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ESTIMATION THE INFLUENCE OF TOOL GEOMETRY ON THE SURFACE QUALITY AND TOOL WEAR

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ABSTRACT

This study introduced to estimation the influence of cutting tool geometry on the surface roughness and tool wear all have an essential effect on the achievement of desired product quality and acceptable cost. There are seven various parameter (figure 1) such as relief angle (α), rake angle (γ), side cutting edge angle (φ), end cutting edge angle (φ_1), nose radius(r_ε), end relief angle (α_1) and back rake angle (γ_1) that are known to have a large impact on surface quality and tool wear, thus tool shape have a decided effect upon the cutting efficiency of the tool. The results of experiment allow considering the evaluation of each parameter of tool geometry on the surface roughness and tool wear, and then obtain the optimum shape of turning cutting tool. The goal of this work is to identify a relationship between surface quality of cast iron and tool wear, turning process with tool geometry of high speed steel HSS, then develop tool geometry which is termed the multiple regression model and to evaluate prediction ability of model. Application of new progressive rates of correct shape lathe tools, it is very benefit when using expensive and accurate machines.

An attempt was made to minimize the number of experimental run and increase the reliability of experimental results. MINITAB software [2] which is used in this paper can be used for evaluation, with few experimental run and [3, 4, 5].

الخلاصة:

دراسة تأثير الأبعاد الهندسية لأداة القطع على نعومة السطح، وعلى تأكل أداة القطع، وهى تمثل التأثيرات الآساسية للوصول الى أفضل جودة للمنتوج وبسعر مناسب. هنالك سبع متغيرات مختلفة هي كل زوايا القطع مع نصف قطر القمة وهي (γ_1 ،α_1، r_ε، φ_1، φ، γ،α)هذه الزوايا لها تأثير كبير على جودة السطح وتأكل أداة القطع. نتائج التجارب تعطي تصورعن تقييم كل متغيير من متغيرات الأبعاد الهندسية على نعومة السطح وتأكل أداة القطع، بعد ذلك تم ايجاد الشكل المثالي لأداة القطع. هدف هذا البحث هو ايجاد علاقة بين جودة سطح معدن حديد الصب على الآبعاد الهندسية لاداة القطع من معدن فولاذ القطع السريع. ان تطبيقات التطورات على الشكل الصحيح، جدا مفيد عند استخدامات ألات القطع عالية الدقة والغالية. من أهداف البحث الاخرى هو تقليل عدد التجارب وزيادة الوثوقية للنتائج التجريبية. باستخدام برنامج احصائي.

KEY WORDS

Geometry of turning tool, Surface quality, tool wear, machining process, statistical research, MINTAB software, regression analysis, Analysis of Variance ANOVA.

INTRODUCTION

The complex phenomenon associated with the machining process, with multiple factors, influence on the surface micro-irregularities. The most important reasons for the emergence of the surface irregularities in turning, is the geometrical dimensions Fig. 1, of the cutting tool[1], the change in the angles of the tools affected on the surface irregularities and affected on the form of irregularities [5, 8]. Using cutting tools with a large radius leads to different surface irregularities too.

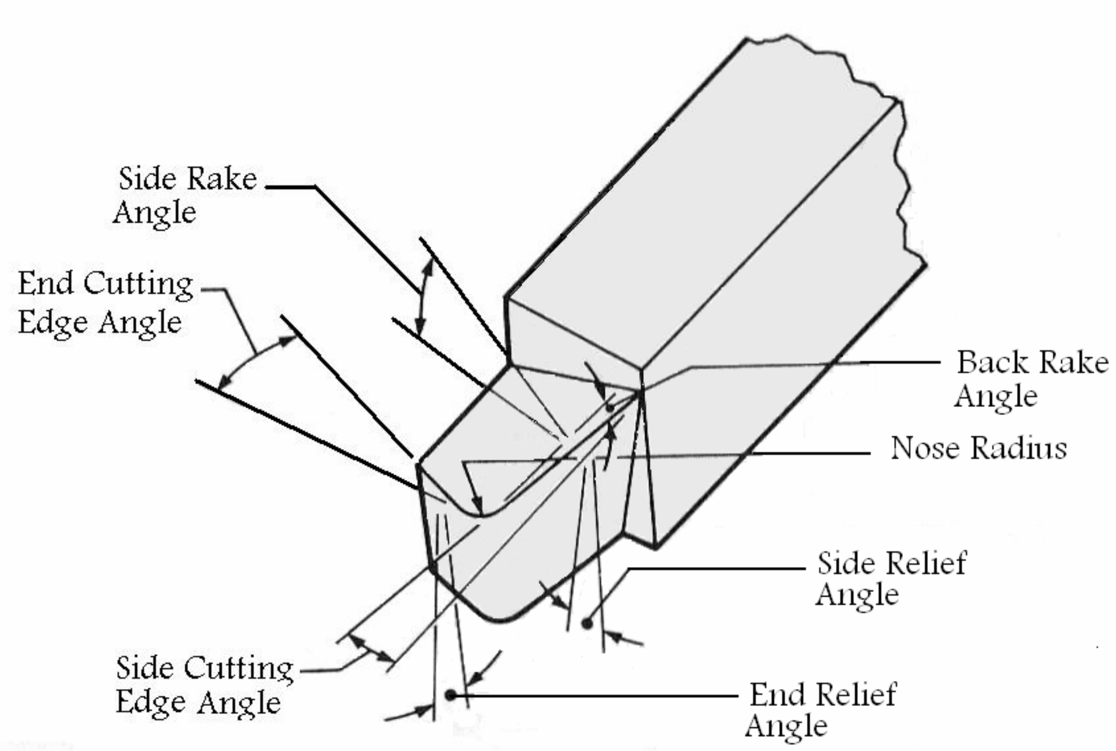


Fig.1.

The friction and the wear are largely depending upon the altitude and the form of the surface micro-irregularities and the direction of the operation. The biggest effect on the contact area of the tool wear is the shape and dimension of cutting parts, the change is accompanied by a change in the tool wear and change in surface roughness, which will lead to a change in the performance characteristics of the work piece [7, 10]. The most appropriate situation is to obtain the greatest tool life within an acceptable speed, and to obtain better quality surfaces.

To estimate the cutting process it is necessary to find a relationship between the parameters of tool geometry with surface roughens and tool wear, depending on the mathematical expression, finding from plan experimental relations by using statistical relationships [9]. This plan require a change in the parameters, in order to increase the accuracy of the experiment and reduce the effort, so that the change from small to large. The relationships which obtained have greater reliability than if the study experiences a factor of one variable.

ORGANIZING EXPERIENCE

An experiment was conducted using lathe machine. In general turning tool shape content from seven various parameters such as relief angle (α), rake angle (γ), side cutting edge angle (φ), end cutting edge angle (φ_{1}), nose radius(r_ε), end relief angle (α_1) and back rake angle (γ_1) (figure. 1). These parameters have combined effects on forming surfaces and tool wear. In the case of a large range angles, the change in the surface roughness would be uneven for several reasons. Therefore, the study was confined to specific range. According to experiments data obtained from reference [1]. Recommended values of these parameters can be taken as following table 1, which shows Coding and the level of the tool geometry parameters.

Table 1 the Level of the Factors

Level	limit	X_1	X_2	X_3	X_4	X_5	X_6	X_7
		α, deg	γ, deg	φ, deg	φ_{1}, deg	r_ε, mm	α_1, deg	γ_1, deg
High	+1	12	15	50	18	2	12	15
Low	-1	8	5	10	5	0.5	8	5

Design of experiments with several factors

Experiments are performed in all engineering disciplines and are an important part of the way we learn about how cutting processes effects. The factorial experimental design will be introduced as a powerful technique for experiments with several factors. Several special cases of general factorial design are important because they are widely employed in research work [6].

Because the tool shape has more than one parameter at the same time, a plan factors must be used to obtain the multifunction relationship which evaluate the combination between the main parameters. In general, a 2k design may be run in a $1/2^p$ fraction called a 2^{k-p} fractional factorial design. Thus, a 1/16 fraction is called a 2^{k-4} design. For seven factors, we can reduce the number of run. The 2_{III}^{7-4} design is an eight- run experiment accommodating seven variables [6, 8]. The design is shown in table 2.

Table 2 A 2^{7-4} Fractional Factorial Design

Run	X_1	X_2	X_3	$X_4=x_1x_2$	$X_5=x_1x_3$	$X_6=x_2x_3$	$X_7=x_1x_2x_3$
1	-	-	-	+	+	+	-
2	+	-	-	-	-	+	+
3	-	+	-	-	+	-	+
4	+	+	-	+	-	-	-
5	-	-	+	+	-	-	+
6	+	-	+	-	+	-	-
7	-	+	+	-	-	+	-
8	+	+	+	+	+	+	+

Table 2 list the eight run, with each row representing one of the run are the – and + setting indicating the low and high levels for each of the seven factors.

Test specimens

Due to the experimental investigation cast iron (hardness of 150 HB), samples of dimensions Ø20×200 mm are prepared and used in tests.

Cutting tool material

In attempts to evaluate the effects of cutting tool geometry parameters on surface roughness value and tool wear values, we have used M_2 high speed steel HSS, their recommended cutting speed will be 250 rpm.

Surface roughness and tool wear measuring

Surface roughness test executed three times for each samples, value are determined by profile meter tester, then the mean value of R_z obtained. To measure roughness of surface formed while processing the workpiece, the cut-off length is taken as 0.8 mm and the sampling length as 7mm. The form and dimensions of the surface irregularities is measured in different directions where given different values, including longitudinal and cross. There are many factors, including the form of cutting tool and the amount of feed where they have an impact on the cross surface roughness only. Cross value will be greater than the longitudinal values from 2 to 3 times. Tool wear tests are determined by the difference weights.

RESULTS AND DISCUSSION

In this study, the average surface roughness values (y2) and tool wear (y1) obtained with cutting tool geometry by turning process of eight different shapes of cutting tools at suitable technological environment are shown in table3.

Table (3): Final Results

run	α, deg	γ, deg	φ, deg	φ_1, deg	r_ε, mm	α_1, deg	γ_1, deg	y1,gr	y2,µm
1	8	5	10	18	2	12	5	0.02	1.72
2	12	5	10	5	0,5	12	15	0.021	5.539
3	8	15	10	5	2	8	15	0.023	1.506
4	12	15	10	18	0.5	8	5	0.02	2.777
5	8	5	50	18	0.5	8	15	0.032	4.111
6	12	5	50	5	2	8	5	0.025	3.092
7	8	15	50	5	0.5	12	5	0.012	4.87
8	12	15	50	18	2	12	15	0.041	3.457

Regression Analysis

Regression analysis is used to investigate and model the relationship between a response variable (yi) and one or more predictors (X_i). Coefficient can be obtained by using the MINITAB windows.
The regression equation is for tool wear (y1) with respect to cutting tool geometry (X_i).
y1 versus $X_1, X_2, X_3, X_4, X_5, X_6, X_7$.

y1 = - 0.168 + 0.0125 x1 +0.000000 x2 + 0.00125 x3 + 0.00769 x4 + 0.0333 x5 - 0.00x6 + 0.0100 x7

Stepwise	1	2	3	4	5	6	7

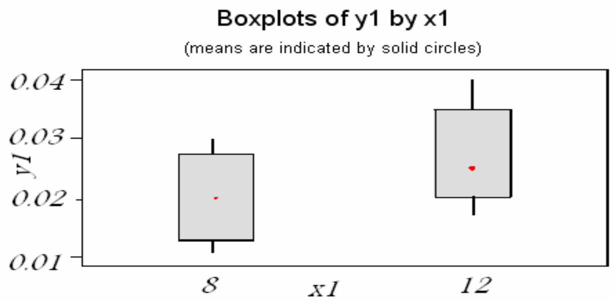
Const.	0.0125	0.003654	0.0183	0.0188	0.01	0.00	0.00
X_7	**0. 001**	0. 001	0.001	0.001	0.001		
X_4		**0.0007**	0.0007	0.0007	0.0007		
X_5			**0.00333**	0.00333	0.00333		
X_3				**0.000125**	0.000125		
X_1					**0.00125**		
X_2					0.00		
X_6					0.00		
R^2 %	**36.4**	**72.73**	**81.83**	**90.9**	**100**		

The R^2 value of 36.4% tells us the amount of variability X_7 in the response y1 that this model accounts for. The value 72.73% tells the amount of two variables (X_7 and X_4) in the response y1. The values 81.83% tells the effect of three variables (X7, X_4, X_5) in the response y1. The values 90.9% tells the effect of four variables (X7, X_4, X_5, X_3) in the response y1. The values 100% tells the effect of five variables only (X7, X_4, X_5, X_3, X_1) in the response y1.

Boxes Plot

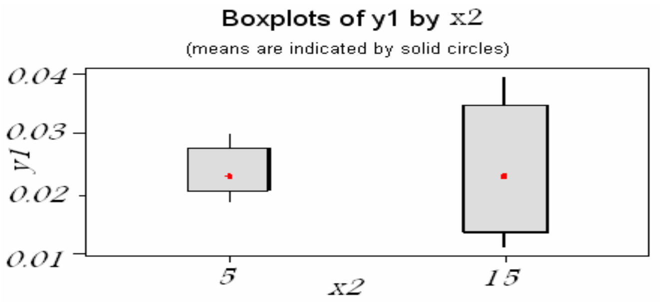
The box plot is a graphical display that simultaneously describes several important features of data set, such as center, spread, departure from symmetry, and identification of unusual observations or outliers. A line is drawn through the box at the second quartile (which is the 50th percentile or the median), box plots are very useful in graphical comparisons among data sets, because they have high visual impact and are easy to understand [6].

The analysis of variance output (y1) and box plots (fig.3) clearly show that the minimum and maximum values of γ1 are different. The 95% confidence interval for average tool wear at γ1= 5^o is between about 0.010 and 0.027 gr. For γ1=15^o, it is between about 0.018 and 0.037gr. γ1 and φ1 is the same effect is about 36.4% .While no relationship between (y1) and(X_2, X_6). At φ =10^o, the tool wear equal 0.02gr. at φ =50^o the tool wear is between 0.015 and 0.034gr. Figure 2and 3 presents the box plot from MINITAB for the alloy compressive strength data shown in Table 3.

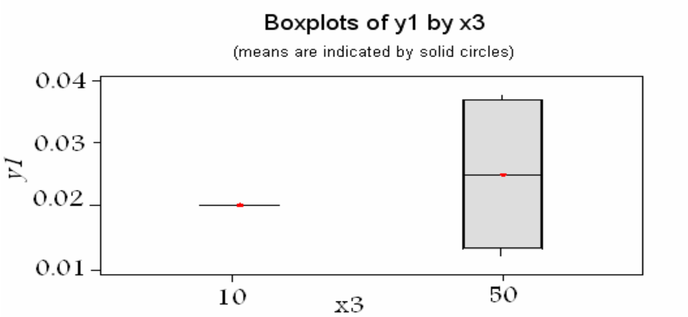



```
                 Individual 95% CIs for Mean
                 Based on Pooled StDev
Level    N   Mean    StDev  ---------+---------+---------+-------
 8       4  0.20000  0.08165 (------------*------------)
12       4  0.25000  0.10000     (------------*------------)
```

```
                    ---------+---------+---------+-------Pooled  StDev  =  0.09129
0.160    0.240    0.320
```

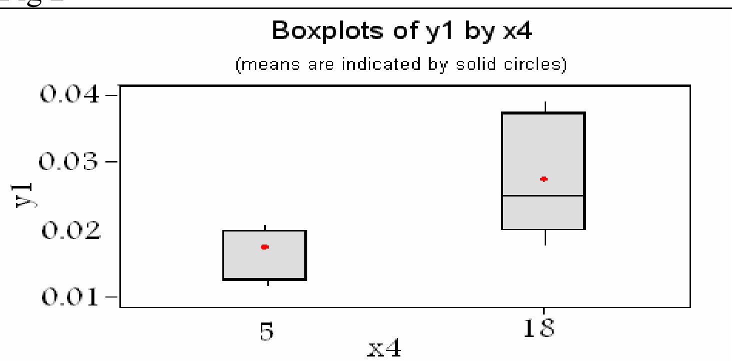



```
Individual 95% CIs for Mean
                    Based on Pooled StDev
Level      N     Mean      StDev  -----+---------+---------+---------+-
 5         4   0.22500   0.05000  (----------------*----------------)
15         4   0.22500   0.12583  (----------------*----------------)
                    -----+---------+---------+---------+-
Pooled StDev =  0.09574         0.140     0.210     0.280     0.350
```

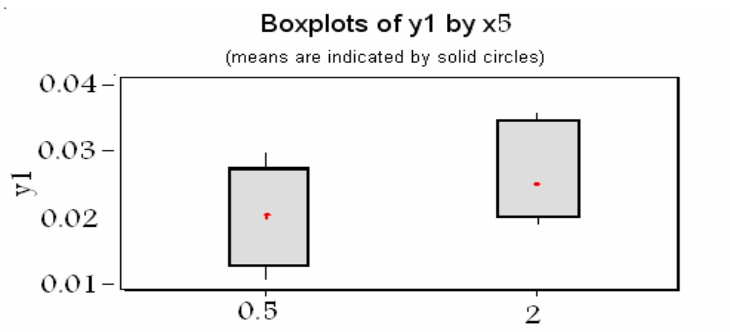



```
                    Individual 95% CIs for Mean
                    Based on Pooled StDev
Level      N     Mean      StDev  ---------+---------+---------+-------
10         4   0.20000   0.00000  (-------------*-------------)
50         4   0.25000   0.12910      (-------------*-------------)
                    ---------+---------+---------+----
```

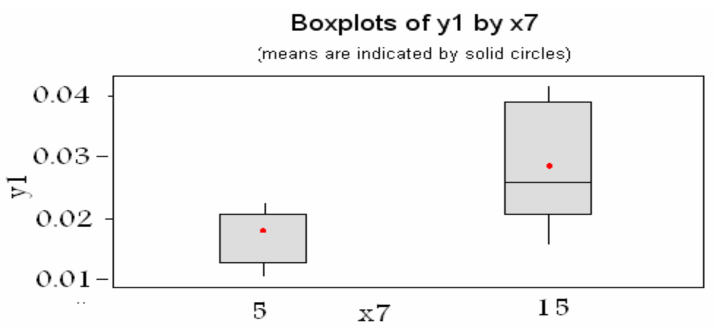
Fig 2



```
                         Individual 95% CIs for Mean
                         Based on Pooled StDev
Level    N    Mean    StDev  ---------+---------+---------+------
 5       4  0.17500  0.05000 (-----------*-----------)
18       4  0.27500  0.09574          (----------*-----------)
                             ---------+---------+---------+------
Pooled StDev = 0.07638             0.160     0.240     0.320
```




```
                         Individual 95% CIs for Mean
                         Based on Pooled StDev
Level    N    Mean    StDev  ---------+---------+---------+-------
0.5      4  0.20000  0.08165 (-------------*-------------)
2.0      4  0.25000  0.10000      (-------------*-------------)
                             ---------+---------+---------+-------
Pooled StDev = 0.09129             0.160     0.240     0.320
```




```
                         Individual 95% CIs for Mean
                         Based on Pooled StDev
Level    N    Mean    StDev  ---------+---------+---------+------
 5       4  0.17500  0.05000 (-----------*-----------)
15       4  0.27500  0.09574          (----------*-----------)
                             ---------+---------+---------+------
Pooled StDev = 0.07638             0.160     0.240     0.320
```

Fig 3

Regression analysis:. The regression equation is for surface roughness (y2) with respect to cutting tool geometry (X_i).

y2 versus X_1 , X_2, X_3, X_4, X_5, X_6, X_7

y2 = 0.555 + 0.166 x1 - 0.0463 x2 + 0.0249 x3 - 0.0566 x4 - 1.25 x5 + 0.256 x6 + 0.0538 x7

Stepwise	1	2	3	4	5	6	7
Const.	4.95	0.82	2.64	4.03	1.72	2.85	3.85
X_5	**1.25**	1.25	1.25	1.25	1.25	1.25	1.25
X_6		**0.256**	**0**.256	0.256	0.256	0.256	0.256
X_3			**0.0249**	**0**.0249	0.0249	0.0249	0.0249
X_4				**0.0566**	0.0566	0.0566	0.0566
X_1					**0.166**	0.166	0.166
X_7						**0.054**	0.054
X_2							**0.046**
R^2%	**50**	**64.9**	**79**	**86.7**	**92.9**	**97**	**100**

R^2 = 50%, the amount of variability X_5 in the response y2.
R^2 = 14.9%, the amount of variability X_6 in the response y2.
R^2 = 14.1%, the amount of variability X_3 in the response y2.
R^2 = 7.7%, the amount of variability X_4 in the response y2.
R^2 = 6.2%, the amount of variability X_1 in the response y2.
R^2 = 4.1%, the amount of variability X_7in the response y2.
R^2 = 3%, the amount of variability X_2in the response y2.

Analysis of Variance (ANOVA)

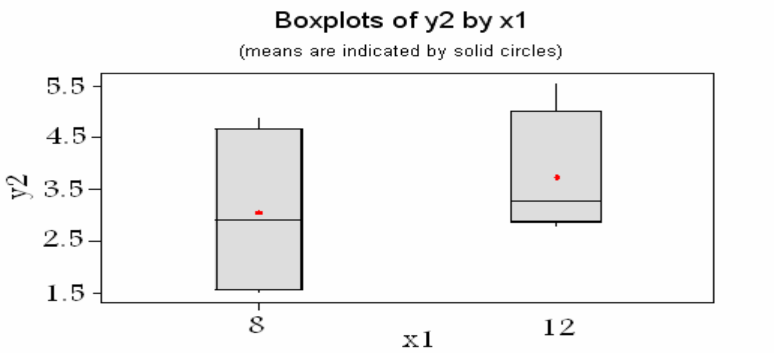
Analysis of variance (ANOVA) extends the tow-sample t-test, which compares two population means, to a test that compares more than two means. MINITABs ANOVA capabilities include procedures for fitting one-way ANOVA test (fig.2, 3, 4, 5, 6) for the equality of population means when classification is by single variable. Display confidence intervals for the differences between means, using four different multiple comparison method: Fisher s LSD, Tukey s, Dunnett s, and Hsu s MCB (multiple comparisons with the best)[2].

The analysis of variance output y2 and boxes plot (fig.4-6) show that the 95% confidence interval for median.

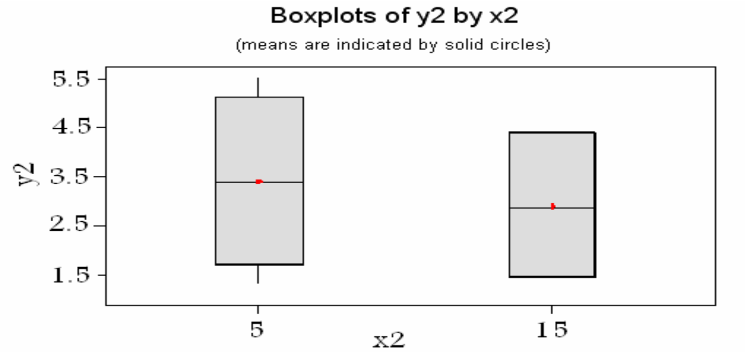
Nose Radius(x5):

The relationship between surfaces roughness y2 and nose radius x5 (fig.5) at $r_\varepsilon = 0.5$ is between about 2.2 and 4.7 µm. For, rε =2.0, it is between about 0.8 and 3.2 µm. The values of surfaces roughness at $r_\varepsilon = 0.5$ are smaller than those roughness in, $r_\varepsilon = 2.0$, about twice, because the mean values, at $r_\varepsilon = 0.5$, is 4.324 µm, but the mean values, at

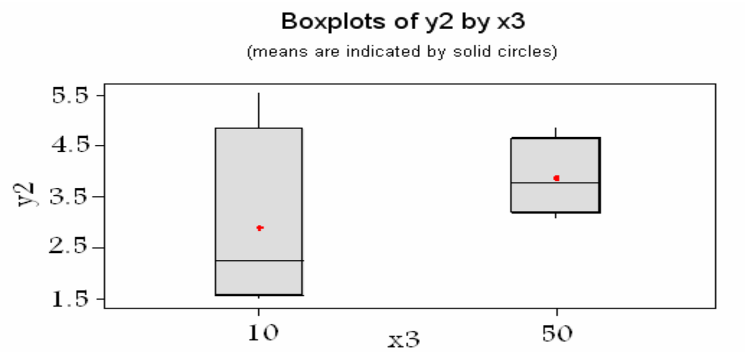
r_ε =2.0, is 2.444 μm. (4.324/2.444) ≈ 2. More influential on the surface roughness is nose radius (x5), it affects by 50% on the quality of the surface (fig 7).




```
Individual 95% CIs for Mean
Based on Pooled StDev
Level   N   Mean    StDev  ----------+---------+---------+------
8       4   3.052   1.692  (--------------*---------------)
12      4   3.716   1.247      (--------------*--------------)
                           ----------+---------+---------+------
Pooled StDev =  1.486           2.4       3.6       4.8
```



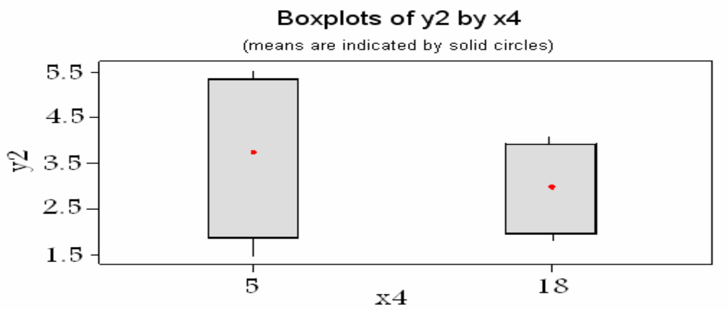

```
Individual 95% CIs for Mean
Based on Pooled StDev
Level   N   Mean    StDev  ----------+---------+---------+------
5       4   3.616   1.614     (--------------*---------------)
15      4   3.153   1.402  (--------------*---------------)
                           ----------+---------+---------+------
Pooled StDev =  1.511           2.4       3.6       4.8
```



Individual 95% CIs for Mean
Based on Pooled StDev

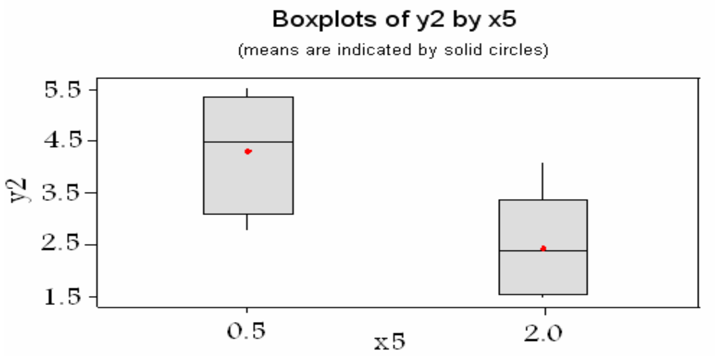
```
Level      N     Mean     StDev  ---+---------+---------+---------+---
10         4    2.886    1.854  (----------*-----------)
50         4    3.883    0.782       (-----------*----------)
                               ---+---------+---------+---------+---
Pooled StDev =    1.423          1.5       3.0       4.5       6.0
```

Fig 4



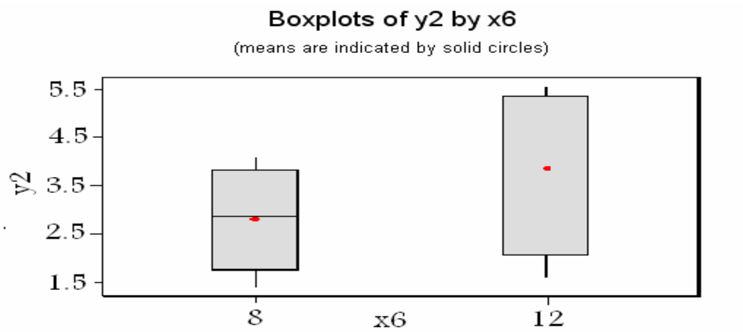
Individual 95% CIs for Mean
Based on Pooled StDev

```
Level      N     Mean     StDev  ----------+---------+---------+------
 5         4    3.752    1.819      (--------------*--------------)
18         4    3.016    1.021  (--------------*--------------)
                               ----------+---------+---------+------
Pooled StDev =    1.475                 2.4       3.6       4.8
```



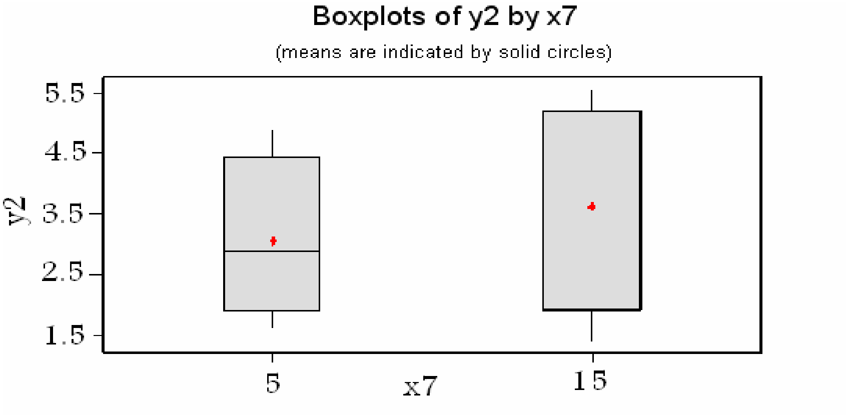
Individual 95% CIs for Mean
Based on Pooled StDev

```
Level      N     Mean     StDev  ---+---------+---------+---------+---
0.5        4    4.324    1.185            (--------*--------)
2.0        4    2.444    0.975  (--------*--------)
                               ---+---------+---------+---------+---
Pooled StDev =    1.085          1.5       3.0       4.5       6.0
```



```
             Individual 95% CIs For Mean
                          Based on Pooled StDev
Level    N    Mean    StDev  ---+---------+---------+---------+---
 8       4    2.871   1.074  (----------*-----------)
12       4    3.897   1.691      (-----------*-----------)
                          ---+---------+---------+---------+---
Pooled StDev =   1.416       1.5       3.0       4.5       6.0
```

Fig 5




```
                        Individual 95% CIs for Mean
                          Based on Pooled StDev
Level    N    Mean    StDev  ----------+---------+---------+------
 5       4    3.115   1.309  (--------------*--------------)
15       4    3.653   1.675     (--------------*---------------)
                          ----------+---------+---------+------
Pooled StDev =   1.503              2.4       3.6       4.8
```

Fig 6

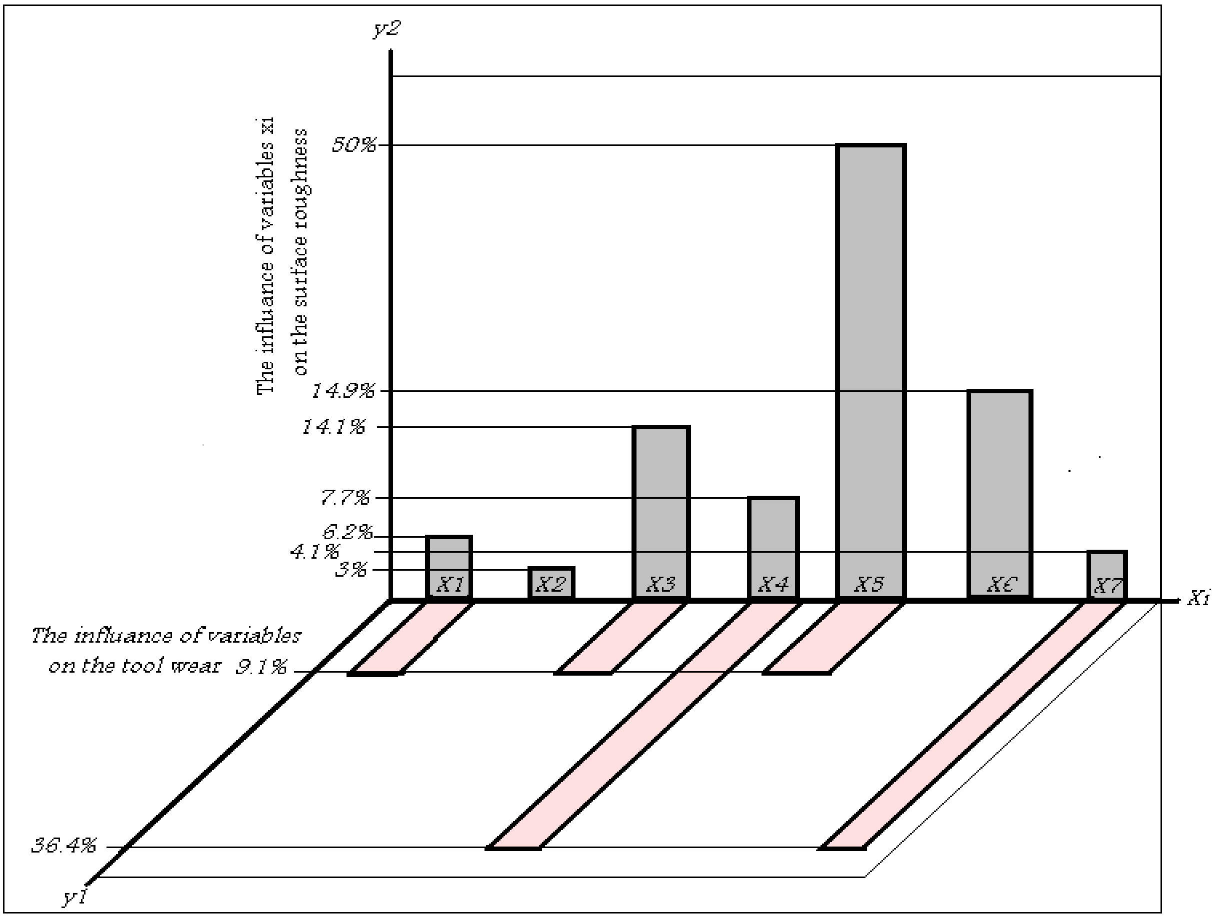


Fig 7. Estimation the Influence of Tool Geometry on the Surface Quality and Tool Wear

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From Figure 5, an increase of nose radius the values of (Ra) decreased, lead to improve the properties of the surface and vice versa, the reason is to increase the plastic deformation of the surface layer. Large nose radius will also improve the tool life, but at the influence of 9.1%.

End Relief Angle(x6):

The relationship between y2 and end relief angle X_6 (fig 5) at $\alpha1=8^o$ is between 0.8 and 4.0 μm. For, $\alpha1=12^o$, it is between 1.6 and 4.8 μm. The mean value at $\alpha1=8^o$ is 2.871 μm, the mean value at $\alpha1=12^o$ is 3.897 μm. End relief angle is affected by 14.9% on the quality of the surface; increasing α1 lead to increased Ra (within the 8-12 degrees, in the ideal values). Prefers to choose a smaller value of 8^o represents a necessary value for the condition of this work . End relief angles that are too small will cause the rate of wear on the flank of the tool below the cutting edge to increase, thereby significant reducing the tool life (fig 2). No influence on the tool life within the $8\text{-}12^o$ from (fig 7).

Side Cutting Edge Angle(x3)

The relationship between y2 and side cutting edge X_3 (fig.4) at $\varphi = 10^o$ is between 0.8 and 4.0 μm. For, $\varphi = 50^o$, it is between 1.6 and 4.7μm. The mean value at $\varphi =10^o$ is 2.886 μm, the mean value at $\varphi = 50^o$ is 3.883 μm. Side cutting edge is the next affect, affected with 14.1% on the quality of the surface. Decreasing x3 lead to improve the properties of the surface. The influence 9.1% is small, between tool wear y1 and X_3.

End Cutting Edge Angle(x4)

The relationship between y2 and X_4 (fig.5) at $\varphi1 = 5^o$ is between 1.6 and 4.8 μm. For, $\varphi1 = 18^o$, it is between 0.8 and 4.0μm. The mean value at $\varphi1 = 5^o$ is 3.752 μm, the mean value at $\varphi1 = 18^o$ is 3.016 μm. Increasing this angle, lead to improve the properties of the surface by the influence of 7.7%.. The size of the end cutting edge angle is very important when tool wear by cratering occurs the influence is about 36.4%.

Relief Angle(x1):

The relationship between y2 and X_1 (fig.4) at $\alpha = 8^o$ is between 0.8 and 4.0 μm. For, $\alpha = 12^o$, it is between 1.6 and 4.8μm. The mean value at $\alpha = 8^o$ is 3.752 μm, the mean value at $\alpha = 12^o$ is 3.016 μm. The impact of this parameter (x1) is small influence by 6.2%, decreasing (x1) lead to improve the surface roughness (within the 8-12 degrees)only in roughing machining, the reason is that ranges limited within the ideal range, depending on the circumstances of the machining own experience. Relief angles that are too small will cause reducing the tool life (fig 2) (the influence is about 9.1% on the tool life within the $8\text{-}12^o$ (fig 7).

Bake Rake Angle(x7):

The relationship between y2 and X_7 (fig.6) at $\alpha1 = 5^o$ is between 0.8 and 4.0 μm. For, $\alpha1 = 15^o$, it is between 1.6 and 4.8μm. The mean value at $\alpha1 = 5^o$ is 3.115 μm, the mean value at $\alpha\ 1=15^o$ is 3.653 μm. The influence of variability X_7 in the response y2 is 4.1% it is very small, decreasing (x7) lead to improve the surface roughness (increases and decreases within the ranges established in the experiment). The tool life will increase with the decrease in the rake angle after the optimum values. The optimum value should be less than 5^o. The influence of x7 is 36.4%.

Relief Angle(x2):

The relationship between y2 and X_2 (fig.4) at $\gamma = 5^o$ is between 1.6 and 4.8 μm. For, $\gamma = 15^o$, it is between 0.8 and 4.0μm. The mean value at $\gamma= 5^o$ is 3.616 μm, the mean value at

$\gamma=15^o$ is 3.153 μm. The increase x2 leads to improve the properties of the surface by the influence of 3%. No influence on the tool life within the 5-15 (fig 7) because the optimum values in the range.

CONCLUSIONS

The change in the ideal values of x2 and x6 (within the $5\text{-}15^o$) does not affect on the cutting tool wear, and little affect on the quality of the surface. While X5 affected on the quality of the surface with 50% in 901% on the wear and because the X5 affected. Wear of the bake and end flange occurs at low speed operation and at machining of the iron r_ζ 2 - 2 × 9.1/100 = 108 mm give good tool life.

1. Estimation the influences of cutting tool geometry on the surface quality and tool wear is the most important factor to increase the efficiency and productivity, improved surface roughness and increase cutting tool life, thus reducing the time wasted.
2. The large influence on the surface roughness is the nose radius estimate with 50% after using optimum values for cutting tool geometry. The large influence on the tool wear is the bake rake angle and end cutting edge angle with 72.73%. when the angle x7 leads to the tool wears, at the same time lead to a decrease surface roughness. Therefore requires evaluation the geometry of tool

with scale of tool wear and surface roughness, from here requires a evaluation relationship of tool wear and surface roughness with the tool geometry.

3. Relationship between the surface roughness and the tool wear not similar non-Identical fig 7. The most appropriate when the machining of the cast iron with tool from HSS. Used the following shape according to the estimation of the Influences of the tool geometry on the surface quality and tool wear.

Estimation y_2 %	Tool geometry	Values for better quality	Values for good life y_2
50%	X_5	2 mm	1.8 mm
14.9%	X_6	8°	8°
14.1%	X_3	43°	10°
7.7%	X_4	18°	5°
6.2%	X_1	8°	8°
4.1%	X_7	5°	5°
3%	X_2	15°	15°

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