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"Research Note"

AN INVESTIGATION OF THE EFFECT OF HEAT TREATMENT ON SURFACE ROUGHNESS IN MACHINING BY USING STATISTICAL ANALYSIS*

F. KAHRAMAN** AND A. SAGBAS

Tarsus Technical Education Faculty, Department of Mechanical Education, Mersin University
33400, Tarsus-Mersin/Turkey
Email: fundakahraman33@hotmail.com

Abstract– In the present paper, the effect of heat treatment on the surface roughness of AISI 4140 steel has been investigated by use of paired t-test and one way analysis of variance (ANOVA). The paired t-test was performed to determine the differences between the means before and after heat treatment. One way ANOVA was used to further evaluate the effect of heat treatment on the difference in variances between two groups. According to the statistical analysis, it was concluded that heat treatment has decreased the surface roughness at the 95% confidence level. The improvement of surface roughness varies from 37% to 45% with various combinations of experimental parameters.

Keywords– Surface roughness, Heat treatment, Statistical analysis

1. INTRODUCTION

The surface roughness of machined parts is a significant design specification that is known to have considerable influence on properties such as wear resistance and fatigue strength. Surface roughness in turning has been found to be influenced in varying amounts by a number of factors such as cutting parameters, cutting fluid, and workpiece hardness. Important properties such as hardness, strength and toughness are greatly influenced by heat treatment processes [1].

Al-Qura'n [2] studied the effect of heat treatment on the hardness of chromium-nickel steel. The best result of microhardness test was for the annealed samples at 740 °C for a period of 60 min. Dwivedi et al. [3] examined the influence of melt treatment and heat treatment of cast Al alloys on machining behaviour. Heat treatment of Al alloy reduced the surface roughness. Jun et al.[4] studied the effect of heat treatment on the friction and wear properties of hybrid composites by using paired t-test and one way ANOVA. Heat treatment contributes to improving the dry sliding friction and wear properties of the hybrid composites. Brunzel and Fomin [5] determined the effect of heat treatment on the surface roughness of structural steels after turning on a lathe. After this treatment improvement the surface becomes cleaner, even for low rates of cutting. Choi et al. [6] examined the effects of heat treatment on the surface roughness of a die steel. Heat treatment improves the quality in terms of microstructures and surface roughness. Ozcatalbas and Ercan [7] investigated the effects of heat treatment on the machinability characterised by measuring the cutting force, surface roughness and surface hardness of SAE 1050 steel.

In the present work, the effect of heat treatment on surface roughness of AISI 4140 steel in the machining process was investigated at different cutting conditions by using statistical techniques.

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**Corresponding author

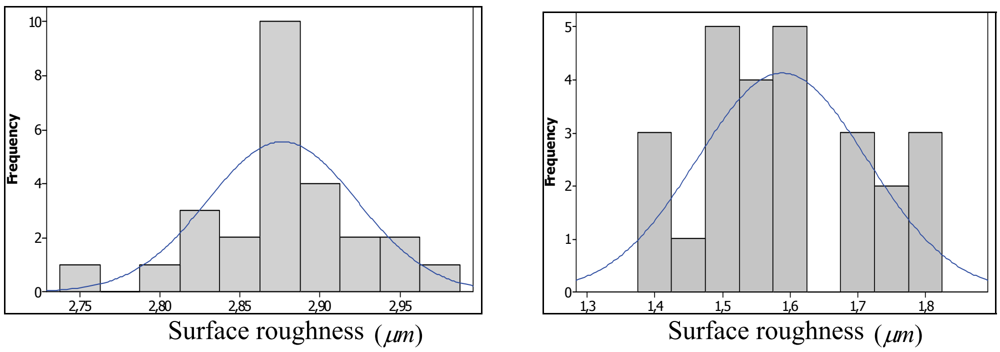
2. EXPERIMENTAL DETAILS

An industrial CNC lathe was used for the turning of AISI 4140 steel with cutting fluid. Turning experiments were carried out at three different cutting speeds which were 47, 94 and 150 m/min. The feed rate and depth of cut were kept fixed at 0.1 mm/rev, 0.5 mm respectively. The average of the three measurements in different areas of the 78 specimens was recorded. These specimens were later used for heat treatment. Before and after heat treatment, the average surface hardness was measured as 30, 58 HR_{C}, respectively. For the heat treatment of AISI 4140 steels, the workpieces were austenized at 850 ^{o}C for 1 h and quenched with oil, and then tempered for 1 h at 200 ^{o}C. The work material bars were cleaned by removing a 0.5 mm depth of cut from the outside surface.

3. STATISTICAL ANALYSIS RESULTS AND DISCUSSION

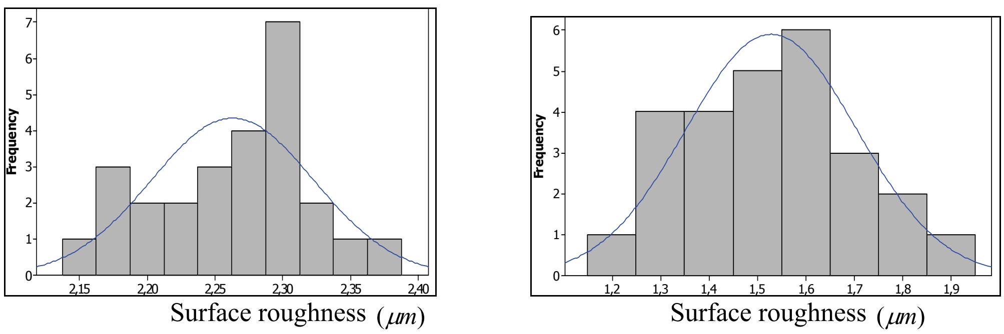
The paired t-test was used for the test and estimation of the difference between the means of the two groups. The paired t-test assumes that the variances are equal. Determination of whether the assumption of equal variances is valid requires the use of a one way ANOVA conducting a variance test [8-10]. The null hypothesis is that, there is no difference between the variances unheat treated and heat treated populations. The alternative hypothesis is that there is a difference between the variances before and after the heat treatment. Histograms for the surface roughness before and after the heat treatment for different cutting speeds were shown in Figs. 1-3, and from these figures the sample data appears to be normal.

The means and the variances of two normally distributed variables with the paired sample t-test and one way ANOVA were compared. The paired t-statistic was performed to determine the difference between the means before and after the heat treatment. The results of the paired t-test are shown in Table 1.



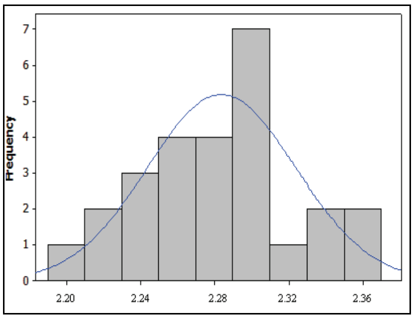
(a) (b)

Fig. 1 Histograms for unheat-treated samples (a) heat-treated samples (b) for 47 m/min



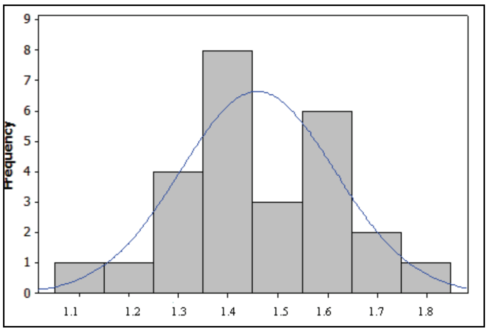
(a) (b)

Fig. 2 Histograms for unheat-treated samples (a), heat- treated samples (b) for 94 m/min



Surface roughness (μm)

(a)



Surface roughness (μm)

(b)

Fig. 3. Histograms for unheat-treated samples (a) heat treated samples (b) for 150 m/min

Table 1. Paired t-test results

Cutting speed (m/min)	Paired differences						
	Mean	Standard deviation	Lower	Upper	t	df	p
47	1,271	0.136	1.216	1.326	47.63	25	0.000
94	0,720	0.185	0.645	0.795	19.81	25	0.000
150	0.823	0.0315	0.760	0.880	26.110	25	0.000

Since the p-value in Table 1 is less than 0.05, the difference in the mean surface roughness between the unheat-treated samples and the heat-treated samples was statistically significant. Therefore, the null hypothesis was rejected and the alternative hypothesis was accepted. It was concluded that heat treatment had decreased the surface roughness. One way ANOVA test was performed to further evaluate the effect of heat treatment on the difference in variances surface roughness between the unheat-treated and the heat-treated samples. The results of the one way ANOVA are shown in Table 2.

Table 2. The results of one way ANOVA

	Source	DF	SS	MS	F	p
47 m/min	Factor	1	20.2866	20.28662	3521.74	0.000
	Error	50	0.2880	0.00576		
	Total	51	20.5746			
94 m/min	Factor	1	7.3920	7.3920	680.22	0.000
	Error	50	0.5434	0.0109		
	Total	51	7.9354			
150 m/min	Factor	1	8.8121	8.8121	678.63	0.000
	Error	50	0.6493	0.0130		
	Total	51	9.4600			

The one way ANOVA reveals a statistically significant difference among the two groups. One way ANOVA for the results of surface roughness in Table 2 revealed that there was a significant difference ($p<0.05$) between the variances. So, the alternative hypothesis with a 95% confidence level is acceptable. It was concluded that the effect of the heat treatment was statistically significant on the difference in variances of the two groups. Figure 4 represents the surface roughness of AISI 4140 steel as a function of the cutting speed under a feed rate value of 0.1 mm/rev and at a depth of cut value of 0.5 mm.

Surface roughness for the unheat-treated and heat-treated samples was compared at different cutting speed conditions (47, 94 and, 150 m/min). The improvement of the surface roughness was calculated as 45%, 41% and 37%, respectively. The surface roughness of AISI 4140 steel decreases with the increase in cutting speed. A higher observed value of the improvement of the surface roughness was obtained for the lower cutting speed.

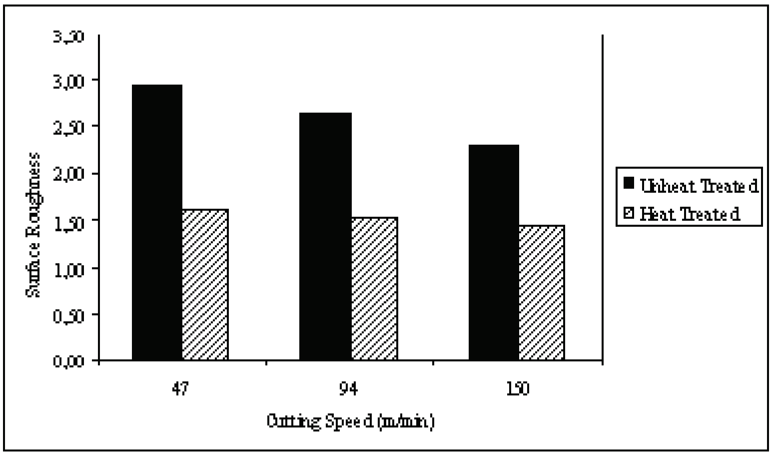


Fig. 4. The effect of the cutting speed on the surface roughness for unheat-treated /heat- treated samples

4. CONCLUSION

In this study, the differences between unheat-treated and heat-treated groups were tested by use of paired t-test and one way ANOVA. A better surface roughness was obtained for the heat-treated samples than those of the unheat-treated samples at all cutting conditions. The improvement of the surface roughness varies from 37% to 45% with various combinations of experimental parameters. A higher observed value of the improvement of the surface roughness was obtained for the lower cutting speed. Additionally, the cutting speed was found to be a significant factor on surface roughness. Surface roughness decreases with increasing the cutting speed.

Most of the previous investigators examined the effect of the heat treatment on the mechanical properties. However, only a few researchers have focused on the relationship between heat treatment and surface roughness. Dwivedi et al.[3] found that the heat treatment of Al alloy reduced the surface roughness. Brunzel and Fomin [5] observed that the thermal treatment reduced surface roughness at low rates of cutting conditions. Choi et al. [6] indicated that heat treatments improved the quality in terms of microstructures and surface roughness. Ozcatalbas and Ercan [7] showed that the minimum surface roughness of SAE 1050 steel is observed on the hot rolled specimen at the higher cutting speeds. As shown in this study, the heat treatment operations applied bring about a considerable difference in surface roughness at different cutting conditions. The results obtained from this study are in good agreement with the previous researcher's works.

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