https://doi.org/10.26682/sjuod.2023.26.2.59

Journal of University of Duhok., Vol. 26, No.2 (Pure and Engineering Sciences), Pp 661 - 670, 2023
(Special Issue)

ROLE OF HOT MACHINING TECHNIQUE ON MACHINABILITY ENHANCEMENT FOR HARDENED STEELS

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(Accepted for Publication: November 27, 2023)

ABSTRACT:

This paper investigates the effects of cutting factors on surface roughness of hardened steel work piece in hot machining process with heating temperature of (150 and 250) ºC, including depth of cut, feed rate, and cutting speed. The experimental side made use of the flam method. The work highlights the advantages of hot machining and how it can be used effectively on materials that are challenging to cut. The best results were obtained with the recommended cutting parameters of 90.64 m/min cutting speed, cutting feed rate of 0.64 mm/rev, and cutting depth by 1 mm at 250 ºC.

***KEYWORDS*:** Hot machining, cutting speed, Depth of cut, Feed rate, Hardness and Surface roughness**.**

1. INTRODUCTION

Hot machining, also known as high-temperature machining or dry machining, is indeed an advanced method used to overcome the challenges associated with machining hardened steels. It entails using high temperatures throughout the cutting process to enhance the material's machinability and surface polish. Valuable studies have been published to investigate the impact of heating temperature on critical variables like tool wear, cutting forces, chip formation, and surface finish; that affect the machinability of hardened steels. These studies have been conducted experimentally, theoretically, and numerically. Due to their high mechanical characteristics as high strength and hardness, corrosion and wear resistance, toughness, ability to weld, and low thermal conductivity, hard-to-cut materials are used in the production of components for the electrical, chemical, dental, orthopedic, aerospace, and nuclear industries. These materials include powder metallurgy, stainless steels, hardened steels, tool steels, nickel, titanium, etc. Materials that are hard to cut in general face some problems including, poor speeds, weak surface smoothness, high tool wear, limited tool life, and low production are all problems with conventional machining of these materials. On the other hand, unconventional machining is frequently used to machine these materials. [1, 2, 3, 4, 5, 6]

Material machining is a common manufacturing method for producing various parts and machine components in improved dimensional precision and surface quality. [7]. Although strain hardening, which takes place during material machining, is an important factor in determining machinability, Shear deformation, which depends on material behavior and machining parameters that affect performance characteristics, is the basic element of material removal in the machining process. Selecting a material that can be machined with a suitable material removal rate and surface quality is crucial for achieving design and production requirements at a lower cost without compromising performance. In his definition of the term, George Schneider Jr [8] explains that factors influencing machinability include the work material's condition and physical qualities that allow for optimal machining and higher productivity (individually and in combination). The yield strength, hardness, and tensile strength of the work material are significant factors. Decreases in hardness enhance productivity by slowing down cutting and lengthening tool life. Decreases in yield strength and tensile strength have a similar effect. A material's machinability can be assessed by using the following standards:

a. The effect of tool life on manufacturing costs, machining time, and other factors

b. The forces applied by the tool affect power consumption.

c. How temperature of cutting affects tool abrasion.

d. Machined item’s surface polishing.

e. Chip shape

A material that is simple to machine will have a lower tool wear i.e. longer tool life, lower tool pressures and power consumption, and acceptable levels of surface polish. [8, 9]Hot machining is one strategy and method for preventing and resolving machining issues with complex and challenging-to-cut materials. In order to solve issues like inadequate tool wear, cutting speed, feed and depth of cut , Instead of making the cutting tool stronger or harder, researchers assert that it is a typical practice to soften the materials to be machined in order to facilitate machining. Therefore, hot machining is considered as a popular method for increasing machinability of difficult to cut materials. [1, 2, 4, 10, 11, 12, 13]In hot machining process, the work item can be heated as a whole or in specific areas. It is preferable and more practical to heat the work piece only where it is directly in contact with the cutting tool. To avoid any issues during the milling of the work piece material [14], This machining method is perfect for cutting tough technical materials like these because they are so much harder and have higher tensile strength than standard materials. When external heating is given to the work piece material, they become softer, The impact of temperature on hardness and strength (tensile) can be presented using two graphics (fig 1.and fig 2) [14,15]

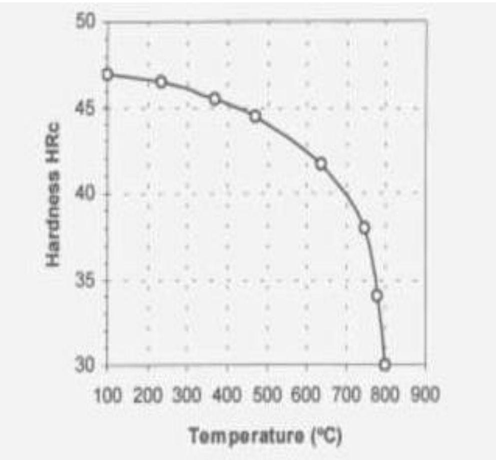
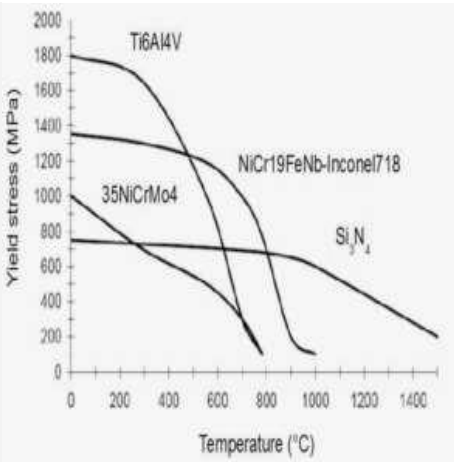


Fig.(1):- Temperature's influence on hardness [14]



Fig(2):- Temperature's impact on strength [15]

Because engineering materials' shear strength and hardness often decrease with temperature, it was believed that increasing the temperature of the work piece would decrease the amount of power required for cutting and increase the tool's lifespan.

Heating the workpiece makes it easier to manufacture by lowering the material's hardness and yield stress. The yield strength limit of the material could be lowered by increasing the heating temperature. [16]

There are a variety of conventional machining methods, however using them diminishes tool life by increasing tool wear, which leads to an increase in manufacturing costs. In conventional machining methods, when tool life declines, the number of tools required for a given material increases, and the amount of time required likewise increases, resulting in a loss in output rate. The cost of production is inversely proportionate to the tool's life as a result; a machining method that can assist in dealing with high-strength is a need when dealing with difficult-to-cut materials. With the use of the Torch flame technology, hot machining has shown to be an excellent alternative. For flame preparation, we can utilize oxygen-LPG Experiments in hot machining conducted by researchers utilizing various heating methods. It is critical to use the right heating procedure to avoid damaging the workpiece and failing to achieve the desired outcomes. Some of the techniques created especially for hot machining include laser heating, electric current, flame, induction heating, arc heating, and plasma arcing [17].

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2. Previous Works

N.Tosun & l.Ozler(2004)[18] reported an inquiry in optimization and effect of cutting settings on numerous performance aspects, work piece surface roughness and cutting tool life used high manganese steel workpiece material. AISI 1060 (45 HRC) material was evaluated by Dawami and Zadshakoyan(2008)[3]. using an uncoated TNNM 120608 SP10 tool while maintaining all other variables constant. They found that machining at 300 °C gave a better surface finish than machining at room temperature. Mechanical properties of Ti-5553 material that reduce cutting forces Cutting force decreases by 13% at 500°C and by 34% at 700°C. Liliana Popa(2008)[19] looked into turning operations and found that using plasma heating to heat workpiece material improved productivity. Productivity rose by up to 10 to 15 times, and drop in tensile strength by 60 to 70 percent, according to the findings**.** Rajopadhye et al.(2009) [20] developed a hot machining experimental setup in order to improve cutting tool life and reduce manufacturing costs**.**The impact of cutting parameters on tool wear for AISI 316 stainless steel at 200°C, 400°C, and 600°C was examined using the Taguchi technique by Kiran Kumar and Ranganathan et al(2010)[21]. At various temperatures, they found that various qualities matter. When the temperature is 200 °C, cutting speed and depth of cut are crucial factors, whereas at 400 °C and 600 °C, feed and depth of cut are crucial. They found low error values at 200 and 400 °C together with a high R2 value, highlighting the significance of the ANOVA table for optimization cutting speed was one of the machining elements that S.K.Thandra and S. K. Choudhury(2010)[22] looked at. The cutting forces, surface roughness, and tool wear during oxy-acetylene hot machining and conventional machining on a lathe were all influenced by the depth of cut, feed rate, and work piece surface temperature. An analysis of the effects of the cutting conditions using a factorial regression method revealed that hot machining reduce surface roughness, cutting forces and flank wear by around 34% when compared to conventional machining. Ranganathan and Senthilvelan(2011)[23] employed the Taguchi design on stainless steel 316 for tool wear, changing the temperature while maintaining the other variables constant. With the use of an orthogonal array and the ANOVA test, the interaction between input elements for tool wear was investigated. It has been determined that input variables and tool wear have a relationship using a regression equation. N. M. Kamdar and V. K. Pate(2012)[24] investigated the effects of various machining parameters on feed force, cutting force, and surface roughness while hot machining (with a gas flame) EN 36 steel specimens at 200 °C, 300 °C, 400 °C, 500 °C, and 600 °C with a constant depth of cut of 0.8 mm. Using Taguchi experiment design and ANOVA analysis, the trials' outcomes were evaluated, and the best machining parameters were selected. The feed force, cutting force, surface roughness, and power consumption all decreased as the temperature increased. Baili et al(2011)[25] used induction heating in hot machining to reduce mechanical properties and cutting forces in Ti-5553 material. to enhancement the machinability of Ti-5553. He discovered a 13% loss in cutting force at 500 degrees Celsius, and a 34% reduction at 700 degrees Celsius. Ketul M. Trivediet et al(2014) [26] investigated how the cutting parameters affected the surface roughness of AISI 4340 steel that had been hot machined using a tungsten carbide cutting tool and a gas mixture of oxygen and acetylene at working temperatures of 200°C, 400°C, and 600°C. The findings indicated that the cutting parameters were the main causes of the steel's surface roughness. A multiple linear regression equation is used to investigate the type of relationship between the parameters and the performance indicator. Raising the feed rate will increase output, which is good because the surface roughness at 200 degrees Celsius measured 1.52 meters at its worst and 0.678 meters at its best. It uses FEM analysis. Shalini Singh(2014)[5].talked about the hot machining method and did study to find out what makes hot machining better than conventional machining. Tool life, power consumption, surface roughness, chip reduction coefficient, and tool wear were all measured using the design of response surface methodology technique. Rahul D. and Achyut S. both(2015)[27] It was necessary to apply Taguchi methodology and an analysis of variance (ANOVA) to determine the ideal values for the machining parameters that affect the tool life of carbide tools used in hot machining of high manganese steel. The results showed that tool life increased along with temperature. The most successful variables were found to be feed rate (0.05 mm/rev), depth of cut (0.5 mm), and spindle speed (140 rpm. The

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results of the ANOVA for tool life show that the temperature and depth of cut are the two most important factors that influence tool life. P. Venkataramaiah(2018)[28] employed the finite element method to investigate how the hot machining of the alloy Inconel 718 will be impacting the cutting speed, feed rate, and preheating temperature on von Mises stress. According to simulation tests and results, stress was reduced by decreasing speed, raising temperature, and decreasing feed rate. The settings that have the biggest impact on stress are V = 150 m/min and f = 0.5 mm/rev at a preheating temperature of 600 ºC. Asit kumar Parida and Kalipada Maity(2019)[13].In order to examine the impact of heating temperature under various machining settings, the finite-element technique of hot machining Ti-6Al-4V alloy is used. The results from the simulation and those obtained during hot machining and at room temperature are in excellent agreement. Cutting force, shear strength, chip thickness, and chip pitch all decrease in hot conditions as process zone temperature rises. In heated temperatures as well as at room temperature, it also causes a reduction in cutting force with an increase in cutting speed and an increase in feed rate. Asit Kumar Parida(2019)[29] investigated and performed calculations to ascertain how preheating temperature impacts tool wear during hot machining of Inconel 718. The same cutting settings were employed in machining operations at room temperature in order to compare the outcomes. There is a substantial correlation between experimental outcomes and anticipated tool temperature, tool wear, chip morphology, and tool wear. Preheating temperature increases tool life by minimizing tool wear.

3. EXPERIMENTAL WORK:

The experimental work in this research was done by using a turning machine and using the flam heating system.

3.1 Work-piece material and cutting tool insert.

Ck35 hardened steel work piece used in this present work (figure 3), the workpiece diameter 43mm and 375mm the length. The hardness of the material is 56 HRC and its chemical composition and mechanical properties as shown in Table 1 and Table 2. Cutting tool insert that used SNMG 643 1025 P25 190612.

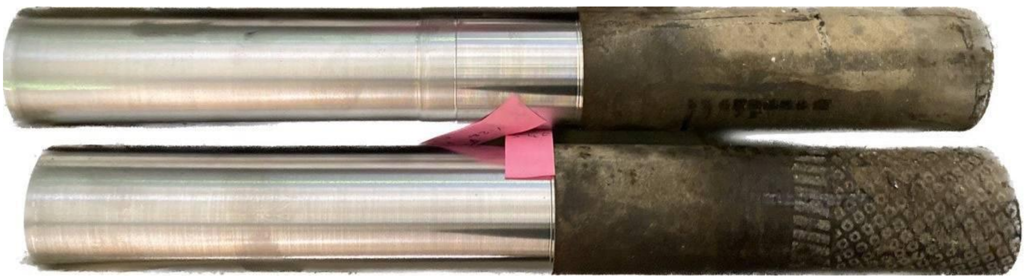

Fig.(3):- workpiece material

Table (1):- Material chemical composition of workpiece.

Elements	C	Si	Mn	P	S	Cr	Mo	Ni	Al	Cu	Fe
%	0.360	0.273	0.711	0.0138	0.0373	1.00	0.0518	0.170	0.0342	0.247	Bal.

Table (2):- Mechanical properties of CK35 hardened steel [34].

Yield Strength (MPa)	370
Ultimate Tensile Strength (MPa)	585
Elastic Strength (GPa)	190-210
Elongation (%)	30

3.2 Experimental procedures:

In this work using turning operation by hold the workpiece on the lathe machine, using LPG heating system, the flam focused on the workpiece and the tool moved in a parallel direction to the axial of rotation machine experimental setup as shown in figure 4. The (infrared thermometer) a non-contact equipment measuring focused to the workpiece while the flam heating the workpiece.

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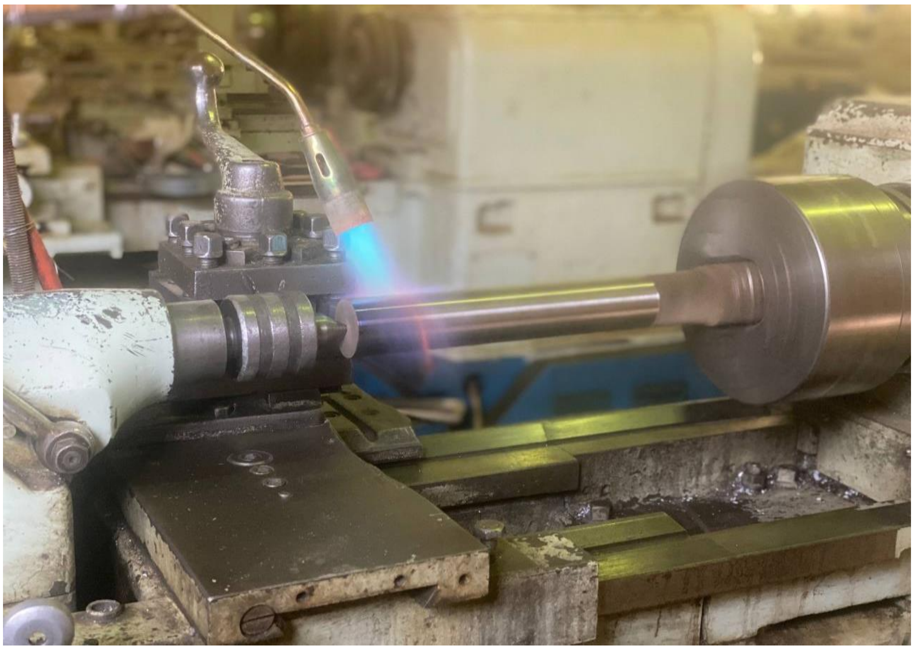

Fig.(4):- Experimental of hot machining process

To show how the machinability effect by temperature, three variables cutting parameter were used, the speed of cutting, the feed-rate and the cutting depth at 150 ºC, 250 ºC. Table 3. Given the parameter selection level rang, the experimental plan shows how the cutting parameters affect the surface roughness. The material is tested for hardness variation.

Table(3):- Parameters rang of machining operation(before and after preheating)

Cutting Speed	**(34.98,54.97,90.64) m/min**
Feed Rate	(0.26,0.64,1.5) mm/rev
Depth of cutting	(0.52,1,1.5) mm
Temperature	(25,150,250)ºC

3.4 Measurements

3.4.1 Micro-hardness measurement:

Micro-hardness measurement was done (as shown in Table.4) by applying loads range from 10 to 1000 gf, as the Vickers test, the hardness is tested by choosing a diamond indentation. Provided that the surface is polished using (DIGITAL MICROHARDNESS TESTER).

3.4.2 Surface roughness:

The surface roughness in this work was measured (as shown in Table.4) by MarSurf pocket Surf PS1.surface roughness of the work piece measured under variables cutting parameter at room temperature and two work piece surface temperature (150ºCand 250ºC).

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Table(4) :-Experimental results

Sr. No	Temperature ºC	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of Cut (mm)	Micro-hardness HV	Surface Roughness (μm)
1	25	43.98	0.26	0.52	631.6	4.202
2	25	54.97	0.64	1	629	4.076
3	25	90.64	1.5	1.5	627	4.368
4	150	43.98	0.26	0.52	422.1	2.772
5	150	43.98	0.64	0.52	415	3.598
6	150	43.98	1.5	0.52	411.6	4.534
7	150	54.97	0.26	0.52	419	2.632
8	150	54.97	0.64	0.52	415.4	3.192
9	150	54.97	1.5	0.52	402	4.121
10	150	90.64	0.26	0.52	423	2.531
11	150	90.64	0.64	0.52	413	2.243
12	150	90.64	1.5	0.52	417	3.942
13	250	43.98	0.26	1	360	2.517
14	250	43.98	0.64	1	363	2.742
15	250	43.98	1.5	1	350	3.631
16	250	54.97	0.26	1	327	2.502
17	250	54.97	0.64	1	326	2.558
18	250	54.97	1.5	1	355.1	3.542
19	250	90.64	0.26	1	336	2.001
20	250	90.64	0.64	1	320	1.921
21	250	90.64	1.5	1	318	2.964

4. RESULTS AND DISCUSSION

The figure 5 shows the effect of the preheating temperature on the hardness, which caused its decrease, this leads to a decrease in the strength of the material, and this is reflected positively on the ease of cutting which improve surface quality by reducing the surface roughness.

The figures (6, 7, 8, 9, 10) below show the surface roughness results, at varying parameter of cutting speed, feed rate, depth and temperature by hot machining process ,these figure explain that lowest surface roughness that can be obtained when the cutting speed at 90.64 m/min, feed-rate 0.64 mm/rev, depth 1 mm and temperature 250ºC with Noting that increasing the feed causes an increase in roughness in contrast to the cutting speed, as shown in Figures(9,10).

The effect of hot machining is clear in reducing the surface roughness of hardened steel compared to conventional machining at room temperature, as shown in Figure 11.

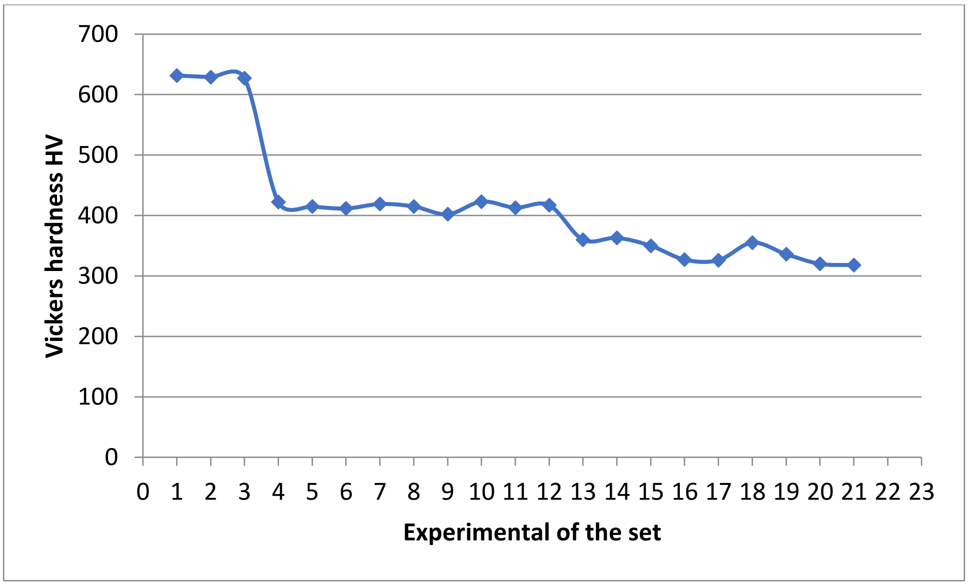

Fig.(5):-. Micro-hardness variation with preheating temperature at different cutting parameter

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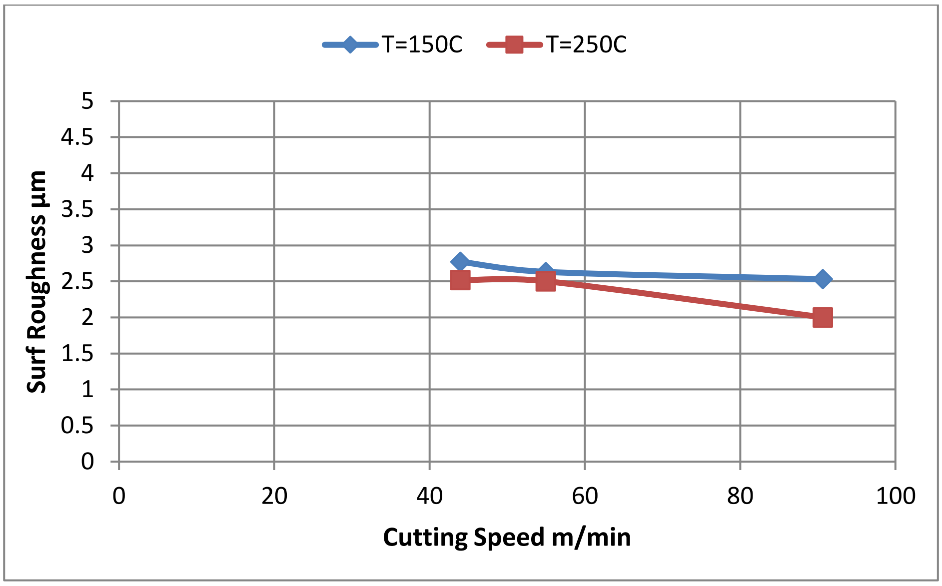

Fig.(6):- Surface roughness Vs cutting speeds at feed rate 0.26mm/rev

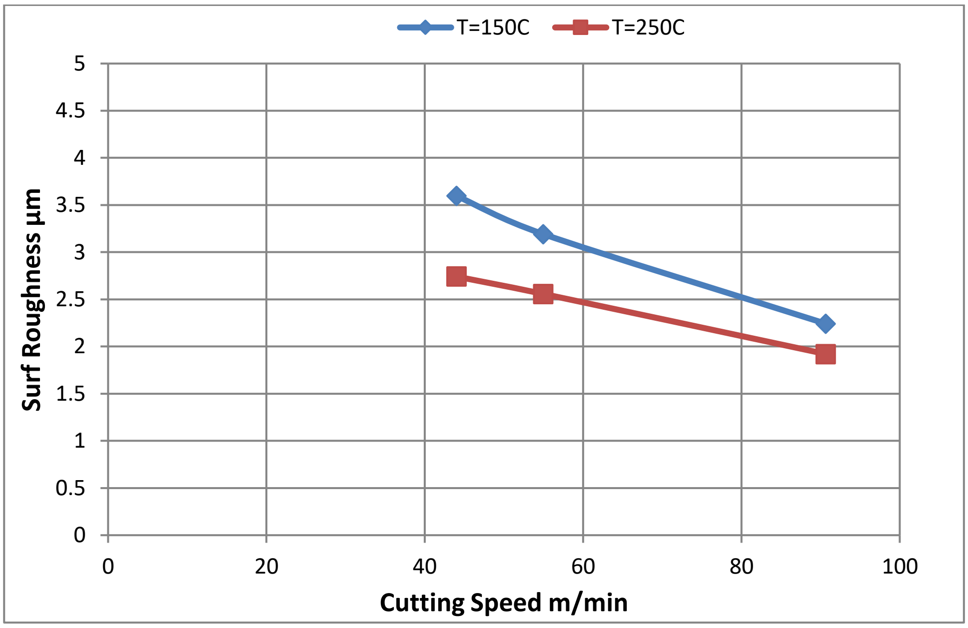

Fig.(7):-. Surface roughness Vs cutting speeds at feed rate 0.64 mm/rev

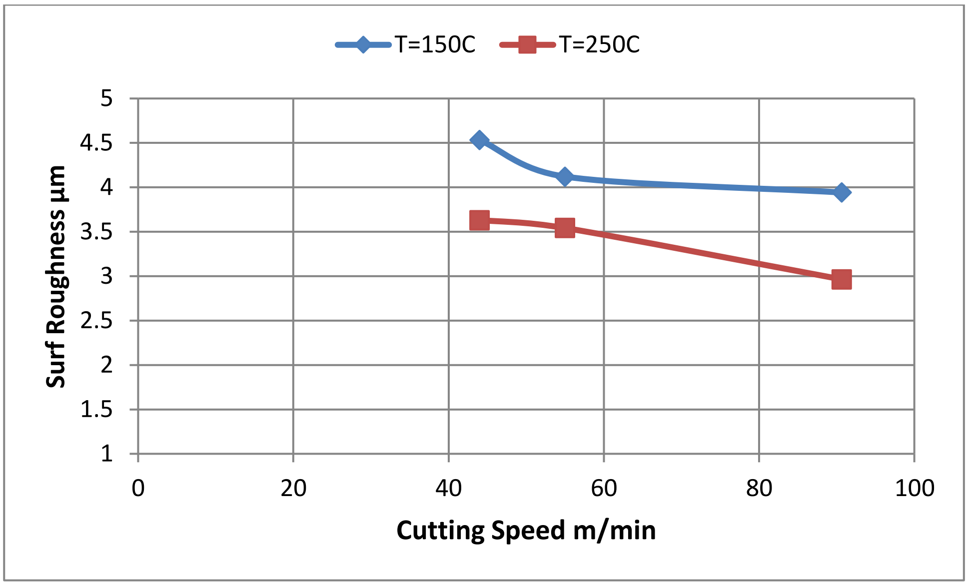

Fig.(8):- Surface roughness Vs cutting speeds at feed rate 1.5 mm/rev

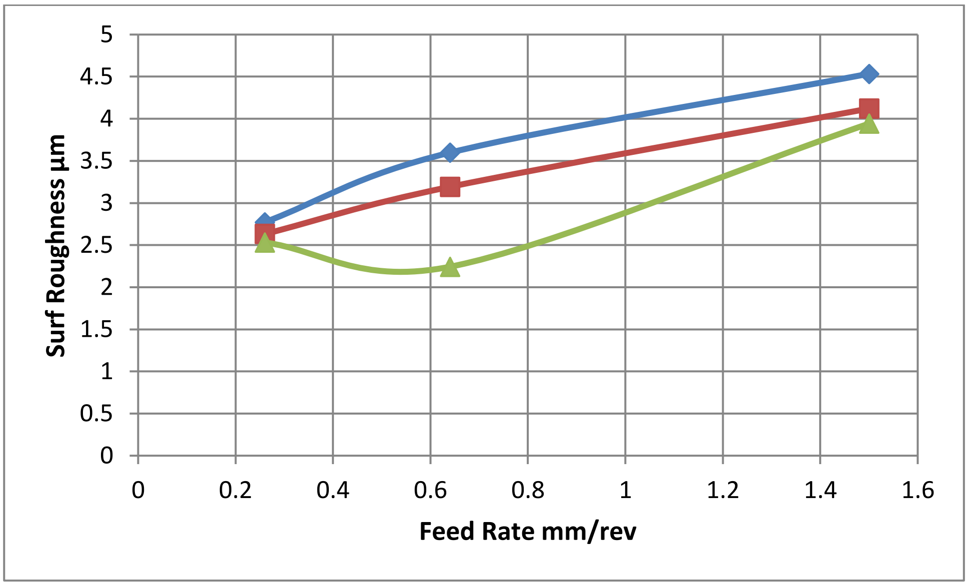

Fig.(9):-. Surface roughness Vs feed rate at depth 0.52 mm

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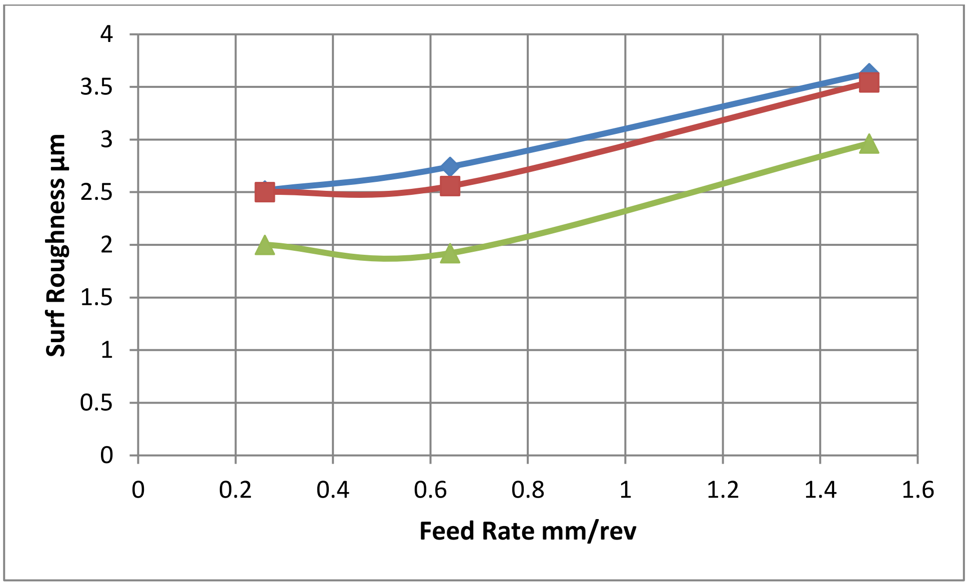

Fig.(10):-. Surface roughness Vs feed rate at depth 1 mm

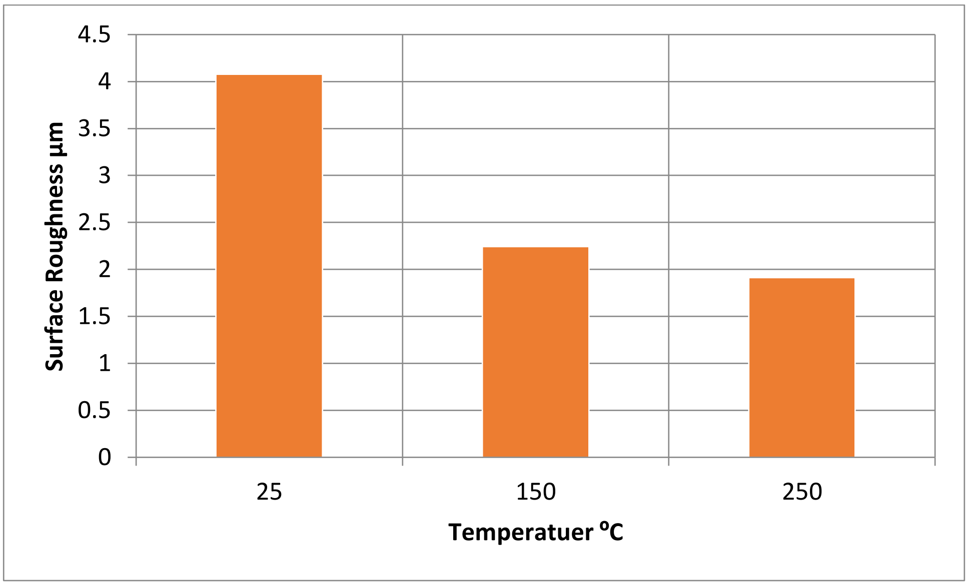

Fig.(11):- Effect of temperature on surface roughness

5. CONCLUSIONS

Following are the conclusions drawn from the present work:

1. The surface finish was improved by decreeing the hardness due to preheating the material to be cut

2. In the hot machining process the Shear strength decreases and provides ease in machining.

3. The most important parameters that influence surface finish are cutting speed, feed rate, and temperature, the best result was obtained at the highest value of cutting speed 90.64 m/min, feed-rate 0.64 mm/rev, depth 1 mm and temperature 250ºC.

4. Hot machining is the most effective technique for cutting materials that are hard to cut, and can reduces machining costs and time, as well as power consumption.

6. Acknowledgment

The authors would like to thank Mustansiriyah University, Baghdad- Iraq (www.uomustansiriyah.edu.iq) encouraging this research work. Furthermore, the authors also want to express their gratitude to the College of

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Engineering for their support in conducting this research work successfully.

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