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ESTIMATION OF MODELLING PARAMETERS FOR TOOL WEAR ON TURNING OF TI6AL4V BY USING GRAVITATIONAL SEARCH ALGORITHM

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Abstract - Titanium and its alloys have become more widespread by advantages of the high strength, low weight ratio and outstanding corrosion resistance. Ti6Al4V alloy, which is preferred in medical, electronics and aeronautics, is a material with the highest machinability in titanium alloys. Thus, machining parameters designing of this alloy and pre-calculation by modeling of them is very important to decrease of the tool wear. There are several modelling techniques and assumptions to predict parameters of machinability. In this study, for modelling of machining parameters, cutting speed and volume of chip are defined as input parameters and tool wear is defined as output. Then, all these parameter values have been experimentally obtained. Linear, quadratic and exponential formulations have been used for modelling. The coefficients of these equations have been found optimally by using Gravitational Search Algorithm (GSA). The objective function is aimed to decrease error value between predicted and measured. Obtained results from three different formulations have been compared each other.

Index Terms - Ti6Al4V, linear regression, tool wear, Gravitational Search Algorithm

I. INTRODUCTION

Improving machinability and increasing cutting performance of cutting tools has been the subject of many researches. The development of new high-performance materials and alloys with superior properties compared to conventional materials has led researchers to the problems of machinability of these new materials [1]. In particular, medical, electronic, computer, aviation and space industries, the need for strong and light materials is increasing. Titanium and its alloys meet most of these expectations because of their high strength, heat and corrosion resistance properties [2-4]. These alloys retain the characteristics they have, even at high temperatures during machining. Therefore, titanium alloys are generally called "difficult to handle material" group is located in. Among these alloys with different properties, Ti6Al4V titanium alloy is the most widely used in industrial applications [5-7]. The cutting tool can lose its strength under such high temperature and pressure, while maintaining the strength of the titanium alloy at very high temperatures during the process. One of the most important reasons for affecting processing cost and productivity is the tendency of the work piece to enter the reaction with the cutting tool material at high temperatures and the adhesion to the cutting tool [8-11]. Siekman has stated that the processing of these alloys is always a problem if any of the conventional methods are used [12]. Therefore, it is important to investigate proper processing conditions in the processing of these materials.

In their study, Pratap and colleagues modeled the cutting forces generated in the micro milling of Ti6Al4V alloy by the finite element method. They used the basic equation of Johnson-Cook in their work. Experiments were performed in the ABAQUS / Explicit 6.12 simulation program. Depending on the proposed finite element model, tool corner radius, depth of cut, cutting speed and feed rate, it simulated the production of strength distribution, temperature distribution and cutting force. The cutting forces obtained have been experimentally verified [13]. Mahruni and colleagues mathematically modeled the tangential cutting force generated in the milling of Ti6Al4V alloy. Experiments were carried out using carbide tools under wet cutting conditions. Angle of cutting edge, feed rate and cutting speed are used as cutting parameters. Variance analysis was used to determine the effective parameters on the tangential forces generated in the experimental study. Three suitable prediction models, 3F1, linear CCD and second order CCD model, were used to formulate the relation between processing parameters such as cutting speed, feed rate and angle of cutting edge. As a result, a decrease in cutting forces was observed with increasing cutting speed. It is also seen that the rate of progression is the most important factor affecting shear force. In other words, the cutting force increases with the increase of the advance [14]. Sharif et al. mathematically modeled the optimization of surface roughness values formed by milling Ti6Al4V alloy under wet cutting conditions with carbide tools. For optimum cutting conditions, 3D reaction surface contours were created. The adequacy of prediction models has been verified by ANOVA. Experimental results have shown that the best surface roughness value at the milling of Ti-6Al4V alloy is at high cutting speed, low feed speed and high cutting tool tip angle [15]. Nikos has investigated the determination of the most effective processing parameters of the surface roughness of Ti6Al4V during the turning operation, depending on the experimental input (processing parameters) - output (surface roughness) data. Experimental findings have been converted to fuzzy logic system via Response Surface Methodology (RSM) and Polynomial Models and Adaptive Neuro-Fuzzy Inference System (ANFIS). These two methodologies compared the ability to predict the surface roughness that occurs during the turning of Ti6Al4V. It appears that surface roughness is predicted with fewer errors, especially when the data used for evaluation are not completely different from those used for training [16].

II. MATHEMATICAL MODELLING OF THE PROBLEM

The tool wear is the most important parameter for turning applications and thus it requires good prediction of wearing. In this study, the effect of chip volume, cutting speed and hardness of the material on the tool wear was explored. To realize this correlation, linear regression models (equations) were described. The developed mathematical equations for linear, quadratic and exponential assumptions are given below.

$$V_b = \omega_0 + \omega_1 C_s + \omega_2 V + \omega_3 H_V \quad (1)$$

$$V_b = \omega_0 + \omega_1 C_s + \omega_2 V + \omega_3 H_V + \omega_4 C_s V + \omega_5 C_s H_V + \omega_6 V H_V + \omega_7 {C_s}^2 + \omega_8 V^2 + \omega_9 {H_V}^2 \quad (2)$$

$$V_b = e^{\omega_0 + \omega_1 C_s + \omega_2 V + \omega_3 H_V} \quad (3)$$

Here, ω with indices are coefficients of the prediction model equations. V_b , C_s , V , H_V represent tool wear, cutting speed, chip volume and hardness, respectively. As seen equations, Chip volume, hardness and cutting speed are inputs and tool wear is output of the equations. Linear and quadratic approach have four parameters, quadratic has ten parameters. The proposed equations were aimed to find these parameters to achieve minimum error by using GSA algorithm.

III. GRAVITATIONAL SEARCH ALGORITHM (GSA)

Gravitational Search Algorithm (GSA) is developed based on two rules as law of gravity and the law of motion by Rashedi et al [17]. GSA is a nature-inspired algorithm that solve optimization problems by using force of particles and their attraction with each other ones [18]. In GSA algorithm, there are agents (objects) and masses of them. Each object in the solution space corresponds to solution candidate and mass of an object corresponds to fitness value of it. All objects interact with each other with a gravitational force and the motion resulting from this force is to the object, which is heavier. At the end of the search process, the heaviest object gives the most suitable solution (global optimum). The general principle of the GSA is given in Figure 1.

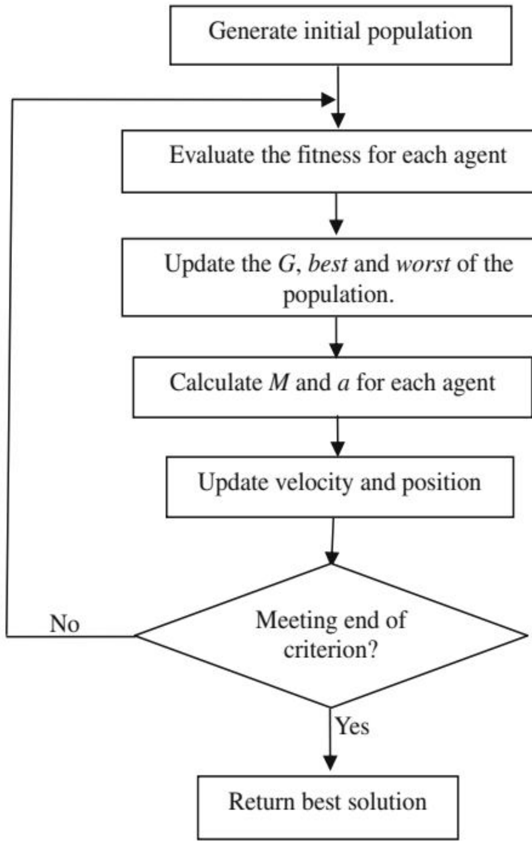

Figure 1. The flow chart of the GSA algorithm [17]

III. EXPERIMENTAL STUDY

Due to the high cost of the Ti6Al4V alloy used in the tests, a cementite carbide-cutting tool was used in the H13A grade to determine tool wear. Cryogenic processing has been applied to half of these cutting tools, so two different cutting tools were formed. Wear tests were carried out with these tools at constant chip volume (20, 40, 60 and 80 cm^3) and four different cutting speeds (30, 45, 60 and 75 m / min). Experiments were carried out using cooling fluid. Totally 32 number of experimental results were performed to predict parameters with minimum error.

The statistical results of the predicted model are given in TableI. The performance assessment of the model have been evaluated by Mean Absolute Error (MAE), Mean Squared Error (MSE), Root Mean Squared Error (RMSE) and correlation coefficient (R). The minimum error and good correlation was achieved by linear model.
The parameters of the proposed models are given in Table II and III. The parameter may use all

applications related with input and output variables.

Table I: Performance assessment of the models

	MAE	MSE	RMSE	R
Linear	0,01562	0,00040	0,02011	0,79231
Quadratic	0,10965	0,02997	0,17313	0,24450
Exponential	0,08928	0,00880	0,09382	0,41631

Table II: The first four parameters of the models.

	ω_0	ω_1	ω_2	ω_3
Linear	0,39696	0,00090	0,00060	-0,00023
Quadratic	0,71185	0,14798	0,07577	-0,00823
Exponential	-0,71413	0,39369	0,83908	-0,08137

Table III: Other parameters of the quadratic model

	ω_4	ω_5	ω_6	ω_7	ω_8	ω_9
Quadratic	-0,00015	-0,00006	-0,00004	-0,00033	0,00000	0,00000

The R graph of the linear model is given Figure 2. The result of R is 0.79231 and it is average goodness. It is caused by independent values of the inputs have not good correlation. It needs more complex and high order assumptions. Regression analysis of the quadratic and exponential are given in Figure 3 and 4, respectively.

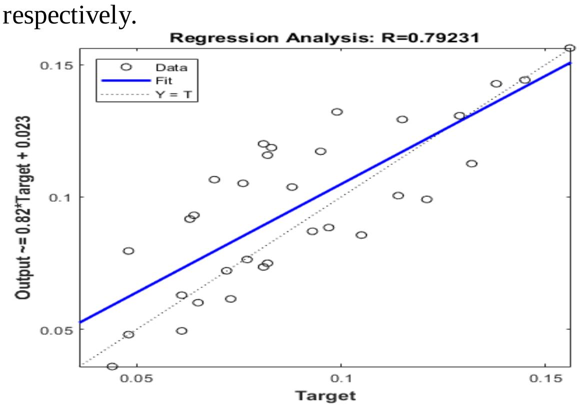

Figure 2. The R graph of the linear model

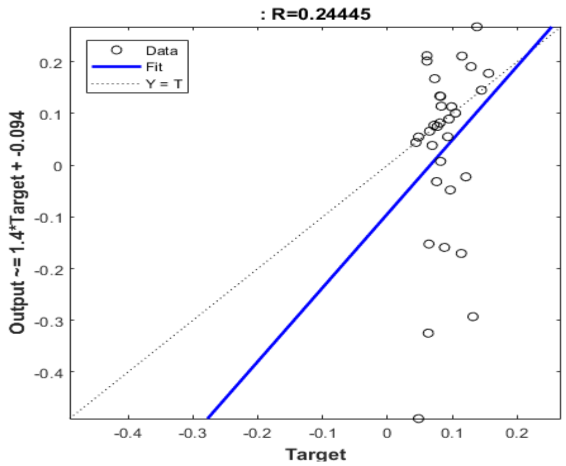

Figure 3. The R graph of the quadratic model

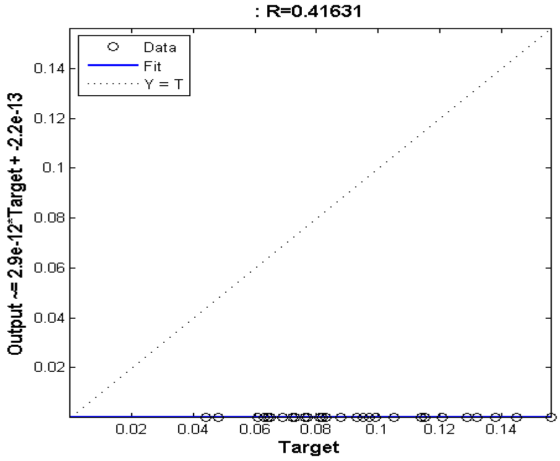

Figure 4. The R graph of the exponential model

CONCLUSION

In this study, linear regression models was investigated to describe tool wear for Ti6Al4V alloy that have widespread applications in industrial. Gravitational Search Algorithm was performed to find parameter of linear, quadratic and exponential approaches. Independent variables of the models are cutting speed, hardness and volume of chip. The results show that the best accuracy and the lowest errors were reached for linear modelling of tool wear. Parameter of the models were given in tables.

REFERENCES

[1] S.Köksal, “Face Milling of Nickel-based Superalloys with Coated and Uncoated Carbide Tools”, PhD. Thesis, School of Engineering, Coventry University, England, pp. 1-60, 2000.

[2] BülentKurt, “ Ti – 6Al – 4V Alaşımı İle Farklı Tip PaslanmazÇeliklerinDifüzyonKaynağı”, PhD Thesis, FıratUniversity, Turkey, 2005. (in Turkish)

[3] F.Nabhani, “Machining of Aerospace Titanium Alloys”, Robotics and Computer Integrated Manufacturing, vol. 17, pp.99 – 106, 2001.

[4] E.O. Ezugwu, Z.M. Wang, “Titanium alloys and Their Machinability – a review”, Journal of materials processing technology, vol. 68, pp. 262 – 274, 1997.

[5] C. Ensarioğlu, M.C.Çakır, “Titanyumvealaşımlarınınişlenebilirliketüdü”, Engineer and Machine, vol. 46, no. 546, 2005.

[6] H.A. Kishawy, J.Wilcox, “Tool wear and chip formation during hard turning with self – propelled rotary tools”, International Journal of Machine Tools and Manufacture, vol. 43, pp.433 – 439, 2003.

[7] J.K.Schueller, J.Tlusty, S.Smith, E.Leigh, “Advanced machining techniques on titanium rotor parts”, American Helicopter Society, 56th Annual form, Virginia, VA, May 2000.

[8] C.H. C. Haron, A. Jawaid, “The effect of machining on surface integrity of titanium alloy Ti – 6Al – 4V”, Journal of Materials Processing Technology, vol. 166, pp. 188 – 192, 2005.

[9] A. Jawaid, C.H.Che – Haron, A. Abdullah, “Tool wear characteristics in turning of titanium alloy Ti – 6246”, Journal of Materials Processing Technology, vol. 92 – 93, pp. 329 – 334, 1999.

[10] “Machining titanium & its alloys”, www.superalloys.com /machining titanium.htm

[11] T.Kitagawa, A.Kubo, K.Maekawa, “Temperature and wear of cutting tools in high – speed machining of Inconel 718 and Ti – 6Al – 6V – 2Sn”, Wear, vol. 202, pp. 142 – 148,1997.

[12] M.V.Riberiro, M.R.V.Moreira, J.R. Ferreira, "Optimization of titanium alloy (Ti-6Al – 4V) machining", Journal of materials processing technology, vol. 143 – 144, pp. 458 – 463, 2003.
[13] T. Pratap, K. Patra, A.A. Dyakonov, "Modeling Cutting Force in Micro-Milling of Ti-6Al-4V Titanium Alloy", Procedia Engineering, vol. 129, pp. 134-139,2015.
[14] A. Mohruni, S. Sharif, N.M. Yusof, "Cutting Force Prediction Models in End milling Titanium Alloy Ti-6Al-4V", Regional Postgraduate Conference on Engineering and Science, Johore, 2006.
[15] S. Sharif, A. Mohruni, N.M. Yusof, V.C. Venkatesh, "Optimum Surface Roughness Prediction Model when End Milling Titanium Alloy (Ti-6Al-4V)", Regional Postgraduate Conference on Engineering and Science, Johore, 2006.
[16] N.C. Tsourveloudis, "Predictive Modeling of the Ti6Al4V Alloy Surface Roughness", JIntell Robot Syst., vol. 60, pp.513-530, 2010.
[17] E. Rashedi, H. Nezamabadi-pour, S. Saryazdi, "GSA: A Gravitational Search Algorithm", Information Sciences, vol. 179, no. 13, pp. 2232-2248,2009.
[18] S. Al-Zubaidi, J. A. Ghani, and C. H. C. Haron, "Optimization of cutting conditions for end milling of Ti6Al4V Alloy by using a Gravitational Search Algorithm (GSA),"Meccanica, vol. 48, no. 7, pp. 1701-1715, Sep 2013.

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