0.04	0.05	98

Table (1) Chemical composition of ASTM A36 steel

2. Experimental setup and procedures

The experiments were conducted on Wellon machinery surface grinding machine model SG40A/1600, shown in fig. (1). The coolant was a mixture of saponification dissolved oil and water. The two components of grinding forces were measured by V-TECH Grinding Tool Dynamometer model 220B. Qualitest surface roughness tester model TR200 Surf Test was utilized to determine the results of surface roughness caused by surface grinding process.

Fig. (1) Surface grinding machine

2.1. Workpiece material

The workpiece chosen for this study was ASTM A36 mild carbon steel shown in fig. (2).The mild and hot rolled steel ASTM A36 is the most widely utilized. It is appropriate for grinding, punching, tapping, drilling, and machining process and has excellent welding qualities. The specimens (10 cm x 6 cm x 1.5 cm) were prepared by electric saw machine.

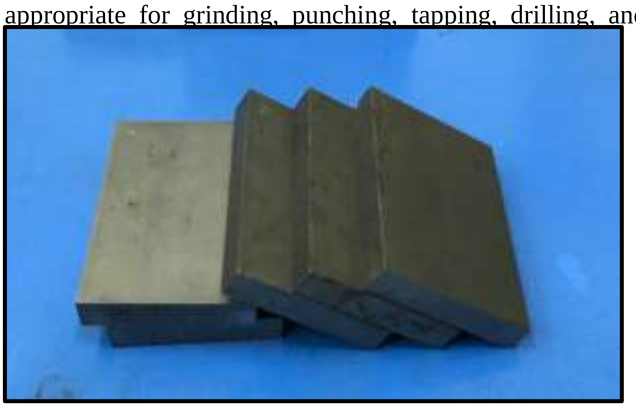


Fig. (2) Workpiece configurations

The Chemical composition of ASTM A36 steel which analyzed in STCEI lab is given in table (1).

2.2. Grinding wheel material

In this study an (WA-F46-K6-V40) grinding wheel is used as the tool. This wheel has dimensions of (350x40x127 mm).

The characteristics of the grinding wheel are given below:

- Density = 3890 kg/m^3
- Thermal conductivity = 18 W/m.k
- Thermal expansion coefficient = 1x10^{-5} K^{-1}
- Specific heat = 880 J/kg.k
- Elastic properties;
- Young's Modulus= 375 GPa and Poisson's ratio= 0.22

2.3. Surface roughness results

Surface roughness is a term used to describe the condition of a machined surface and is concerned with geometric imperfections and surface quality [15]. The arithmetic average Ra µm was used to measure the surface roughness, using the surface roughness tester model TR200 Surf Test shown in fig. (3).

Fig. (3) TR200 Surf Test

2.4. Cutting forces

The forces that existed during the grinding process are results of the resistance to penetration into the workpiece by grinding grains and as a result of plastic deformation in the tool and workpiece [16].

The Grinding tool dynamometer can measure simultaneously 3 forces in mutually perpendicular directions, i.e. X, Y and Z. Number of important points such as exact location of forces, the stiffness required, minimum cross sensitivity (i.e., minimization of effect of forces in one direction from the other), ability to withstand extraneous force, etc., have been considered in the design of V-TECH Grinding Tool Dynamometer.

The dynamometer uses strain gauges to measure the cutting forces A particular full bridge strain gauge connection have been employed for all orthogonal directions of the three forces inside the dynamometer. The outputs of these strain gauge bridges are available via the 12-pin connector sockets on the sensor body.

Fig. (4) V-TECH Grinding Tool Dynamometer- Model 220B sensor.

2.5. Experimental procedures

The selected machining parameters are as follow:-

Table (2) Factors and their levels

Machining Parameters	Units	Factors Levels				
		1	2	3	4	5
Feed rate	m/min	2.5	4	6	-	-
Depth of cut	mm	0.03	0.06	0.1	0.15	0.25

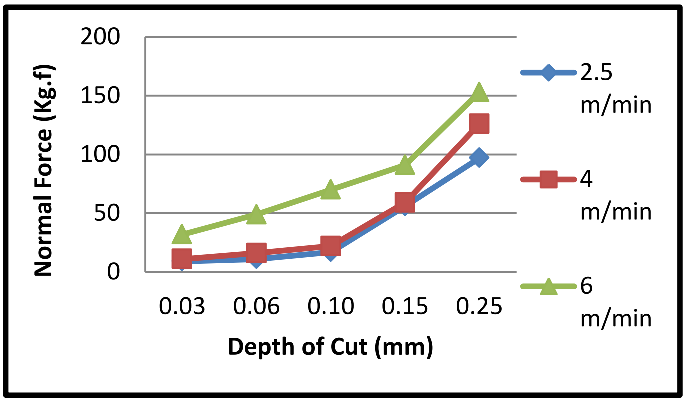
Coolant fluid is pumped into the tank and flushes above the specimen. Before machining each piece, the surface is ensured to be perpendicular on the grinding wheel and the dynamometer reading is equal to zero. Surface roughness is measured with Roughness Taster TR200 shown in fig. (3); four sampling points were taken with a sensitivity of 0.001 m for each specimen and a specified cut off value of 0.25 mm. On the specimens, roughness measures were taken in both the direction of side flushing and normal to that direction. The force is measured with V-TECH Grinding Tool Dynamometer shown in fig. (4).

3. Results and discussions

3.1. Effect on normal force

Fig. (5) shows how the normal force changes with changing the input parameters in grinding of ASTM A36 with high quantity of cooling. Different depths of cut and feed rates were used to obtain the results. It is observed that the as the feed rate and depth of cut increase, the normal force increases as well.

The normal force would be marginally increased by increasing the feed rate; however, increasing the depth of cut would result in the most significant increase in grinding force.



The picture of the V-TECH Grinding Tool Dynamometer is shown in fig.(4) below.

Fig. (5) Effect of depth of cut on the normal force with different feed rates

3.2. Effect on tangential force

Fig. (6) shows how the tangential force changes with changing the input parameters in grinding of ASTM A36 with high quantity of cooling. The results were achieved using a variety of cut depths and feed rates. As seen in fig. (6), raising the feed rate and depth of cut increases the tangential force. The cooling rate was controlled to be in higher rates than in dry/low quantity lubricant grinding, improving grain sliding between the tool and the work-piece, resulting in lower cutting force values as the experiment progressed. Increasing the feed rate would increase tangential force slightly, but increasing the depth of cut would result in the most significant rise in tangential force. As the depth of cut is increased, the average values of tangential force tend to rise as well. Because a large contact area between the grinding wheel and the work-piece is produced as the depth of cut increases, this phenomenon might be considered a consistent presupposition. As the number of grains in contact was higher, the strength to remove a greater volume of material rose, resulting in higher cutting forces.

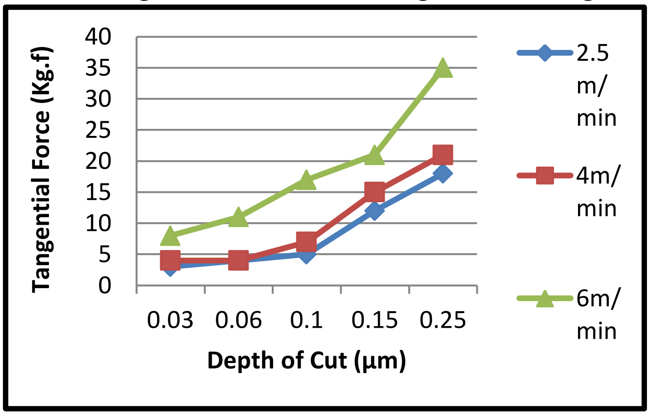


Fig. (6) Effect of depth of cut on the tangential force with different feed rates

3.3. Surface roughness results

Increases in feed rate and depth of cut, as shown in fig.(7), result in a significant increase in surface roughness. Because the tool's abrasive grains in the cutting region were effectively lubricated, the higher quantity lubricant approach provided lesser surface roughness. The use of higher cooling rates helped the grinding wheel's cutting edges to stay sharper for longer before they were renewed. Increasing feed rate would increase the surface roughness; on other hand increasing depth of cut will also lead to increase in the surface roughness, using the ANOVA and S/N ratio will reveal the most significant parameter upon them.

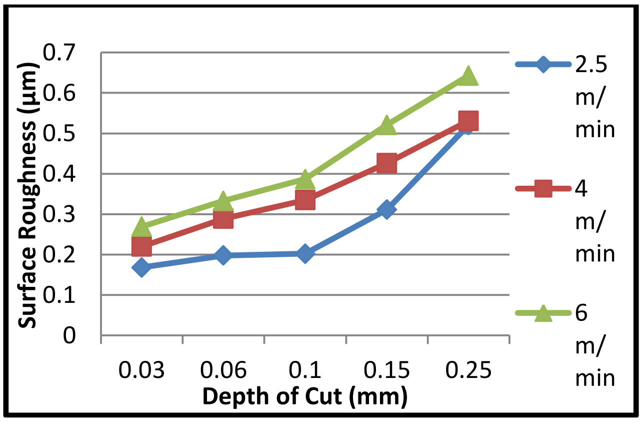


Fig. (7) Effect of depth of cut on the surface roughness with different feed rates

3.4. ANOVA and SNR

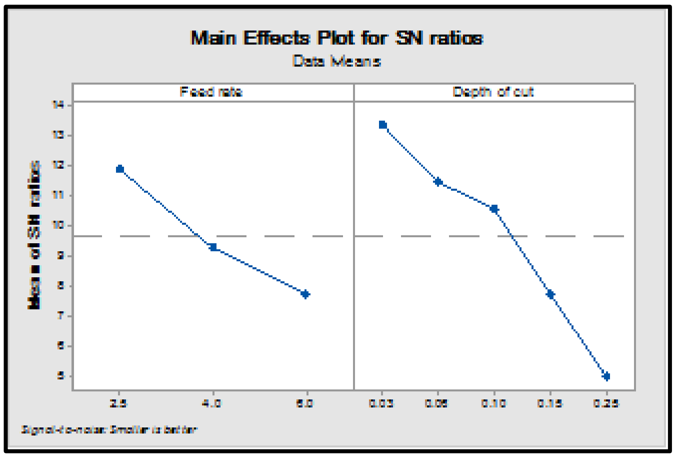
The significance and influence of the cutting parameters on the response variable were investigated using analysis of variance (ANOVA), and the best condition was determined using S/N ratio analysis.

Table (2) ANOVA Results on Surface Roughness

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Feed rate	2	0.056781	0.028390	31.11	0.000
Depth of cut	4	0.226784	0.056696	62.13	0.000
Error	8	0.007300	0.000913		
Total	14	0.290865			

Table (3) Response Table for Signal to Noise Ratios (Smaller is better)

Level	Feed rate	Depth of cut
1	11.852	13.350
2	9.269	11.467
3	7.740	10.546
4	7.740	
5	4.999	
Delta	4.112	8.351
Rank	2	1



Tables (3 and 4) shows that the depth of cut is the most influential factor on surface roughness, followed by feed rate. Also we can exclude the optimum parameters form the S/N ratio plot shown in fig. (8).

Fig. (8) Plot of the S/N ratio for surface roughness

3.5. Cutting grit behavior

An investigation is done by using the best combination parameters that we obtained in the previous part with different cooling techniques to study the cutting grit behavior and to reach the appropriate time to perform a dressing for the grinding wheel, if necessary.
The behavior of the cutting grit can be divided into 4 regions, as shown in fig. (9)

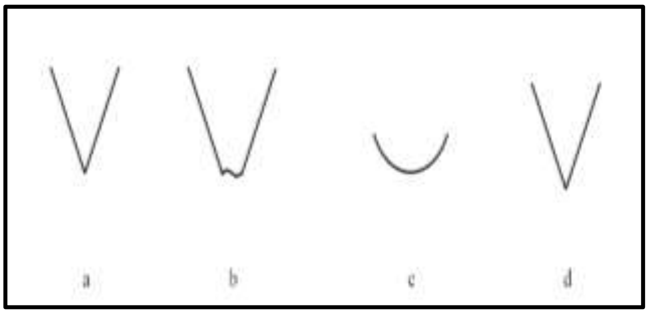


Fig. (9) Different forms for a single grit

Region a: At the beginning the grit is supposed to be sharp.

Region b: After a certain machining time, attrition of this sharp edge occurs.

Region c: As the machining continues, the cutting grit completely erodes to become a blunt grain.

Region d: The grit begins to dislodge and a new sharp grit is formed.

Fig. (10) shows that all the experimental cases have pass through the previously mentioned regions.

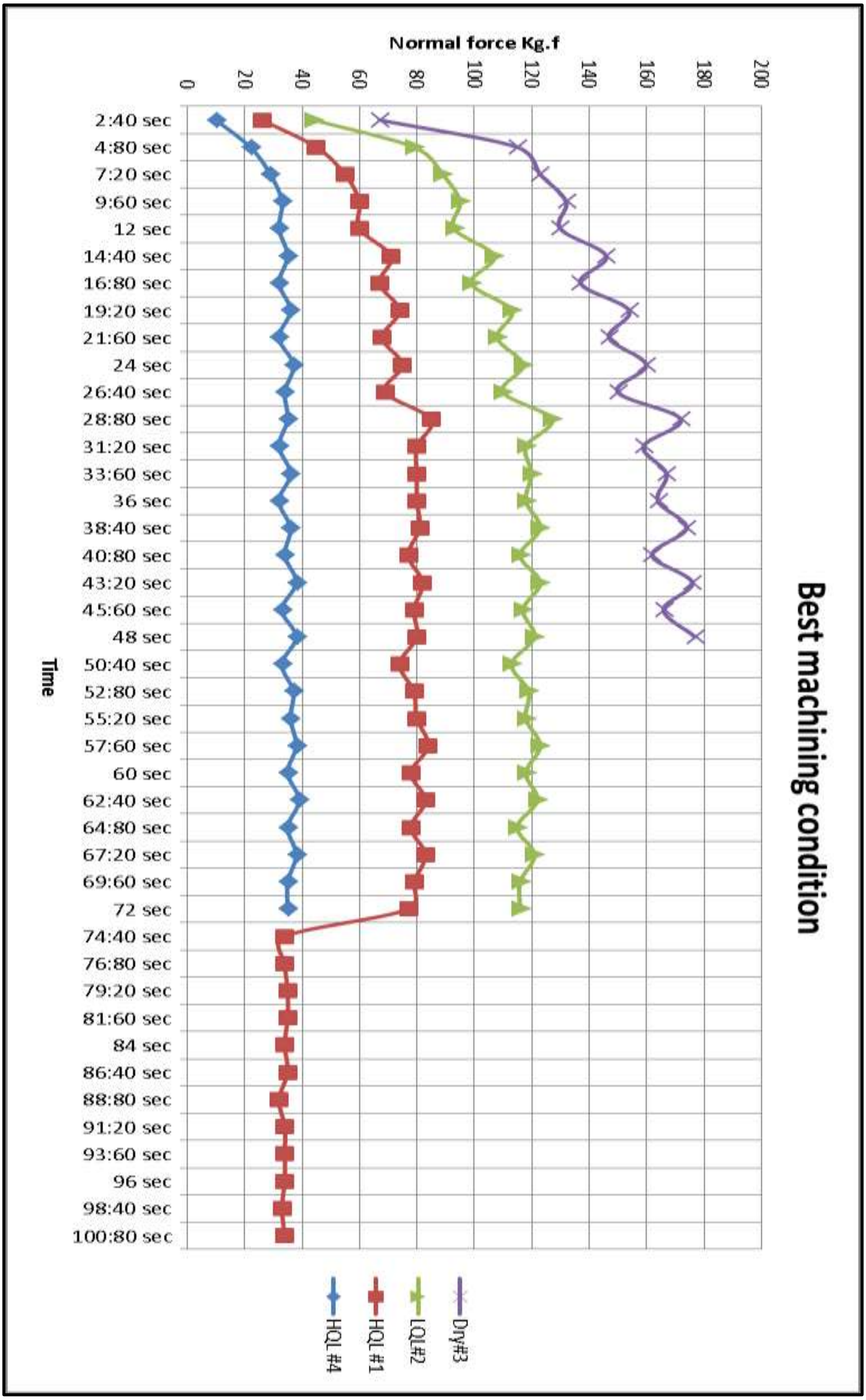


Fig. (10) Relation between the machining time and the max normal cutting force

machining start on samples 1, 2 and 3 the grinding wheel has been itched to remove any chips sticking to the grains and to create new sharp cutting edges.

Sample 1 is machined by using the best combination parameters with high quantity lubricant, in the time from the start of machining until about 2:40 sec, the values of the normal cutting force were small and thus the behavior of the grain follows the region a.

In the time from 2:40 sec until 26:40 sec, the values of the cutting force increased, which means that attrition of the sharp edge occurs, and thus the behavior of the grain follows the region b.

In the time from 26:40 sec until 72 sec, the values of the cutting force have greatly increased, which means that the cutting edges are completely eroded, and thus the behavior of the grain follows the region c.

In the time from 72 sec until 100:80 sec, the values of the cutting force are returned to be small, which means that the grain is dislodged and a new sharp edge is formed and thus the behavior of the grain follows the region d.

After this time the quality of the surface was measured and it was found to be 0.372µm and it is a quality that is relatively higher than the results obtained previously, which indicates the existence of a relationship between the machining time and the quality of the machined surfaces, this point may need an independent study.

The samples 2 and 3 were passed through the same regions in a relatively shorter time than the first sample. In the second sample a lower cooling technique was used. As for the third sample, no cooling was used, which means that there is an effect of the cooling efficiency also on the behavior of the grains as mentioned previously in part 3.2.

The quality of the surface for samples 2 and 3 were measured and found to be 0.913 µm and 2.515 µm respectively. Thus ensure that, there is an effect for the efficiency of the cooling on the quality of machined surfaces as it is previously indicated in part 3.3.

For sample 4 the grinding wheel was ground by using a dresser to make sure that we remove entire layer from the wheel circumference and all edges are sharp.

As the machining continues sample 4 passed through regions a, b only until the experimental selected time ended and didn’t pass through region c, d.

The quality of the surface for samples 4 was measured and found to be 0.202 µm and it is a quality that is slightly higher than the results obtained previously, which confirms that there is importance to make the grinding wheel sharp in order to produce a machined surface with high quality.

4. Conclusions

The effect of surface grinding parameters on the surface roughness of a grounded surface of (ASTM A36) mild carbon steel workpiece using an aluminum oxide wheel was investigated in this study. The effect of two important process parameters, feed rate and depth of cut, on the surface roughness of a grounded surface of (ASTM A36) mild carbon steel workpiece was determined at different test conditions.

The following are concluded from the investigation:-

1. Surface roughness increases as cutting forces increase.
2. The depth of cut and feed rate had a significant impact on surface roughness.
3. Increasing feed rate and depth of cut would increase the normal/tangential forces; corresponds for higher surface roughness.
4. The depth of cut has the greatest influence on surface roughness.

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