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Multi-Objective Optimization in Hard Turning of Tool Steel Using Integration of Taguchi & TOPSIS under wet Conditions

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Abstract

In this paper authors attempted to estimate/evaluate the optimal value of input parameter that gives a satisfactory level of surface finish level and cutting speed in term of removal of material while hard turning of tool Steel using carbide insert using water based coolant. Taguchi method have been utilised for designing the experiment post experiments decision making analysis is used for or obtaining the multi optimisation of the controllable factors/parameters for response namely material removal rate and surface finish. Paper focussed on using TOPSIS to arrive a result of multi Optimisation for the tool Steel. Article presented use of Multi criterion methods of decision-making in field of production engineering.

Keywords — Taguchi, TOPSIS, MCDM, L9.

I. INTRODUCTION

Owing to day by day changing environment of design and materials, complexity in the product increases thus production hubs faces the challenge to turn the hard material as these hard material are very challenging to get machine bye usual or traditional methods so we focus on non-conventional machining like EDM, wire EDM, USM, ECM to get them machine but at the same time they are low material removal rate increase the production cost drastically so we have to take balance between cost and the machinability of the hard material like tool Steel when the material is having hardness above 50HRC. Turning of these materials commonly known as Hard turning. While turning this material mostly supervisor uses his or her expertise in that area and the manual handbook or that are available to them[I-V]. As a result, output response might not be as good as per our expectation, In literature number of paper has been reported on turning of die Steels but very few of them utilise the decision making methods to get the optimal result out of them. In current paper II techniques namely TOPSIS theme has been utilised to get the optimal setting. These methods are used in the the managerial decisions only but in this paper we attempted to to get the utilise in the area of manufacturing. Oussama Zerti et al[XIII] worked on same material under dry condition and successfully applied taguchi method and annova for optimisaing the responses. Ravinder et al; this group of researcher worked on AISI O3 die steel for multi optimisation of roughness and material removal, they have applied a no. of multi-optimization technique and found WSN method most suitable[I].Vikas et al worked on die sink EDM and used MCDM method as to provide a solution for multi-optimisation. In paper authors applied TOPSIS and PROMETHEE method and suggested a alternative of using multi-critierion decision making method for manufacturing [X-XI]. Pawan et al worked on die steel and modelled cutting force using fuzzy logic. [XII] Chaudhari et al; reported a work on tool wear, they investigated that all major input effect tool wear in turning & suggested minimum quantity lubrication can be solution for hard turning[III]. Thamizhmanii et al; reported work on SCM alloy steel and found depth of cut as most significant factor for surface roughness.

II. EXPERIMENTAL SETUP

In this particular article study of cylindrical work of die steel d-3 has been used & chemical composition of the work-piece tabulated in Table 1. It can maintain strength at raised temperature while maintaining the good wear resistance this property enables the material a good option for production of dies for metal forming process. this Steel possess very high strength and toughness in the range of HRC 60. Experiments conducted on Centre machine with firm Foundation and precision this has been designed especially for conduction of research experiments. The tool cutting tool used was a carbide insert with specification CCMT 060208 (SANDVIK –COROMANT). As a input parameter most commonly used factor cited by different researcher and from the pilot experiments yielded that during turning out of controllable factors speed at which workpiece rotates, rate of travel of tool along axis of work i. e rate of feed, & advancement of tool across axis of work that is commonly known as depth of cut had major contribution toward response factors and range selected for the input parameters has been shown in table below experiments were carried out using Taguchi philosophy precisely orthogonal array L9 as the utilisation of full factor tutorial design might have increased the host of experimentation the orthogonal array helped to reduce the cost without compromising the information.

Table 1 Work-Piece Material Properties

Material	AISI-D3
C	2.2
Cr	12
Ni	0.3
W	1
P	0.03
Si	0.6
Cu	0.25
Mn	0.4

Figure 1 a) Experimental Set Up **b) Surface Roughness Tester (Made-Mitutoyo)**

Fig. 1. a) Experimental Set Up used b) Mitutoyo Roughness Tester

As discussed above for current studies parameters taken were selected from work reported previously and trial/pilot test conducted. Each parameter considered have three value as low mid and high as shown in table 2. A water based coolant for flushing as well as for cooling was used with a grading of SAE40.

Table 2 Cutting Parameters

Sr. No.	A	B	C
Factors	Speed	Feed	Depth of Cut
Units	Rpm	Mm/rev	Mm
Level 1	420	0.2	1
Level 2	325	0.1	0.6
Level 3	192	0.05	0.2

Conventionally number of experiments needed are more as we apply full factorial approach, Taguchi methods of OA preferred as no. of experiments for same information are quite less as it is having balanced designed array. In this method we can estimate influence of each factor without being influenced by others. In table 3 we have L9 array with response as material removal and surface roughness.

Table 3 L9 OA Input Parameters

Exp. No.	Run No.	Spindle Speed(A) (rpm)	Feed(B) (mm/rev)	D.o.c. (mm)	MRR Mm3/sec	SR µm
1	6	420	0.2	1	4.638	106.364
2	4	420	0.1	0.6	2.798	8.115
3	8	420	0.05	0.2	2.376	4.567
4	3	325	0.2	0.6	3.91	12.411
5	1	325	0.1	0.2	2.451	9.098
6	5	325	0.05	1	1.883	21.442
7	7	192	0.2	0.2	2.374	7.399
8	9	192	0.1	1	3.704	24.769
9	2	192	0.05	0.6	2.311	1.807

Productivity of any material removal process mainly depends upon rate of material removal MRR in turning operation is calculated by multiplying cutting speed, feed and depth of cut. Material removal rate is obtained in mm3/min.

$$MRR = Cs.f.Doc$$ **……Equation 1**

Where MRR is in mm3/min,

Cs stands for the cutting velocity,

f is the feed rate and

Doc is depth of cut.

For the measurement of surface finish, a specimen/machined part is checked at six locations around the circumference and then average value is assigned for surface finish. In this study tester used for roughness is shown in fig. That is made from mitutoyo surftest SJ 301 is the model name for that instrument.

III. METHODOLOGY

A. TOPSIS

Multi criteria decision making methods belongs to decision making especially in field of Management. Method can also be applied in the field of machining& production for the for the selection of input parameters. TOPSIS Technique for order of preference by similarity to Ideal solution it was developed by it was first used and invented by Lai &Yoon in the year 1981. and further developed by June in 1987. it is Stems on the theory that our optimal solution is closest approximate with best or positive ideal solution and farthest from the worst solution. In this approach weight is decided for each criterion that is to decide by experience person or we can apply AHP to decide weight for criterion. After identification the weight of each criterion then it is normalized as criterion can be of different nature as MRR is always higher the better whereas surface roughness is lower the better. According to Rao et al we have following steps for applying TOPSIS [V].

Step 1.one of the first step we have to create a matrix that is having alternative and criteria.In our case alternative are the different experiments that we have conducted and MRR and surface roughness are the criteria on the behalf of which we will choose the alternative.

Table 4 Alternative & Criterion Matrix

Alternatives Exp.	Criterion 1 MRR	Criterion 2 SR
1	4.638	106.364
2	2.798	8.115
3	2.376	4.567
4	3.91	12.411
5	2.451	9.098
6	1.883	21.442
7	2.374	7.399
8	3.704	24.769
9	2.311	1.807

$$M9x2 = \begin{bmatrix} 106.364 & 4.638 \\ 8.115 & 2.798 \\ 4.567 & 2.376 \\ 12.411 & 3.91 \\ 9.098 & 2.451 \\ 21.442 & 1.883 \\ 7.399 & 2.374 \\ 24.769 & 3.704 \\ 1.807 & 2.311 \end{bmatrix}$$

Equation 2 Matrix for Criterion * Alternatives

Step 2. In this we will represent our data that was experiments conducted according to OA L9 as the alternative and MRR and surface roughness as the criteria will be having are having a matrix of 9 by 2 precisely as shown in equation no.2.

Step 3. In this step as the criteria's are of different area/nature one is higher the better and another is lower the better so we have to normalize the matrix and the matrix obtained in step number 2 is further revised as per our normalization formula.

$$Ni \times j = \frac{Xij}{\sqrt{\sum X2ij}}$$

Equation 3 Normalization Formulae used

$$N9x2 = \begin{bmatrix} .9413 & .5045 \\ .0718 & .3043 \\ .0404 & .2584 \\ .1098 & .4253 \\ .0805 & .2666 \\ .1898 & .2048 \\ .0655 & .2582 \\ .2192 & .4029 \\ .0160 & .2514 \end{bmatrix}$$

Equation 4 Matrix after Normalization

Step 4. After having a normalized matrix,we usually assign the weight to the different criteria totally depends upon the specialist for the conduct supervisor of the experiments who is having a depth knowledge about the weight of the criteria's in our case equal weight to our both criteria is 50%

so now we will get a weighted normalized Matrix after multiplying the different criteria with the weight assigned to them.

Step 5. From matrix obtained in last step, now we will find our ideal positive and ideal worst solution. after this we have to calculate relative close Ness for alternative for present case for which IX alternatives exist, so 18 separations for each from positive and worst solution will be there.

Step 6. lastly we have to calculate relative closeness to the ideal solution as given below.

Table 5Separation measures from ideal best and worst solution

Sr. No,	Separation from ideal Best	Separation from Ideal Worst	Relative closeness	Rank of Alternative
1	0.375775	0.173201	0.315498	2
2	0.437584	0.103889	0.191864	8
3	0.451243	0.123625	0.215049	6
4	0.430104	0.061394	0.124912	9
5	0.431503	0.123239	0.222155	5
6	***0.149832***	***0.462658***	***0.755372***	***1***
7	0.438727	0.125591	0.222553	4
8	0.374389	0.113595	0.232785	3
9	0.463243	0.126555	0.214574	7

IV. RESULT AND DISCUSSION

The objective of the present study is to optimize the input parameters in turning using MCDM methods TOPSIS for a multi objective optimization. In above discussed study in both we find the relative proximity to best solutions for a particular criterion. Performance characteristic are chosen from different categories i.e. one is higher the better value and other one is lower the better response. For higher the better response chosen is material removal rate and second for lower the better is surface roughness.

For that purpose, we have used TOPSIS method which gave the ranking as 6-1-8-7-5-3-9-2-4.

Whereas PROMETHEE gave ranking as 6-8-1-7-5-9-4-2-3.

From both the method used it is clear that for turning of D3 tool steel while turning under wet condition and using carbide insert keeping equal weightage of MRR and surface roughness

Optimum values of input parameters are cutting speed as 25.5 m/min (325 rpm) feed rate 0.25mm/rev and depth of cut as 1mm. As we are having no of methods for multi-optimization but they need person be conversant with programming languages as they need laborious computation so it has advantage over that methods.

V. CONCLUSION

This article explored application of MCDM method in the area of machining and manufacturing as these are mostly used in management. In this study multi-optimisation of hard turning of tool steel precisely AISI-D3 is dealt by TOPSIS when our criterion MRR and surface finish was of opposite in nature as MRR we need higher the value better for us and roughness we need to restrict as low as possible and even which is difficult to turn with conventional method. But with this method we can apply set of input parameters evident influential from literature & fro initial trials to turn on lathe machine that can result in save time as well cost.

- TOPSIS successfully applied to address problem in the field of machining/turning.
- Experiments conducted treated as alternative for TOPSIS method .TOPSIS sorted the alternate in the rank of closeness with optimum solution as 6-1-8-7-5-3-9-2-4.
- Optimal set of input parameters for hard turning of die tool steel using carbide insert under wet condition for both maximizations of MRR and minimization of surface roughness are cutting speed as 25.5 m/min (325 rpm) feed rate 0.25mm/rev and depth of cut as 1mm.
- For multi optimization usually GUI methods are used where considerable amount of programming is needed whereas in these method with less amount of calculation, we can apply.
- For weighting the criterion, it can be coupled with AHP.

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