*Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)*
*An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2015/04/jls.htm*
*2015 Vol. 5 (S4), pp. 72-78/Cheramin and Nori*
***Research Article***

# EFFECT STATISTICAL DESIGN OF EXPERIMENTS ON TURNING STEEL FOR THE OPTIMIZATION

**Mohammad Cheramin and *Hossein Nori**
*Department of Mechanics, Sanandaj Branch, Islamic Azad University, Sanandaj, Iran*
**Author for Correspondence*

**ABSTRACT**
The design of experiment method due to being an off-line quality control and being an active tool and reducing time and cost of experiment significantly, is superior on other statistical method. In this work in order to save in time and cost, factorial designs $2^k$ (that only two level of each factor is considered) were used. For data analysis, the variance analysis (Anova) that is a power full and well- established technique for data analysis was utilized using Mintab statistical software. The functional principle of Anova is very simple actually, that is comparing different variances and drawing their relative values. The results evaluation shows that the main effects of cutting speed, feed rate, and work piece material and the mutual effects of "cutting speed and feed rate", "cutting speed and work piece material" and "feed rate and work piece material" and the ternary interaction of "cutting speed, feed rate and work piece material" are effective on cost. When work piece material is hard, increasing the cutting speed leads to increase the cost; but when work piece material is soft the production cost decreases with increase in cutting speed. The effective factors on material removing rate (MRR) are cutting speed, feed rate and cut depth that in order to achieve maximum raking rate should be selected in their highest levels, that is $70m/\min$, $0.3mm/rev$ and $3mm$ respectively.

***Keywords:*** *Turning Steel, Statistical Design, Optimization*

## INTRODUCTION

Machining is one of the traditional raking methods that in spite of increasingly development of modern raking techniques, has a significant role in industry particularly in Iranian Industry and this makes recognition and optimization of machining process necessary. In this project optimization of machining process has been addressed using design of experiment (DOE) method that is one of most developed statistical methods and that by which the key variables affecting process quality characteristics of interest can be identified and also has the ability for evaluating mutual effects of factors.

As the design of experiment method being an off-line quality control and being an active tool and reducing time and cost of experiment significantly, is superior on other statistical methods. The use of Design of Experiment of has been started since 1920 by Roland Fischer in agricultural industry (Montgomery, 2004) and since then it's use have been developed significantly in all research fields specially industries. It's significance is such that many experts recognize it as one of main reasons of Japan development and Some Westerners referred to it as secret weapon of Japan.

In this research in order to save in time and cost, the factorial design $2^k$ (that only two levels of each factor is considered) has been used. For data analysis the Variance Analysis (ANOVA) that is a powerful and well-established technique has been utilized using MINITAB statistical software. The functional principle of ANOVA is very simple actually, that is comparing different variances and drawing their relative values (Puertas and Luis, 2003).

Due to long history of machining , a large volume of investigations have been carried out that among all the most current ones can be pointed as follows. Based on Taguchi technique, J. Paulo Davim has investigated optimal condition of cutting for surface leveling in machining using Design of Experiment. In his work the input parameters are cutting speed, feed rate, and cut depth and the target factor (response) considered as surface roughness. The results are as follows:

Feed rate has more effect on surface roughness than cutting speed.

The surface roughness is increased as feed rate increases but is reduced as cutting speed increases. The effect of cut depth on roughness is negligible.
Among analyzed parameters the most important one is interaction between cutting speed and cut depth. Cutting speed-cut depth and feed rate-cut depth interactions has negligible effect on roughness.
A model for machining medium hardness steel as work piece using carbide insert utilizing Response Level Method has been investigated by Yusuf *et al.,* (2004). Considering cutting speed, feed rate, and cut depth they obtained the desired model. The resulted equation shows that the most effective factor on surface roughness is feed rate that is proportional to roughness. With increasing cutting speed and cut depth, the feed rate is decreased. Analyzing the variance also showed that the second order terms has no significant effect on roughness.

$$\hat{Y} = 0.381 - 0.0464V + 0.192f - 0.0249a \quad (1\text{-}1)$$

Variance analysis also shows that F (feed rate) and V (cutting speed) were effective parameters but a (cut depth) has no significant effect on target.
Suresh *et al.,* (2004) investigated a genetic algorithm for optimizing the surface roughness estimation model for carbon steel and concluded that roughness is increased as cutting speed increases.
Despite these investigations on machining optimization, on parameters such as feed rate, cut depth and on optimal condition of cutting in machining process and simultaneous effects of these set of factors related to surface quality and cost in steel work piece machining , however, there is a lack of evaluating achieving some levels of input factors in order to optimizing interaction of surface roughness, so this work aims to identifying effective input factors on surface quality and cost of steel work piece machining , to enable predicting surface quality and cost using input factors, achieving to a levels of input factor to maximum optimization of surface roughness optimization (minimal Ra), minimal cost and minimal MRR. Although MRR data have been obtained using a computational relation and statistical analysis seems not to be so necessary, but it has been considered in order to interactional optimizing with other objectives (minimal roughness and minimal cost).

## MATERIALS AND METHODS

### *Methodology*

This is an experimental-analytical study. The six most important factors of machining process (cutting speed, feed rate, cut depth, work piece material, setting angle and rake angle) has been considered as input parameters and considering 3 iteration for each combination to increasing accuracy and reducing interference, $3 \times 2^6 = 192$ steel bar work pieces have been machined totally and relevant analysis carried out using measurements and calculations. The experiment order was randomly and it's table was created using MINITAB software. The running order of experiments was created by computer and the experiments carried out using TN50A device (made of Tabriz Machine Manufacturing Co.).

### *Required Terminology and Definitions*

*Test Combination (Treatment)*

A specific combination of factors that are tested at defined levels of all factors. The treatment is a combination in which all factors in desired levels are considered in one stage of experiment by operator.

*Full Factorial Design*

Design in which we aim to assess all possible effects. Having L levels for each factor, K factor, and n iterations; the number of experiments is then would be $nL^K$

*$2^k$ Factorial Design*

One of the designs that have many applications in Design of Experiment techniques is $2^k$ factorial design or two-level designs. For experiment to be designed with $2^k$ factorial designs, after specifying experiment factors, only two-levels of each factor should be considered.

*Blocking*

Sometimes we are facing with uncontrollable factors that can be controlled in experiment conditions, but we don't intend to assess these factors. So in this case we block the experiment. There are also situations in which due to financial or physical limits, randomization of experiment runs is not possible and hence blocking is used.

***Calculation and Measurements***

MRR (material removing rate): it can be expressed as the result of cutting speed by feed rate by cut depth.
**Operation cost:** it can be defined as cost per production of each work piece, $C_{P.}$
**Surface quality:** each work piece roughness (Ra) was measured using roughness tester Surtronic and Taylor Habson Unit with 8mm cutoff.

***Experiments Analysis***

It was decided experiment analysis to be carried out in 3 ways:

a) Case without blocking work piece material
b) Case with blocking work piece material
c) Separately for each type of work piece material

Obtained models then are compared with each other and the one that is more appropriate is selected and used as acceptable method. Section 5 is devoted to experiment analysis.

***Results Analysis***

Different models in both cases (without and with blocking piece work material)
Have been obtained and compared with each other. Then in order to characterizing differential effect of parameters with respect to work piece material (in other words to specifying that work piece material to some extent had been effective on factors?), for each material a separate model obtained and compared.

***Ra Analysis in Case without Blocking***

As it can be seen from the curve, B (feed rate), D (work piece material), BD (feed rate and work piece material), DE (work piece material and setting angle), AE (surface cutting speed and setting angle), CE (cut depth and setting angle) factors have significant difference with zero mean and $\sigma^2$ variance while insignificant effects have normal distribution with zero mean and $\sigma^2$ variance.

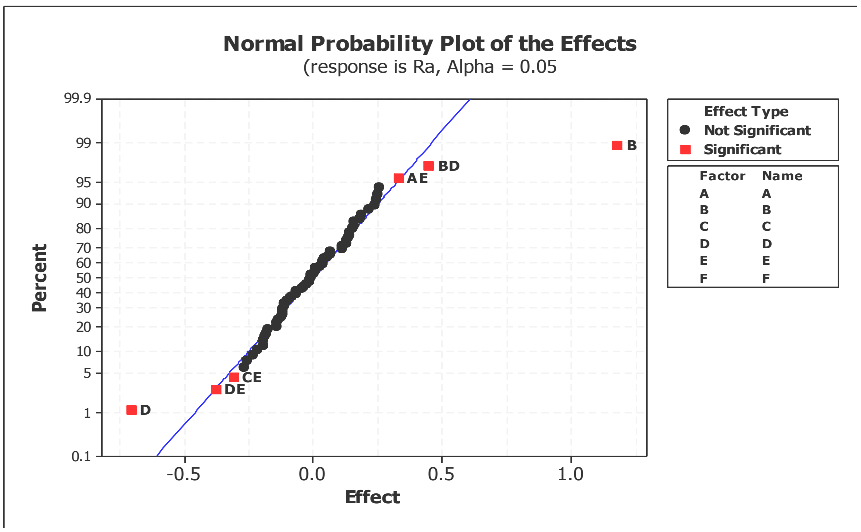


**Figure 1: Normal probability curve of Ra effects**

Because F (Rake angle) is not significant and none of it's mutual effects also has important effect on response (surface roughness, Ra), the design projection rule can be used to remove F from experiment such that instead of a $2^k$ full factorial design without iteration, one can have a $2^5$ full factorial design in terms of A, B, C, D and E but with two iterations, so error estimation become possible. From analyzing new design (neglecting F) we see that the effective terms will be the same as than previously obtained.
From curve it is evident that feed rate (B) has positive and work piece material (D) has negative effect on response (Ra), that is an increase in feed rate and in hardness of material leads Ra to increase and decrease respectively.

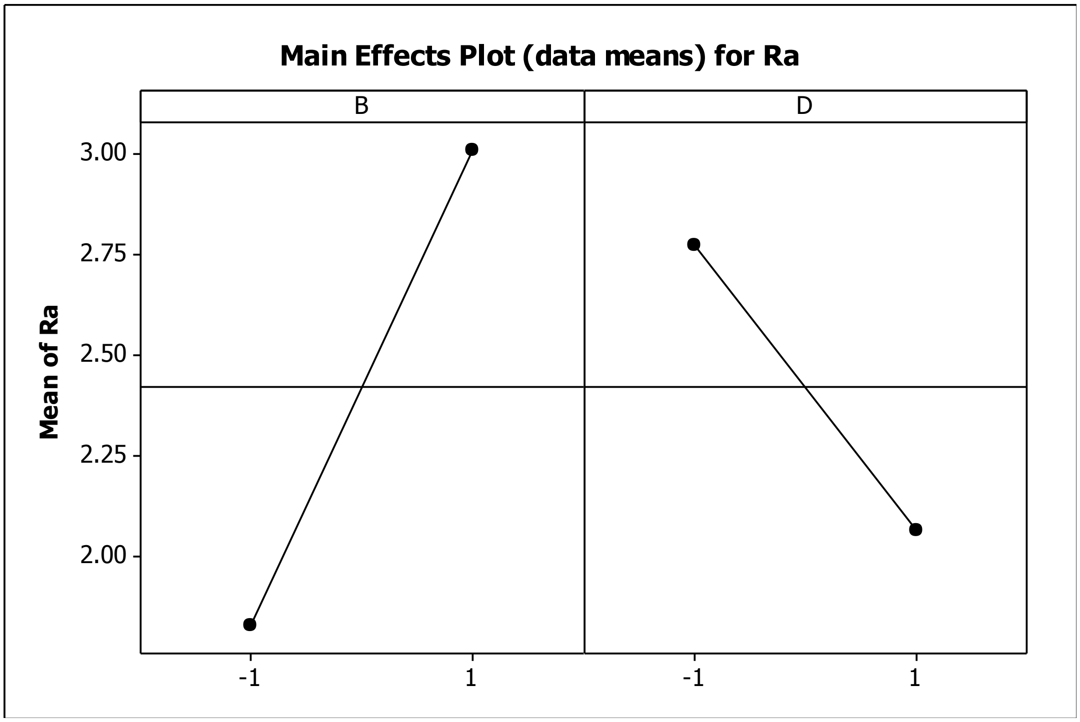


**Figure 2: Curve of main effects of effective factors on Ra**

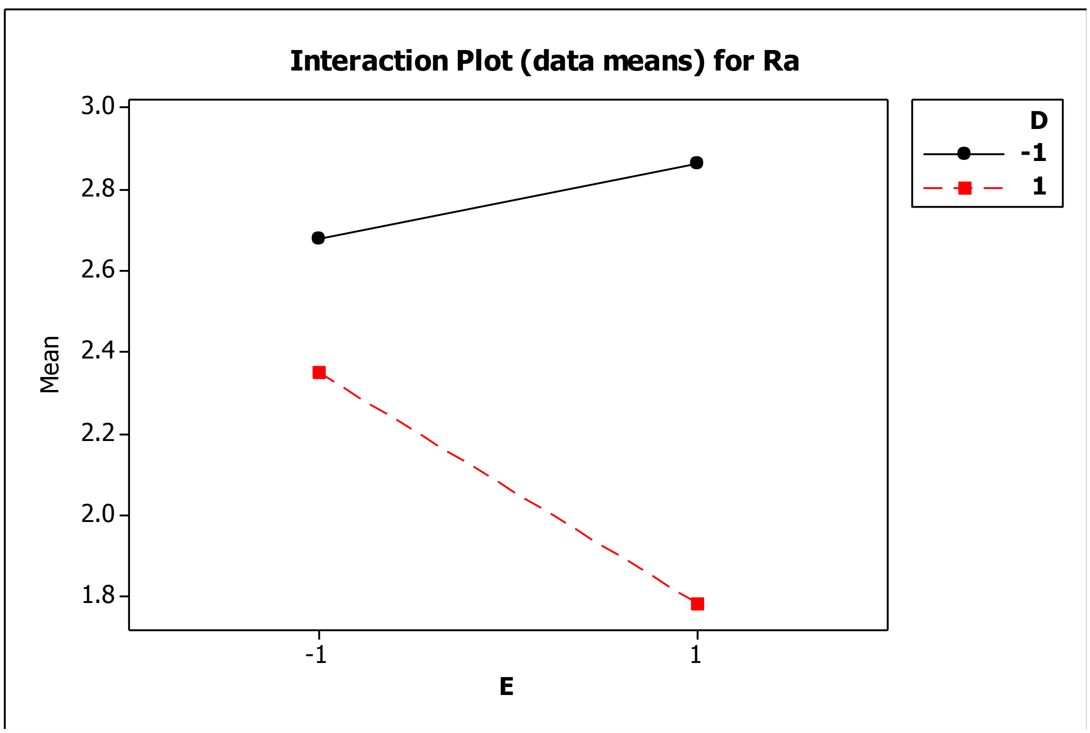


**Figure 3: Mutual effects of DE (work piece material and setting angle)**

Mutual effects of DE (work piece material and setting angle) shows that when work piece material is soft, F has a positive and when it is hard F has a negative effect on Ra, so in order to achieve a desired response (minimal Ra), these two factor (work piece material and setting angle) should be selected at high level.

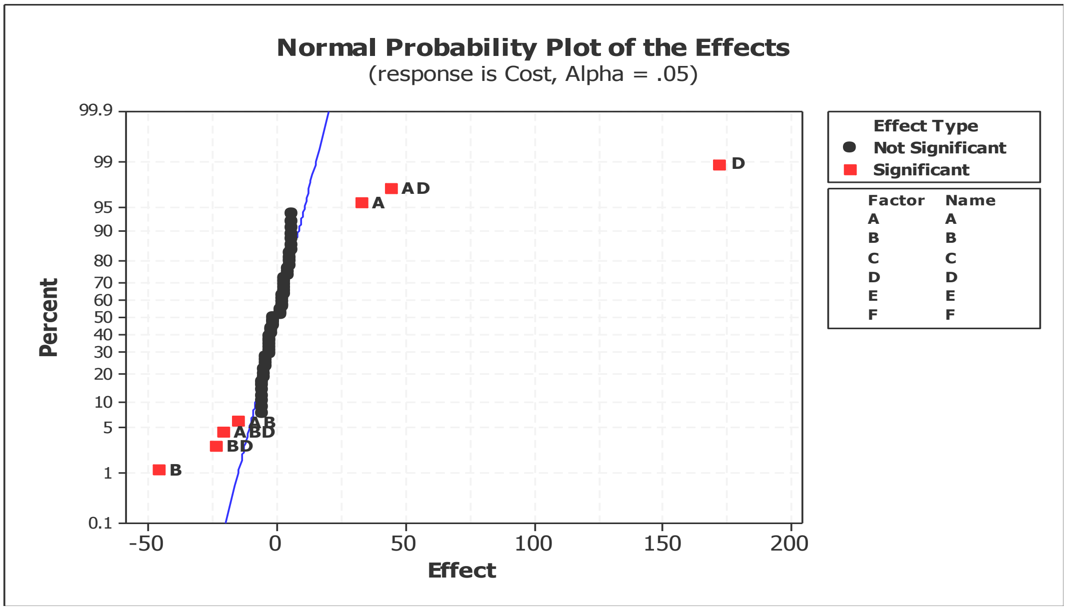


**Figure 5: Normal probability curve of effects on cost**

It can be seen from Figure 4 that terms A (cutting speed), B (feed rate), D (work piece material), AB(mutual effects of cutting speed and feed rate), AD(mutual effects of cutting speed and work piece material), BD(mutual effects of feed rate and work piece material), ABD(ternary effects of (cutting speed, feed rate and work piece material) are effective.
After recognizing main effects, it should be determined that the factor levels in what level might be set for the cost to be minimized. For this the curves for main effects and mutual effects of effective terms should be depicted.

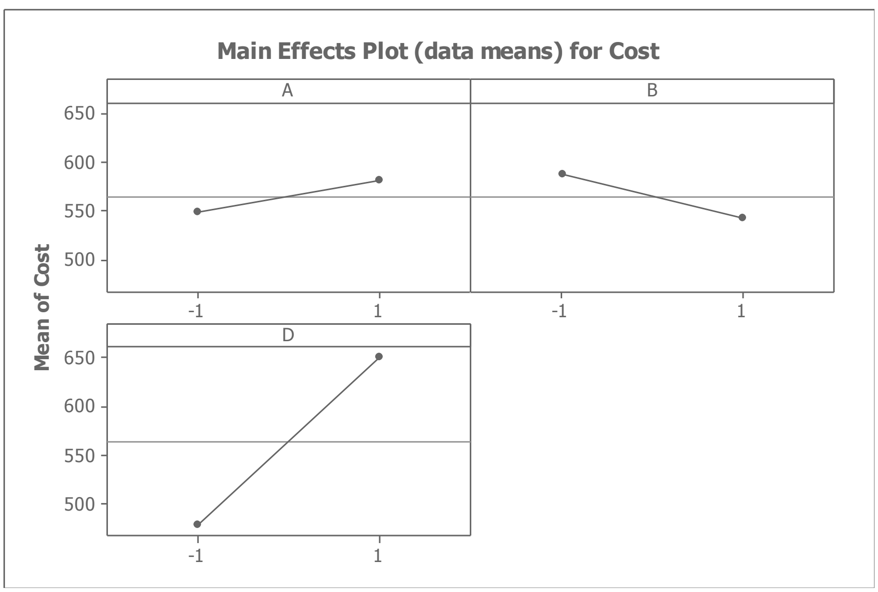


**Figure 5: The curve for main effects of A (cutting speed), B (feed rate), D (work piece material on cost)**

As it can be seen from the curve, an increase in A (feed rate) and D (work piece material) lead response (cost) to increases and an increase in B (feed rate) leads it to decreases. So for cost to be minimized, the factors A (cutting speed), and D (work piece material) should be set at low and D (work piece material) at high level. But when significant main effects include significant mutual effects, they aren't important in their own and it should be concluded based on mutual effects**.**

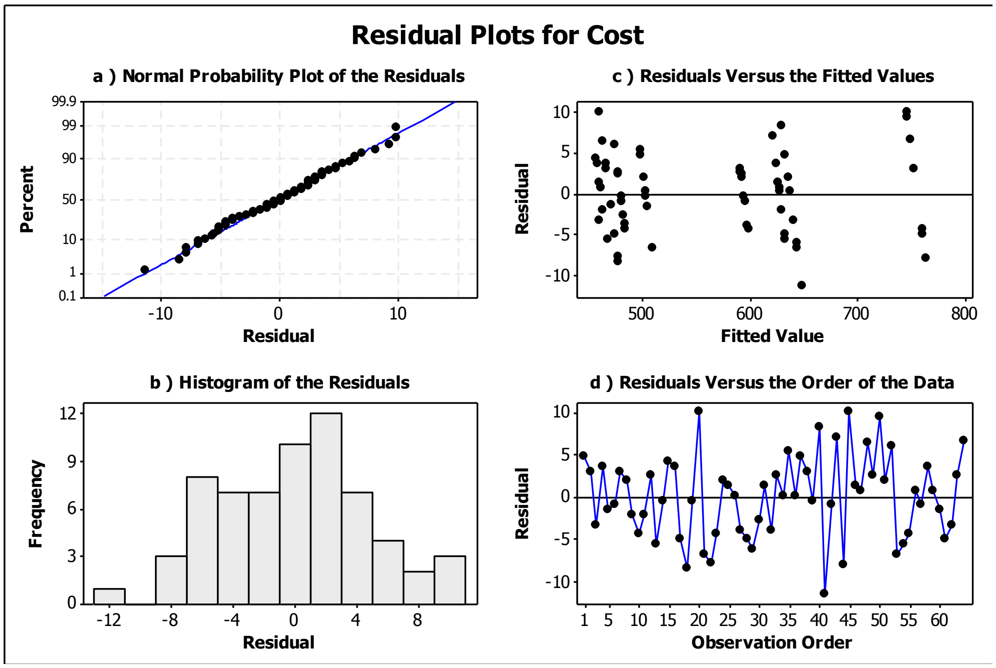


**Figure 6: Different residual errors for case without blocking**

Part a: shows residuals probability. In this curve points are distributed around a straight line appropriately that is a good indicative of appropriateness of fitted model.
Part b: shows residual history. Although this curve is not fully symmetrical, it seems to be acceptable.
Part c: it is the residual curve with respect to fitted values. This figure shows that the residuals are distributed randomly around zero line and consequently variance of independent variable (cost) is nearly constant.
Part d: shows residual with respect to order of data collections. It is noted that residual orders don't show specific pattern and the positive and negative trending of residuals have been repeated frequently and hence one can conclude that the cost of different piece has no dependence on each other and are independent. So it can be concluded totally that the model fitted appropriately.

## RESULTS AND DISCUSSION

### *Results*

- In this project the analysis was carried out in both case (without and with blocking) and it is found that in case without blocking , a more appropriate model is fitted to the data.
- Minimum surface roughness for hard material is obtained at cutting speed= 25 m/mm, feed rate= 0.1 mm/rev, cut depth= 3mm and setting angle = 60 °.
- Increasing feed rate, decreasing cutting speed and using soften material cause the cost to be decreased.
- For production rate to be maximized, the cutting speed, feed rate and cut depth factors should be set at their highest level namely 70 m/mm, o.3 mm/rev, and 3mm respectively.
- For work piece with hard material, the mutual effects of feed rate and setting angle show that when feed rate is at it's low level, increasing setting angle has no significant effect on surface roughness; but for soft material when feed rate is at it's low level, increasing setting angle leads roughness to be increased.

- For soften work piece, increasing setting angle leads roughness to be increased but a reverse trend is the case for hard work piece.
- When the work piece is hard, an increase in feed rate leads to rapidly increasing of roughness but when it is soft, roughness is increased slowly.
- When the work piece is hard, an increase in cutting speed leads production cost to be increased but when it is soft the production cost decreases as cutting speed increases.

**ACKNOWLEDGMENT**
This article is extracted from my thesis under the title of "Effect Statistical Design of Experiments on turning Steel for the optimization". Hereby, I extend my sincere appreciation to Islamic Azad university of Sanandaj for the efforts and supports they provided to me.

**REFERENCES**
**Feng CR (2003).** Turning on the machine: Genetic control of Axon Regeneration by C-Jun. *Journal of Neuron* **43** 1-2.
**Montgomery DC (2004).** *Design & Analysis of Experiments*, fifth edition (John Wily & Sons).
**Paulo Davim J (2001).** A note on the determination of optimal cutting conditions for surface finish obtained in turning using Design of Experiment. *Journal of Materials Processing Technology* **116** 305-308.
**Puertas Arbizu I and Luis Perez CJ (2003).** Surface Roughness Predication by factorial Design of Experiment in Turning Process. *Journal of Materials Processing Technology* **144** 360-396.
**Puertas Arbizu I and Luis Perez CJ (2004).** Surface roughness Prediction by factorial design of experiment in turning processes. *Journal of Materials Processing Technology* **143-144** 390-396.
**Vijaya Kumar K, Prabharan G, Asokan P and Sarvanan R (2003).** Optimization of multi-pass turning operations using ant colony system. *Journal of Machine Tools & Manufacturing* **43** 1633-1639.
**Yusuf Shahin and Motorcu AR (2004).** Surface Roughness Model for Machining mild steel. *Journal of Materials Design* **xxx** 1-6.