Effect Of Cutting Parameters On Surface Roughness And Cutting Tool Temperature In Turning AISI 1045 Steel

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Abstract:-

This work aims to study the effect of cutting speed and feed rate on surface roughness and tool temperature by prediction mathematical models from the experimental data using LAB-Fit Data software. The mathematical models have been used to study the behavior of both surface roughness which is considered an indicator of workpiece quality and tool temperature that is related to tool wear and surface roughness. The experiments were conducted on AISI 1045 carbon steel that has wide range of applications by using CNC turning machine under dry cutting condition. The results shows that surface roughness decreases with increasing cutting speed while it increases with increasing feed rate, also it has been noticed that the temperature of cutting tool increases with increasing both cutting speed and feed rate.

Keywords: - Turning, Cutting Speed, Feed Rate, AISI 1045 Steel, Surface Roughness.

الخلاصة:-

تم في هذا البحث دراسة تأثير كل من سرعة القطع ومعدل التغذية على خشونة سطح قطعة العمل ودرجة حرارة اداة القطع عن طريق التنبؤ بمعادلات رياضية والتي تعتمد على النتائج العملية اثناء عملية الخراطة باستخدام برنامج (LAB-Fit Data). استخدمت هذه النماذج الرياضية لدراسة سلوك الخشونة السطحية والتي تعتبر مؤشر لقياس جودة قطعة العمل وايضا لدراسة سلوك درجة حرارة أداة القطع والتي تؤثر على معدل الاحتكاك لأداة القطع من جانب وعلى الخشونة السطحية من جانب اخر. تم اجراء التجارب على قطعة عمل من الصلب الكربوني AISI 1045 والذي يستخدم في العديد من التطبيقات نظرا لسهولة تشغيله بواسطة ماكنة خراطة مسيطر عليها بالحاسوب وتم إجراء التجارب بدون استخدام سائل تبريد. أظهرت النتائج بأن الخشونة السطحية تقل بزيادة سرعة القطع بينما تزداد بزيادة معدل التغذية، وأيضا لوحظ بأن درجة حرارة أداة القطع تزداد بزيادة كل من سرعة القطع ومعدل التغذية.

1. Introduction:

Metal machining processes compromise a large part of the manufacturing filed, turning is considered the most important one of these processes due to the various shapes that can be manufactured by it. In turning a single-point cutting tool removes unwanted material from the surface of a rotating cylindrical work-piece. The cutting tool is fed linearly in a direction parallel to the axis of rotation [1].

The important issues in machining operations are minimizing cost of machining and producing the desired quality of the machined parts. Therefore an investigation of the effect of cutting parameters on workpiece quality has been adopted in this study, also the experiments were performed under dry cutting condition in order to reduce machining cost that is related to cutting fluids which are usually used in machining processes. Surface roughness is considered important indicator that specifies products quality due to its influence on mechanical properties of the produced parts as fatigue life and wear resistance [2, 3]. In turning, many parameters like cutting speed, depth of cut, feed rate, cutting tool geometry, cutting temperatures and cutting conditions that affect surface roughness of the products.

During cutting process most of the cutting energy transforms to heat because of the plastic deformation in shear zone, in addition to the frictional dissipation energy generated at the tool-chip interface and at the interface between tool and workpiece, this heat distributes among tool, workpiece and chip. Temperature at the tool-chip contact affects the seizure and the sliding conditions at this interface [3]. High temperature is not desired because it leads to accelerate tool wear and as a sequence produces high surface roughness and reduces tool life.

In this paper the effects of cutting speed and feed rate have been studied while the other factors were kept constant during the experiments, also the temperature of the tip of the cutting tool has been measured to control the process. AISI 1045 carbon steel was used as workpiece, which has wide range of applications because it machines readily. Typical applications of AISI 1045 steel are: various axles, bolts, connecting rods, hydraulic clamps and rams, various pins, various rolls, shafts, gears… etc.

2. Previous works and researches

The growing demands of machining operations attract the attention of many researchers to explore the behaviour of factors in turning process that affect surface quality and tool wear. The following researches are listed to cover the works of other researchers in this respect:

Murat Sarkaya et al [2] (2013), investigated the effect of cutting speed, feed rate, depth of cut and cooling condition on surface roughness in turning AISI 1050 steel by using CNC turning machine. The cooling condition involved dry cutting, conventional wet cooling and MQL. Taguchi design and response surface methodology were used to find optimal operating parameters and to create mathematical models for Ra and Rz. The results showed that feed rate is the most effective parameter on the surface roughness. MQL is a good tool to improve surface roughness.

Rogov Aleksandrovich et al [4] (2014), used Taguchi method and ANOVA analysis to find the effect of cutting parameters and tool construction on surface roughness and natural frequency in turning of AISI 1045 steel. Cutting speed, feed rate, depth of cut and cutting tool were the specified parameters under dry turning to study their effect on responses. Two types of cutting tool were investigated according to holder, standard cutting tool and cutting tool with holes in tool holder with carbide cutting insert coated with Tic for both. The results concluded that cutting speed has the significant effect on roughness, while tool overhang is the dominant factor affecting natural frequency for both cutting tools.

Sujan Debnath et al [5] (2015), presented an experimental work to study the effect of cutting conditions and various of cutting fluid levels on surface roughness and tool wear. The experiments were carried out on CNC turning machine and the work material was mild steel. Taguchi orthogonal design array was employed to minimize the number of experiment while ANOVA was chosen to determine the influence of cutting parameters on the responses values. The results showed that feed rate has the highest effect with (34.3%) on surface roughness. The flow rate of cutting fluid showed a significant contribution with (33.1%). Cutting speed with (43.1%) and depth of cut with (35.8%) were the dominant factors influencing tool wear. Optimum cutting factors for desired output were selected.

C R Barik et al [6] (2012), developed a mathematical model for surface roughness in CNC turning of EN 31 steel. Response Surface Methodology with the analysis of variance (ANOVA) were used to find the effect of spindle speed, feed rate and depth of cut on surface roughness. The results indicated that surface roughness decreases with increase in spindle speed and depth of cut but increases with increasing feed rate.

M. Cemal Cakir et al [7] (2009), investigated how cutting speed, feed rate and depth of cut can affect surface finish. In addition, two carbide inserts have the same geometry and substrate with different coating layers were considered as input parameters to find their influence on surface roughness. A mathematical model was obtained by the data gathered from turning experiments. The workpiece material was cold-work tool steel AISI P20. The results indicated that cutting speed has the greatest effect on surface roughness after feed rate, while depth of cut has no effect. The second insert was more efficient in high cutting speed and prevented vibration at lower cutting speeds.

Sthamizhmanii et al [8] (2007), studied surface roughness and tool wear in machining AISI 8620 steel by turning process with ceramic cutting tools. Cutting speed, feed rate and depth of cut were selected as cutting parameters in this study to find their influence on surface roughness and tool wear. The experiments had been performed under dry cutting condition and the results showed that surface roughness decreases when cutting speed increases, while tool wear increases with increase each of cutting parameters.

3. Experimental work

Lathe machine is the conventional machine that performs turning process which is controlled manually to change cutting parameters like spindle speed, feed rate and cutting depth. In the last decades the Computerized Numerical Control (CNC) machines have been developed, the CNC turning machine can make complicated shapes more precisely with less time and efforts, so it replaced the older machine rapidly. CNC turning machine of type FANUC (Series oi Mate-TC) was used in this study for turning the workpieces, which is shown in Figure 1.

Carbide cutting tool was used to cut a workpiece of 1045 steel with length of 90 mm and diameter of 45 mm. The experiments were performed without coolant and the temperature of tip cutting tool was recorded by infrared device of type UNI-Trend (UT303).

Surface roughness of the workpiece was measured after each process by surface roughness tester of type Qualitest TR-110, US, arithmetic average height (Ra μm) was depended. Different levels of cutting speed and feed rate were adopted at constant depth of cut equal to 1 mm, Table 1 shows the readings of both surface roughness and temperature.

Table 1: Experimental Readings of Surface Roughness (Ra) and Temperature at Different Cutting Speed and Feed Rate.

No.	Speed (rpm)	Feed (mm/min)	Ra (µm)	Temperature °C
1	200	50	10.08	28
2	300	50	6.09	34
3	400	50	4.6	42
4	500	50	1.93	48
5	200	100	12.77	35
6	300	100	6.99	48
7	400	100	4.2	59
8	500	100	3.38	62
9	300	150	11.21	45
10	400	150	8.99	55
11	500	150	6.37	71

Figure 1: CNC Turning Machine of Type FANUC (Series oi Mate-TC).

4. Theoretical work

To predict empirical equations of the experimental data the multiple regression method has been used. Mathematical models for surface roughness and temperature were established by using data-fit software. Surface roughness model is given by the equation 1 with good correlation coefficient (R^2) equal to 0.9824, Figure 2 shows the graph of the fitted model and Figure 3 shows the experimental and theoretical data of surface roughness together.

$$\boldsymbol{R_a} = 21.84 * \exp\left(\frac{77.79}{X_1} + 0.00334 * X_2\right) - 7.051 * \ln(\mathrm{X}_2) \qquad \text{…. (1)}$$

Where:

R_a : Surface roughness (μm).

X_1: Spindle speed (rpm).

X_2: Feed rate (mm/min).

Tip cutting tool temperature model is given by the equation 2 with good correlation coefficient (R^2) equal to 0.9766, Figure 4 shows the graph of the fitted model and Figure 5shows the experimental and theoretical data of tip tool temperatures together.

$$\boldsymbol{T} = 3.9308 * X_1^{\left(0.56133 - \frac{6.5945}{X_2}\right)} - 0.19782 * X_2 \qquad \text{…... (2)}$$

Where:

T: Tip temperature of the cutting tool.

X_1: Spindle speed (rpm).

X_2: Feed rate (mm/min).

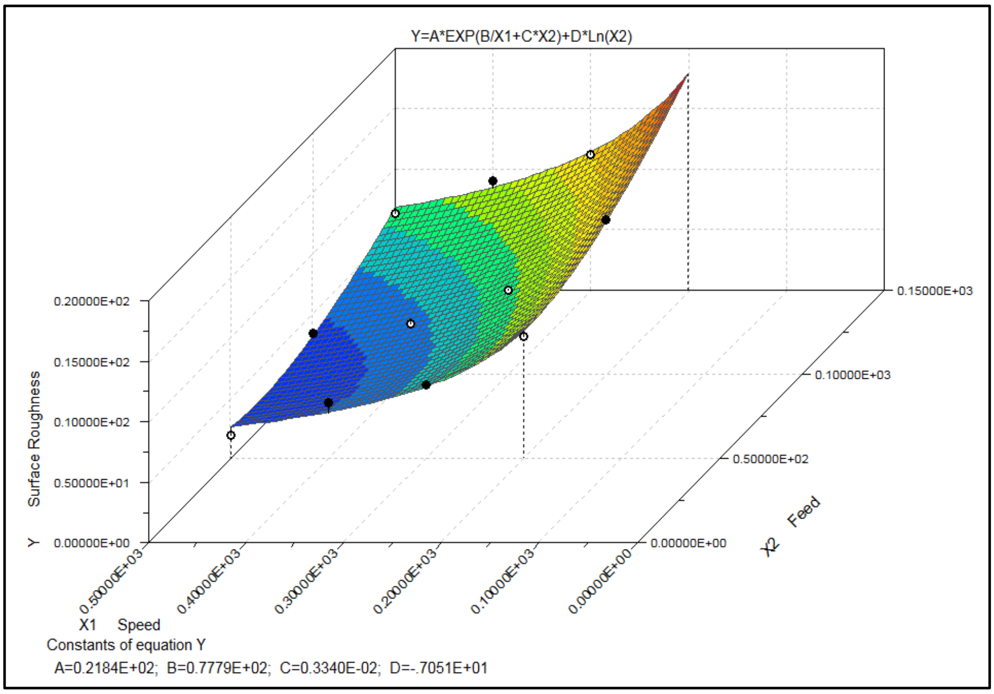

Figure 2: The Fitted Surface Roughness (Ra) Model.

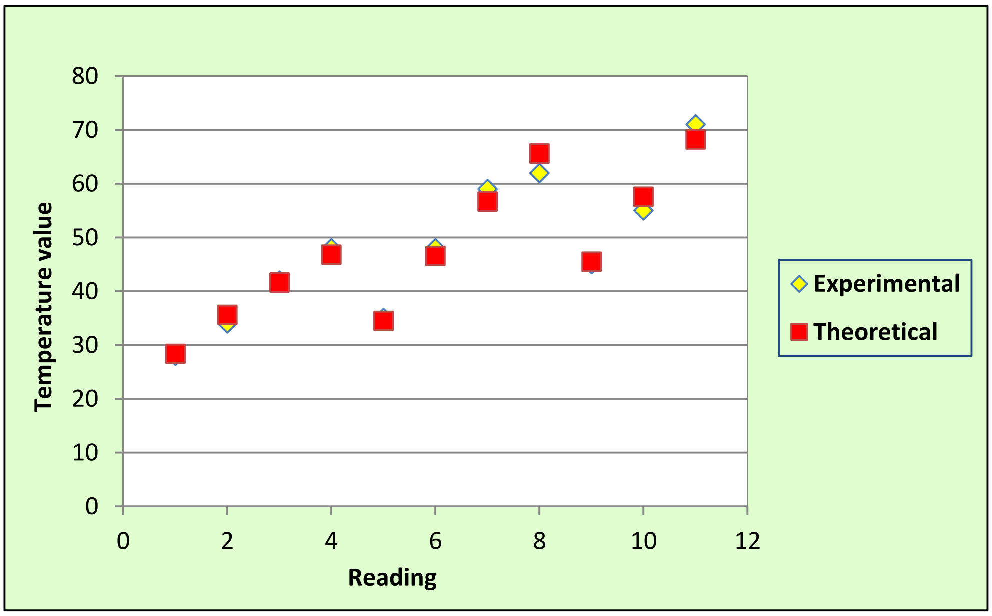

Figure 3: Experimental and Theoretical Data of Surface Roughness.

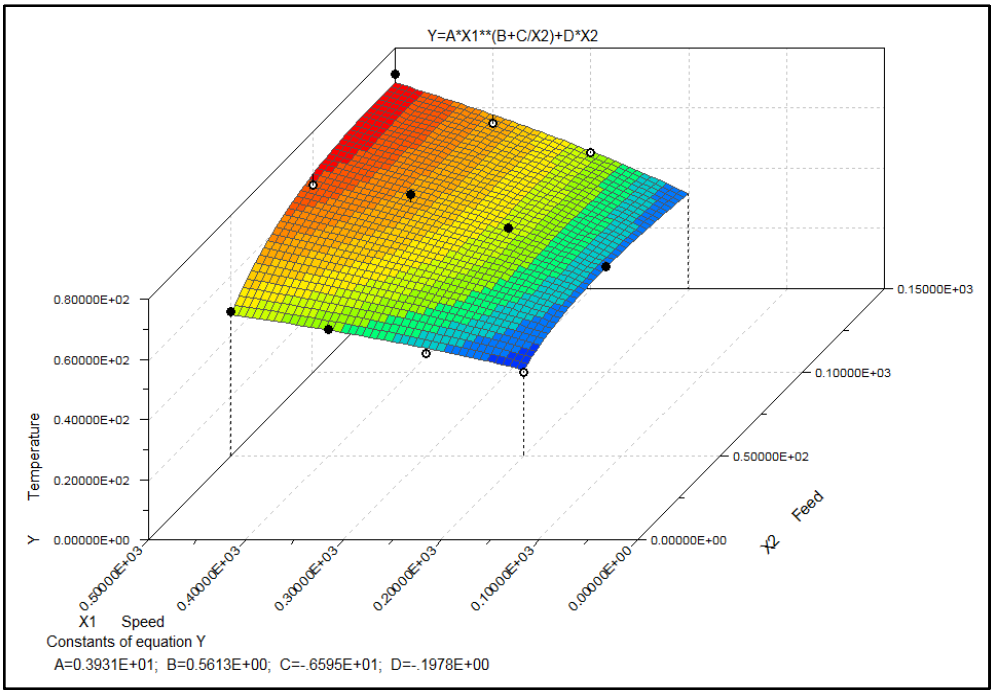

Figure 4: The Fitted Tip Tool Temperature (T) Model.

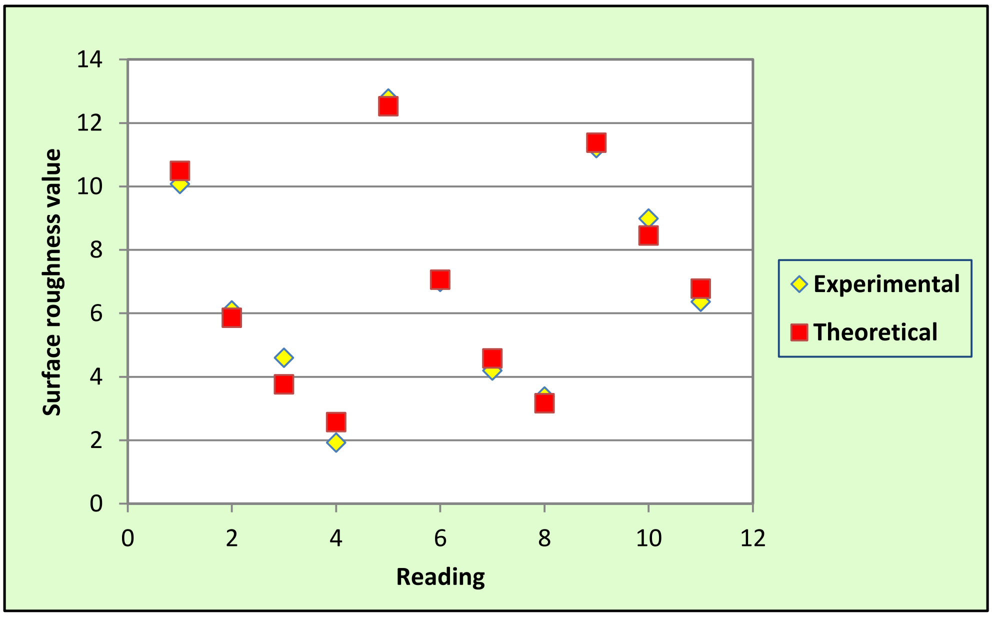

Figure 5: Experimental and Theoretical Data of Tip Tool Temperatures.

5. Results and Discussions:-

Figure 6 shows the effect of cutting speed on tool temperature. Temperature increases as cutting speed increases due to friction between tool and workpiece [9]. In addition, it can be noticed from Figure 6 that the temperature of tool increases when feed rate increases; this can be attributed to the fact that is a larger amount of material has to be removed that leading to increase friction area between tool and workpiece and as sequences the generated heat will increase [9].

Figure 7 explains the behavior of surface roughness with cutting speed at different feed rates. It is obvious that when cutting speed increases surface roughness decreases, and the reason is that when cutting speed increases, the temperature at the cutting zone increases leading to the softening of the material and as a consequence cutting forces reduce and this mean less vibration and smoother surface [2,7,10]. It is also noticed by several researchers that surface roughness decreases with increasing cutting speed because of decreasing in built up edge (BUE) formation as cutting speed increases [11,12,13].

Figure 7 also shows the effect of feed rate on surface roughness. It can be seen that surface roughness increases with increasing feed rate, because of the increasing in the cutting forces due to increase the amount of material in contact with the tool and these forces cause vibration leading to a higher surface roughness [2,7,11,14].

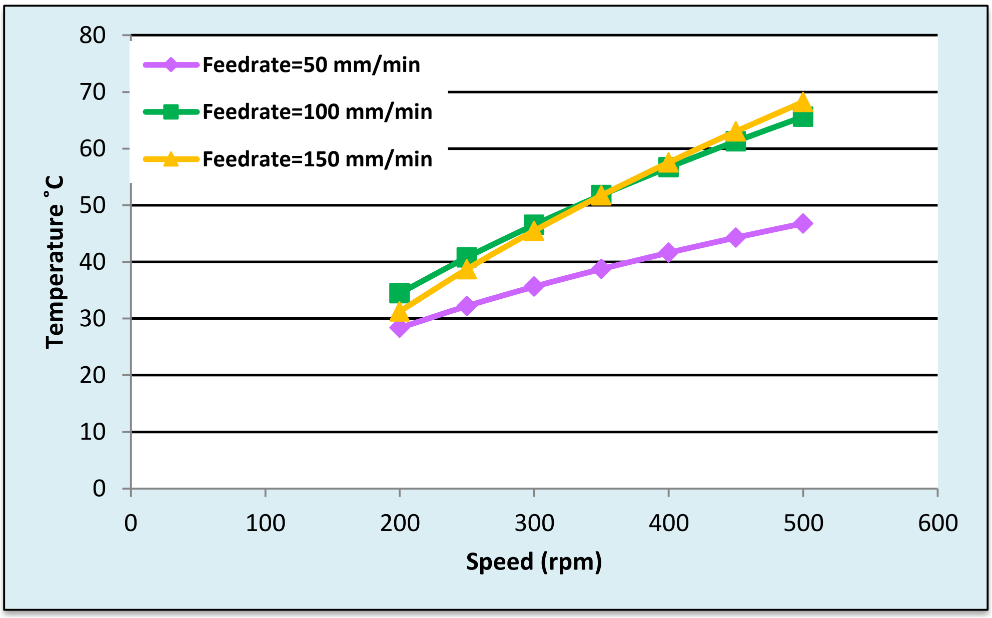

Figure 6: Shows The Effect of Cutting Speed and Feed Rate on Tool Temperature. Temperatures.

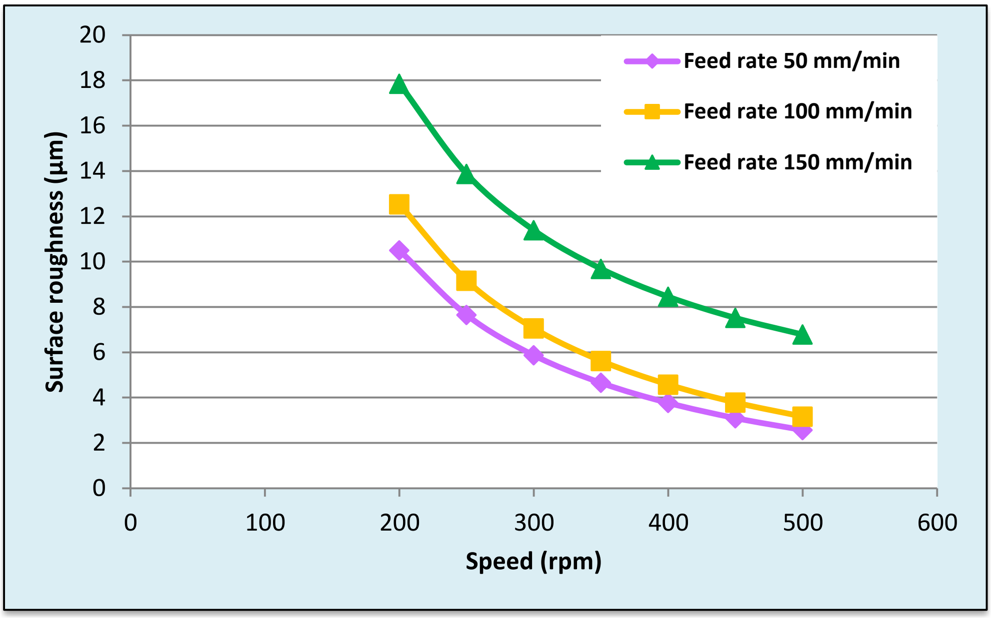

Figure 7: Shows the Effect of Cutting Speed and Feed Rate on Surface Roughness.

6. Conclusion

The effect of cutting speed and feed rate in turning AISI 1045 carbon steel have been investigated in this work. Two mathematical equations were obtained using LAB-Fit Data software for surface roughness and tool temperature. From the empirical model of cutting tool temperature, it has been seen that tool temperature increases with increasing both cutting speed and feed rate. From the surface roughness empirical model, it has been noticed that surface roughness decreases as cutting speed increases while it increases as feed rate increases.

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