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SELECTION OF PROCESS PARAMETERS IN TURNING BY USING ANALYTIC HIERARCHY PROCESS (AHP)

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Abstract

Selection of best combination of process parameters are really important to achieve an economical production system for any production industry. This study mainly focused on the selection of the best combination of process parameters by using Analytic Hierarchy Process (AHP) for turning of EN8 steel by using TiN coated cemented carbide insert type cutting tool. The cutting speed, feed and depth of cut have been considered as process parameters and observed the changes in cutting force, surface roughness and tool wear for each set of experiment. Three output variables have been considered as three different decision criteria during the construction of hierarchy structure. Then pair-wise comparison matrix (PCM) for criteria and alternatives have been developed. After successfully applied of AHP it has been found that alternative $7(A_7)$ achieve rank 1 which is the combination of cutting speed 90 m/min, feed 0.2 mm/rev and depth of cut 0.6 mm. From this study it has been observed that the proposed approach has ability to optimize the cutting parameters for the considered decision criteria. Hence it can be apply for the optimization of process parameters for other machining process also.

Introduction

Lathe is a machine tool on which different traditional machining process can be performed. This study focused on turning operation which is basically selected by the operator as a material removal process. In this turning process material removal takes place in the form of chips. During the formation of chips rubbing takes place between cutting tool, work piece and

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cutting tool, formed chips which leads to the wear of cutting tool and roughness to the finished surface. As a result life of tool and quality of finished product get reduce respectively [1]. At the same time different forces produced in turning operation leads to the tool breakage, vibration and more power consumption which are not the required condition for any machining operation [2, 3]. In a machining process to get the control on the machining time, production cost, product quality the control over the cutting force, surface roughness, material removal rate, tool life are required. Which is possible by operating the process with the best suitable combination of process parameters [4]. For this purpose different optimization techniques are available out of which AHP has been applied in this study. Few of the previous work done with AHP by different researchers in the field of engineering have been written in the form of literature review.

An experiment has been established by Prakash et al. [5] in turning of AISI 1040 steel with coated tools. Taguchi has been used to optimize the surface roughness, power consumption and material removal rate. Then as a MCDM techniques AHP with TOPSIS has been applied. The Ti-6AL-4V alloy has been selected by Singh et al. [6] for the turning under MQL condition. The experiment has been performed by following L27 orthogonal array and for the optimization purpose different multi-attribute decision-making (MADM) techniques such as AHP, Technique for order preference by similarity to ideal solution (TOPSIS) and Simple additive weighting (SAW) have been applied. Babu et al. [7] combined AHP with Utility method. Three controlled parameters cutting speed, feed and depth of cut have been selected during experiment. Three decision criteria material removal rate, surface roughness and machining power have been considered in the hierarchy structure. To achieve the sustainable machining condition for the dry turning of Ti-6AL-4V with help of uncoated H13 carbide inserts Younas et al. [8] combined grey relational analysis (GRA) with AHP. ANOVA has been used to observe which parameters significant to Grey Relational Grade (GRG). From the experiment it have been found that the optimized machining condition increased the material removal rate by 34% also increased the tool life by 7%. Also the surface roughness and specific cutting energy decreased by 2% and 6% respectively. Among all the MCDM technique VIKOR and AHP combined together [9, 10] for the optimization of turning process parameters.

Singaravel et al. [11] used AHP for the multi criteria optimization in turning process. Cutting speed, feed rate and depth of cut have been considered as input in the experiment. The aim of the study has been fixed as minimization of surface roughness and micro hardness and maximization of material removal rate. Not only in turning process in many other different machining processes such as grinding, welding, drilling, electro discharge machining AHP has been applied successfully [12-15].

From the literature review it is cleared that for optimization of turning process parameters AHP can be used without any hesitation. Hence it has been decided to apply AHP technique in this study to find out the best alternatives or the combination of cutting parameters such as cutting speed (v), feed (f) and depth of cut (d) which will be obey all the considered decision criteria cutting force (F), surface roughness (Ra) and tool wear (e).

2. Analytic Hierarchy Process (AHP)

The MCDM method consists different techniques such as AHP, TOPSIS, data envelopment analysis (DEA), fuzzy decision-making to solve multi criteria decision problem [6]. Among this all MCDM method AHP is the most popular due to its flexibility and easy to use. The AHP has been developed in 1980s by Thomas L. Saaty. AHP consist three important phase such as structuring of the problem, priority calculation and consistency check of the matrices [12]. The Figure 1 depict the AHP structure used in this study.

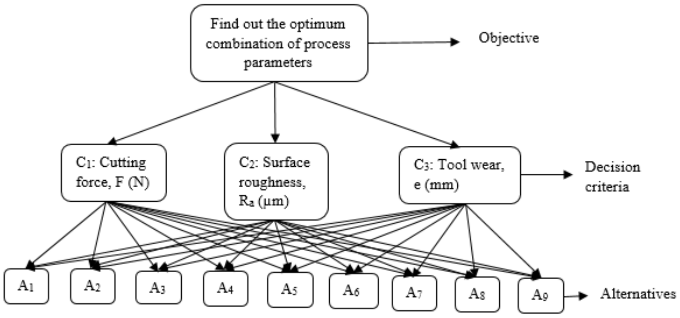

Figure 1. Hierarchy structure.

For the modelling of AHP structure the alternatives and criteria have been taken from an experiment established by Thangarasu et al. [4]. Total 20 set of experiment have been performed. Out of which condition of input parameters $v(m/\min)$, $f(mm/rev)$ and $d(mm)$ for 9 set of experiment considered as alternatives and the outputs $F(N)$, $R_a(\mu m)$ and $e(mm)$ have been considered as criteria in this study. The objective has been considered as find out the optimum condition of process parameters.

3. Results and Discussions

In this section pair-wise comparison matrices have been present. The criteria weights and local weights for the alternatives have been calculated and established the priority matrix. Then the global weights for the alternatives have been calculated and ranking has been done.

Table 1. PCM of criteria regard to objective.

Objective	Criteria			GM	Criteria weights
	C_1	C_2	C_3		
C_1	1	1/6	1/3	0.3816	0.0914
C_2	6	1	4	2.8845	0.6909
C_3	3	1/4	1	0.9086	0.2176

The PCM totally depends upon the decision maker. The weights assigned during the construction of PCM have the following representation as equally preferred (1), equally to moderately preferred (2), moderately preferred (3), moderately to strongly preferred (4), strongly preferred (5), strongly to very strongly preference (6), very strongly preferred (7), very strongly to extremely preferred (8) and extremely preferred (9) [13]. After priorization the GM have been calculated. Then each GM divided by total sum of GM and criteria weights have been founded. Then to check the consistency of a PCM consistency index (CI) has been founded by using the expression, $CI = (\lambda_{\max} - n)/(n-1)$. Where $\lambda_{\max}$ and n are represents the largest eigen value and order of corresponding PCM respectively. Finally consistency ratio (CR) has been founded by using expression $CR = (CI/RI)$ where RI represents random index corresponds to a random matrix of order equal to the order of PCM. The value of CR up to 0.1 or 10% is considered as acceptable. If the CR value exceed 10% then it is the indication of wrong assign of priority in the pair-wise comparison matrix, means again priorizations are required [16].

For the PCM of criteria regards to objective order is $n = 3$ and $\lambda_{\max} = 3.0542$ has been calculated. Then CI has been founded as 0.0271. Finally to calculate CR the value of RI has been taken as 0.58 corresponding to a random matrix of order $n = 3$ and getting $CR = 0.0467, \leq 0.1$ or 10%. Which indicates that the priorization for criteria regard to the goal has been done correctly.

Table 2. PCM of alternatives for criteria 1 (less cutting force).

$C_1 : F$	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	Local weights
A_1	1	3	3	5	3	4	9	6	2	0.2803
A_2	1/3	1	1	3	1	2	8	4	1/2	0.1217
A_3	1/3	1	1	3	1	3	8	5	1	0.1409
A_4	1/5	1/3	1/3	1	1/2	1	5	2	1/4	0.0556
A_5	1/3	1	1	2	1	2	7	4	3	0.1399
A_6	1/4	1/2	1/3	1	1/2	1	6	3	1/3	0.0657
A_7	1/9	1/8	1/8	1/5	1/7	1/6	1	1/4	1/9	0.0151
A_8	1/6	1/4	1/5	1/2	1/4	1/3	4	1	1/5	0.0333
A_9	1/2	2	1	4	1/3	3	9	5	1	0.1474

$\lambda_{\max} = 9.4930; RI = 1.45$ for $n = 9; CR = 0.0425$

Table 3. PCM of alternatives for criteria 2 (less surface roughness).

$C_1 : R_a$	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	Local weights
A_1	1	3	2	2	3	3	1/2	3	3	0.1824

A_2	1/3	1	1/3	1/2	1	1/2	1/5	1/2	1	0.0477
A_3	1/2	3	1	1	2	2	1/3	2	3	0.1209
A_4	1/2	2	1	1	1	1	1/4	1	2	0.0849
A_5	1/3	1	1/2	1	1	1	1/5	1	2	0.0679
A_6	1/3	2	1/2	1	1	1	1/4	1	2	0.0752
A_7	2	5	3	4	5	4	1	4	5	0.3038
A_8	1/3	2	1/2	1	1	1	1/4	1	1	0.0696
A_9	1/3	1	1/3	1/2	1/2	1/2	1/5	1	1	0.0477

$\lambda_{\max} = 9.1679; RI = 1.45$ for $n = 9; CR = 0.0145$

Table 4. PCM of alternatives for criteria 3 (less tool wear).

$C_3 : e$	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9	Local weights
A_1	1	1	1/2	1	6	1	1/9	1	8	0.0759
A_2	1	1	1/3	1	6	1	1/9	1	8	0.0726
A_3	2	3	1	2	7	3	1/8	1	9	0.1275
A_4	1	1	1/2	1	7	2	1/9	1	9	0.0845
A_5	1/6	1/6	1/7	1/7	1	1/6	1/9	1/7	5	0.0183
A_6	1	1	1/3	1/2	6	1	1/8	1/2	8	0.0630
A_7	9	9	8	9	9	8	1	7	9	0.4547
A_8	1	1	1	1	7	2	1/7	1	8	0.0926
A_9	1/8	1/9	1/9	1/9	1/5	1/8	1/9	1/8	1	0.0108

$\lambda_{\max} = 10.0539; RI = 1.45$ for $CR = 0.0908$

From the PCM local weights of alternatives for all the criteria have been collected and established the priority matrix. Now the final step is to find out the global weights for criteria and ranking of alternatives.

$$\begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_4 \\ W_5 \\ W_6 \\ W_7 \\ W_8 \\ W_9 \end{bmatrix} = \left[\begin{array}{cccc} & C_1 & C_2 & C_3 \\ A_1 & 0.2803 & 0.1824 & 0.0759 \\ A_2 & 0.1217 & 0.0477 & 0.0726 \\ A_3 & 0.1409 & 0.1209 & 0.1275 \\ A_4 & 0.0556 & 0.0849 & 0.0845 \\ A_5 & 0.1399 & 0.0679 & 0.0183 \\ A_6 & 0.0657 & 0.0752 & 0.0630 \\ A_7 & 0.0151 & 0.3038 & 0.4547 \\ A_8 & 0.0333 & 0.0696 & 0.0926 \\ A_9 & 0.1474 & 0.0477 & 0.0108 \end{array}\right] \begin{bmatrix} 0.0914 \\ 0.6909 \\ 0.2176 \end{bmatrix} \Rightarrow \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_4 \\ W_5 \\ W_6 \\ W_7 \\ W_8 \\ W_9 \end{bmatrix} = \begin{bmatrix} 0.1682 \\ 0.0599 \\ 0.1242 \\ 0.0821 \\ 0.0637 \\ 0.0717 \\ 0.3102 \\ 0.0713 \\ 0.0488 \end{bmatrix}$$

Where W_i represents the value of global weights of i^{th} alternatives.

Table 5. Condition, global weights and rank of the alternatives.

Alternatives	Cutting speed (m/min)	Feed (mm/rev)	Depth of cut (mm)	Global weights	Rank
A_1	90	0.2	0.30	0.1682	2
A_2	180	0.3	0.30	0.0599	8
A_3	270	0.4	0.30	0.1242	3
A_4	90	0.3	0.45	0.0821	4
A_5	180	0.4	0.45	0.0637	7
A_6	270	0.3	0.45	0.0717	5
A_7	90	0.2	0.60	0.3102	1
A_8	180	0.3	0.60	0.0713	6
A_9	270	0.4	0.60	0.0488	9

Conclusions

From the present work on selection of turning process parameters with help AHP a MCDM technique these points have been concluded

(a) Due to the flexibility to the selection of weights or priority for the criteria regard to goal and alternatives regard to criteria for the same problem rank can be different for alternatives depends on the priorization of the decision maker.

(b) After applying the AHP it has been found that the rank of A_7 is 1 due to its maximum value of global weights. The alternative A_7 represents cutting speed 90 m/min, feed 0.2 mm/rev and depth of cut 0.6 mm which are provides the satisfactory result.

(c) AHP is very easy and effective to use for the purpose of process parameters selection in a machining process. Not only in turning in many other processes also it can be used for the optimization of process parameters.

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