International Journal of Production Engineering
Vol. 1: Issue 1
www.journalspub.com

Statistical Analysis of Factors Effecting Surface Finish in Plain Milling

Siva Prasad Kondapalli*
Associate Professor, Department of Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences, Visakhapatnam, India

Abstract
Now a day's research over improvement of surface finish on mechanical elements has become quite significant in the operational and aesthetical point of view. To enhance accuracy and precision, manufacturing firms are adopting automated systems in order to achieve manufacturing excellence. In the present work the effect of various process parameters like spindle speed, feed, and depth of cut on the surface finish in plain milling process is investigated by using Response Surface Method. Experiments are performed as per Box Behnken Design matrix for three factors and three levels. The coefficients are calculated by using regression analysis and the model is constructed. The adequacy of the developed model is checked using Analysis of Variance (ANOVA) technique. By using the mathematical model the main and interaction effect of various process parameters on surface finish are studied.

Keywords: *Plain milling, brass, surface finish, ANOVA*

Author for Correspondence: *Email ID: kspanits@gmail.com*

INTRODUCTION

Milling is an important machining process in which flat as well as curved surfaces are produced by rotating multi-edged cutting tools. Out of various milling process plain milling is one of the important process where the material removal rate is more when compared to end milling process. Many works are reported on plain milling process; however certain gaps are left over because of certain limitations.

From the literature it is understood that the effect of different parameter like cutting speed, feed and rake angle in surface roughness was studied by Azlon zain, *et al.*[1]. They compared the result of regression modeling and genetic algorithm. V. Tandon *et al.*[2] presented a new approach to optimizing the cutting conditions in end milling (feed and speed) subject to a near to comprehensive set of constraints. I.N. Tansela, *et al.*[3] studied the effect of cutting speed, feed rate and radial depth of cut for milling process using Artificial Neural Networks. Baskar *et al.*[4] reported that there is drastic improvement in conventional milling process optimization by using various non-conventional optimization techniques. J. Balic *et al.*[5] presented systematic design of condition monitoring system for machine tool and machining operations.

Prakasvudhisarn *et al.*[6] discussed about machine learning technique called support vector machine to predict the surface roughness and optimized using Particle swarm optimization. Zarei *et al.*[7] discussed a harmony search (HS) algorithm to estimate the optimum cutting parameters for multi-pass face-milling process to minimize total production cost. Asif Iqbal *et al.*[8] adopted fuzzy expert system in high speed milling process and predicted tool life and surface finish. G.H. Qin[9] developed methodology for integrates the cutting force module consisting of calculating the instantaneous uncut chip thickness (IUCT), calibrating the instantaneous cutting force coefficients (ICFC) and the cutting process module consisting of calculating the cutting configuration and static form errors. Rao.N, *et al.*[10] introduced a new optimization method known as Teaching-Learning Based Optimization (TLBO). Oktem, *et al.*[11] observed closeness in the results between experimental and predicted values in end milling process. They used neural network and genetic algorithm.

From the review of various papers, it is understood that the optimization on milling process has started only in recent past. Most of the researchers were using soft computing based optimization methods and found good results.

The literature related to milling optimization is mainly concerned with minimization of surface roughness. The objective of the present paper is to study and optimize the surface finish of brass alloy using face milling process.

EXPERIMENTAL PROCEDURE AND ANALYSIS

Commercial brass plate of size 300 x 32 x 12 mm is taken and grinded in order to remove any surface irregularity. The chemical composition is specified in Table 1. White chalk is applied on one side of the bras plate. By using steel rule and scriber the brass plate is divided into 15 subdivisions to facilitate milling process. Four input parameters are chosen, namely speed, feed and depth of cut. The width of the plain milling cutter is 25 mm. The levels and values of chosen parameters are presented in Table 2.

Table 1: *Chemical Composition (wt.%).*

Component	**Wt.%**
C	60–63
Fe	Max 0.35
Other	Max 0.5
Pb	2.5–3.7
Zn	35.5

Table 2: *Parameters and Their Limits.*

	Levels		
Parameter	**–1**	**0**	**+1**
Spindle Speed (rpm)	146	212	297
Feed (mm/min)	28.33	42.50	56.67
Depth of cut (mm)	0.5	0.75	1

Design of Experiments (DOE) is used to select the design matrix. Experiments are performed as per Box Behnken Design matrix for three factors and three levels. Total 15 combinations of experiments are carried out in dry machining conditions. Using Talysurf surface finish values for the 15 plain milling slots are measured using universal milling machine as shown in Figure 1 and reported in Table 3 for dry machining.

Fig. 1: *Machining Setup.*

Dry Machining

Milling has been done in dry condition without any coolant as per the design matrix and the measured values of surface finish are reported in Table 3.

Table 3: Experimental Results for Dry Machining.

Experiment No.	Speed (rpm)	Feed (mm/min)	Depth of cut (mm)	Surface Finish (Microns)	
				Actual	Predicted
1	–1	–1	0	1.27	0.97
2	1	–1	0	1.11	0.94
3	–1	1	0	1.99	1.86
4	1	1	0	1.59	1.21
5	–1	0	–1	1.35	1.18
6	1	0	–1	0.99	0.55
7	–1	0	1	1.62	1.23
8	1	0	1	1.41	1.18
9	0	–1	–1	0.55	0.41
10	0	1	–1	2.32	2.06
11	0	–1	1	2.06	1.81
12	0	1	1	1.49	1.33
13	0	0	0	1.22	1.12
14	0	0	0	1.22	1.12
15	0	0	0	1.22	1.12

Development of Empirical Model for Dry Machining

Using MINITAB 14 statistical software package, the significant coefficients were determined and final model is developed using second order polynomial equation to estimate surface finish of the plain milling slots in dry machining.

$$Y = 1.220 - 0.143X_1 + 0.300X_2 + 0.173X_3 + 0.003X_1^2 + 0.266X_2^2 + 0.118X_3^2 - 0.060X_1X_2 + 0.037X_2X_3 - 0.585X_3X_1$$

where X_1, X_2, and X_3 are the coded values of speed, feed and depth of cut .

Checking the Adequacy of the Developed Model in Dry Machining

The adequacy of the developed model was tested using the Analysis of Variance technique (ANOVA). As per this technique, if the calculated value of the F_{ratio} of the developed model is less than the standard F_{ratio} (from F-table) value at a desired level of confidence (say 95%), then the model is said to be adequate within the confidence limit. ANOVA test results presented in Table 4 are found to be adequate at 95% confidence level.

Table 4: ANOVA Table for Surface Finish in Dry Machining.

Source	DFF	Seq SS	Adj SS	Adj MS	F
Regression	9	2.8155	2.8155	0.31283	3.05
Linear	3	1.1268	1.1268	0.37561	3.66
Square	3	0.2997	0.2997	0.09991	0.97
Interaction	3	1.3889	1.3889	0.46298	4.52
Residual Error	5	0.5126	0.5126	0.10252	
Lack of Fit	3	0.4014	0.4014	0.13381	2.41
Pure Error	2	0.1112	0.1112	0.05560	
Total	14	3.3281			

where DF=Degrees of Freedom, SS=Sum of Squares, MS=Mean Square, F=Fishers Ratio

Figure 2 indicates the scatter plot for surface finish of the plain milling slots and reveals that the experimental and predicted values are close to each other with in the specified limits

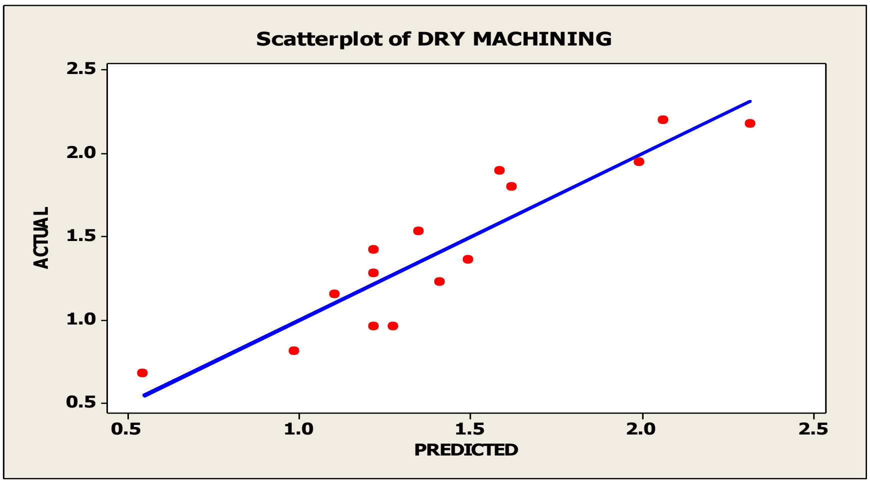

Fig.2: *Scatter Plot for Surface Finish.*

Effect of Milling Parameters on Surface Finish in Dry Machining

Main Effects on Surface Finish in Dry Machining: Graphs are drawn for each milling parameters separately as shown in Figure 3 and the following observations are made:

1. By increasing the cutting speed (rpm), better surface finish is achieved. This is because at higher cutting speeds tool contact with the work piece is less.
2. By increasing the feed rate (mm/min), poor surface finish is achieved. This is because of large contact area of the cutting tool and work piece material.
3. By increasing the depth of cut, poor surface finish is achieved. This is because of more obstruction of tool to move forward at higher depth of cuts.

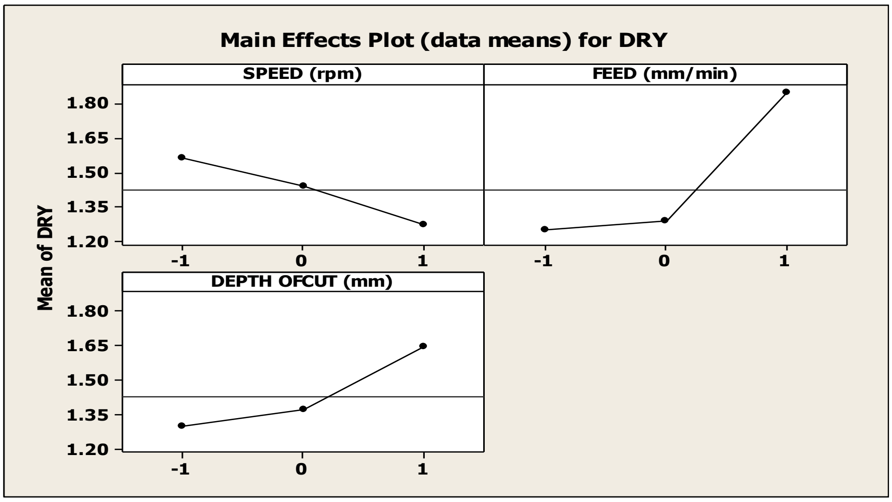

Fig. 3: *Main effects on surface finish in dry machining.*

Interaction Effects on Surface Finish in Dry Machining: Interaction plots are drawn in order to the study the effect of all plain milling parameters at a time on the surface finish as shown in Figure 4.

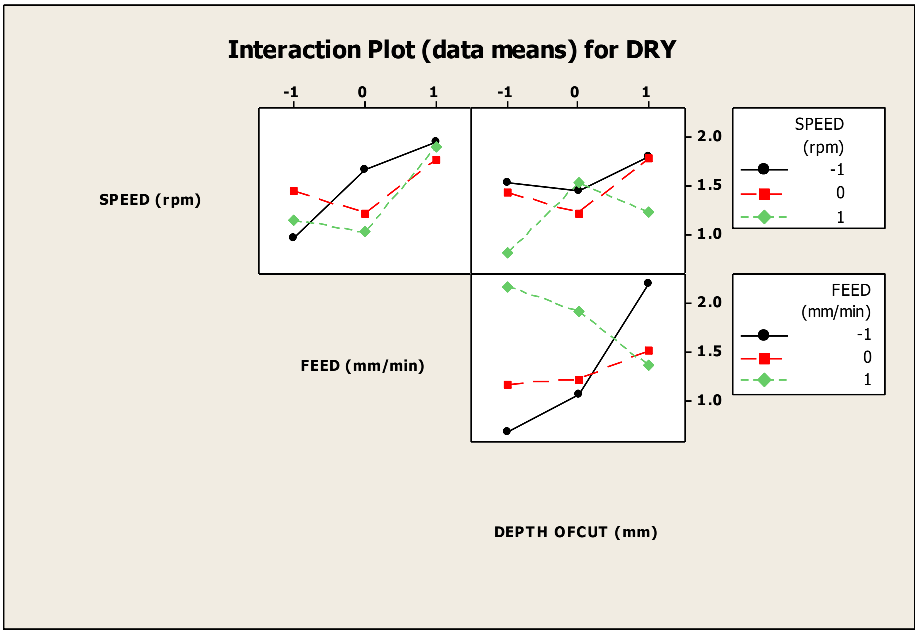

Fig.4: *Interaction Effects on Surface Finish.*

Contour Plots for Dry Machining

The simultaneous effect of two parameters at a time on the output response is generally studied using contour plots. By generating contour plots using statistical software (MINITAB14) for response surface analysis, the most influencing parameter can be identified based on the orientation of contour lines. If the counter patterning of circular shaped counters occurs, it suggests the equal influence of both the factors; while elliptical contours indicate the interaction of the factors. Figure 5 indicates the contour plots for surface finish.

From the contour plots it is understood that depth of cut is the most dominating parameter effecting surface finish followed by feed and speed.

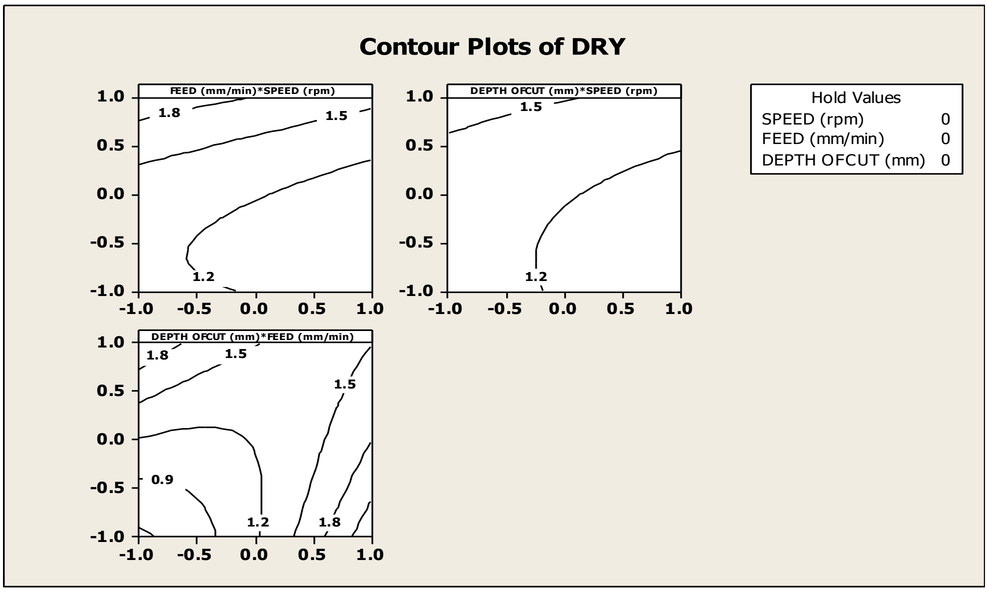

Fig. 5: *Contour Plots for Surface Finish.*

Surface Plots for Dry Machining

Surface plots are drawn to identify the optimal combination of input parameters, so that desired output response is achieved.

From Figure 6, it is understood that better surface finish can be obtained at lower speed and higher cutting speed. From Figure 7, it is understood that better surface finish can be obtained at lower depth of cut and higher cutting speed. Figure 8, it is understood that better surface finish can be obtained at lower feed and lower depth of cut.

From the Figure 6, 7 and 8, it is clear that in order to achieve good surface finish; it is recommended to use high cutting speed, low feed and low depth of cut.

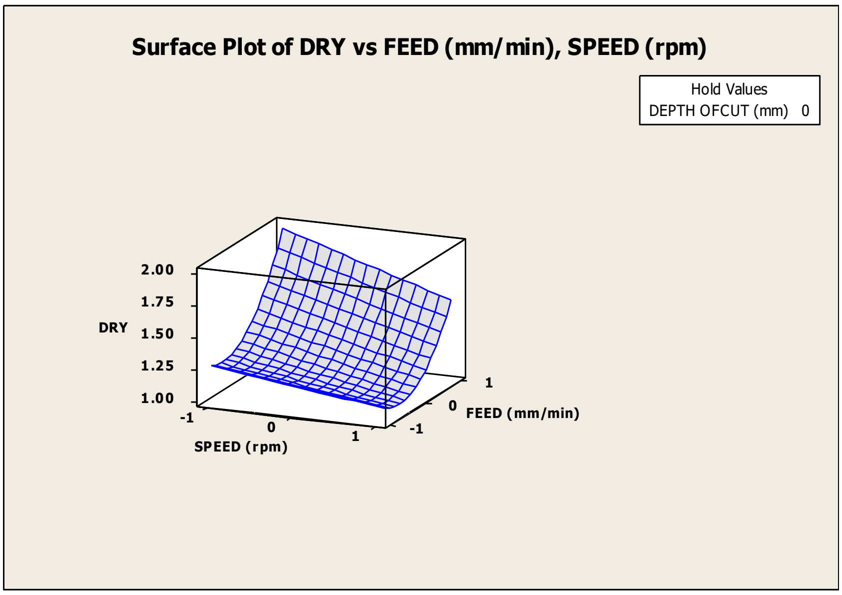

Fig. 6: *Contour Plots for Dry Machining (Speed Vs Feed).*

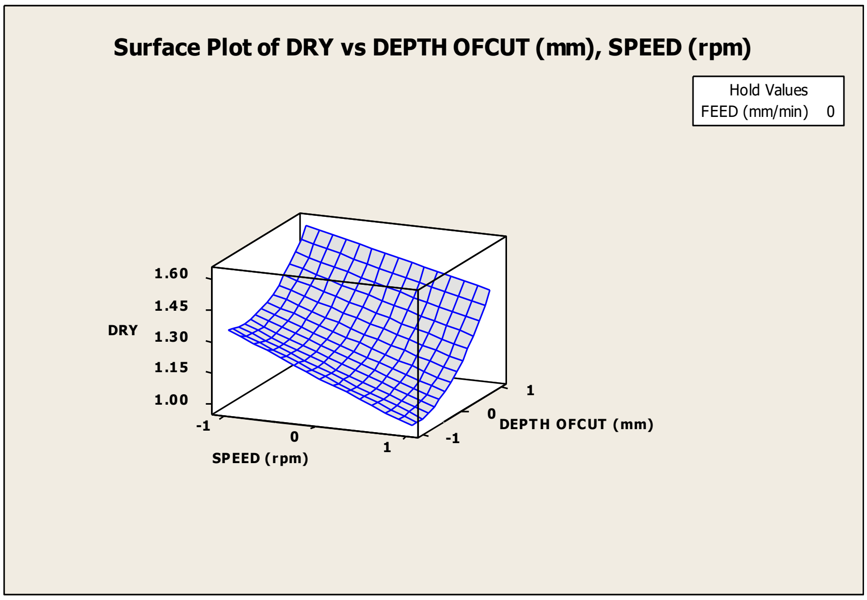

Fig.7: *Contour Plots for Dry Machining (Speed Vs Depth of Cut).*

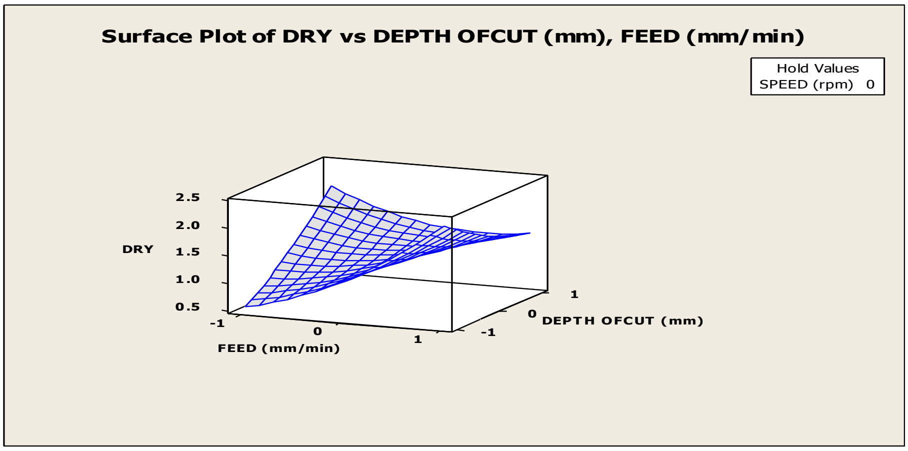

Fig. 8: *Contour Plots for Dry Machining (Feed Vs Depth of Cut).*

Comparison of Experimental and Predicted Values of Surface Finish in Dry Machining

Table 5: *Comparison Table for Dry Machining.*

Experiment No.	Surface Finish (Microns)	
	Actual	**Predicted**
1	1.27	0.97
2	1.11	0.94
3	1.99	1.86
4	1.59	1.21
5	1.35	1.18
6	0.99	0.55
7	1.62	1.23
8	1.41	1.18
9	0.55	0.41
10	2.32	2.06
11	2.06	1.81
12	1.49	1.33
13	1.22	1.12
14	1.22	1.12
15	1.22	1.12

From the developed model, the values of surface finish are predicted by substituting the coded values of the milling parameters in the developed empirical mathematical model. Table 5 indicates the experimental and predicted values of surface finish for all the 15 combination of experiments performed.

RESULTS AND DISCUSSIONS

From the experiments performed the following results are drawn.

1. Empirical mathematical model is developed for predicted the surface finish values in dry machining condition in plan milling process.
2. The experimental and predicted values are very close to each other, which indicate the accuracy of the developed models.
3. The adequacy of the developed model is checked using ANOVA at 95% confidence level ad found to be adequate.
4. From the scatter plot it is understood that experimental and predicted values are close to each other.
5. From the main effect plots, it is clear that surface finish is improved with cutting speed and become worse at higher feeds and depth of cut.
6. From the contour plot, the most dominating parameter effecting surface finish is depth of cut, followed by feed, speed.
7. From the surface plots, it is understood that in order to obtained better surface finish the desired parameters are high cutting speed, low feed and low depth of cut.

8. The developed empirical models are valid within the range of the selected plain milling parameters.

CONCLUSIONS

The following conclusions are drawn based on the experimental results.

Empirical models are developed for predicting surface finish in dry machining condition for plain milling process using Box Benhken Design and their adequacy is checked using ANOVA technique at 95% confidence level. The effect of milling parameters are studied and understood that surface finish improved with higher cutting speed and poor surface finish are obtained at higher feeds and higher depth of cut. In order to obtained better surface finish the desired parameters are high cutting speed, low feed and low depth of cut. The developed empirical models are valid within the specified range of the selected plain milling parameters; however the accuracy can be improved by considering more number of factors and their levels.

REFERENCES

1. Azlon Z., Haron H., Shariff S. Application of GA to optimize cutting condition for minimizing surface roughness in end milling machining process. *Expert Systems with Applications*. 2010; 37: 4650–9p.
2. Yang L.J., Joseph C.C. A systematic approach for identifying optimum surface roughness performance in end-milling operations. *Journal of Industrial Technology*. 2001; 17: 1–8p.
3. Tansela I.N., Baoa W.Y., Reena N.S., *et al*. Genetic tool monitor (GTM) for micro-end-milling operations. *International Journal of machine tools & manufacture*. 2004; 45(3).
4. Baskar, N., Asokan, P., Saravanan, R., *et al.* Optimization of machining parameters for milling operations using non-conventional methods. *International Journal of Advanced Manufacturing Technology*. 2005; 25: 1078–88p.
5. Balic J., Milfelner M., Cus F. An overview of data acquisition system for cutting force measuring and optimization in milling. *Journal of Materials Processing Technology*. 2005; 164–165: 1281–8p. doi:10.1016/j.jmatprotec.2005.02.146
6. Prakasvudhisarn C., Kunnapapdeelert S., Yenradee P. Optimal cutting condition determination for desired surface roughness in end milling. *International Journal of Advanced Manufacturing Technology*. 2009; 41(5–6): 440–51p.
7. Zarei O., Fesangharyb M., Farshia B., *et al.* Optimization of multi-pass face-milling via harmony search algorithm. *Journal of Materials Processing Technology*. 2009; 209(5): 2386–92p.
8. Iqbal A., He N., Li L., *et al.* A fuzzy expert system for optimizing parameters and predicting performance measures in hard milling process. *Expert Systems with Application*. 2007; 32(4): 1020–7p.
9. Wan M., Zhang W.H., Qin G.H. Systematic simulation procedure of peripheral milling process of thin walled workpiece. *Journal of Materials Processing Technology*. 2008; 197(1–3): 122–31p.
10. Rao R. V., Savsani V. J., Vakharia D. P. Teacher – learning – based optimization: A novel method for constrained mechanical design optimization problems. *Computer Aided Design*. 2011; 43(3): 303–15p.
11. Oktem H., Erzurumlu T., Erzincanli F. Prediction of minimum surface roughness in end milling mold parts using neural network and genetic algorithm. *Materials and Designs*. 2006; 27(9): 735–44p.