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A Novel Approach for Selection of Tool Insert in CNC Turning Process Using MADM Methods

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Abstract— In modern decision science the Multiple attribute decision making (MADM) is playing an important role for selection of best from number of alternative. It has been applicable in various areas such as society, economics, military, management, manufacturing, etc., and has been receiving more and more attention over the last decades.

To date, however, most research has focused on single-period multi-attribute decision-making in which all the original decision information is given at the same period, and a number of methods have been proposed to solve this kind of problems.

In this research work we have considered a novel approach for optimum cutting tool insert selection strategy. In this approach, two well-known Multiple Attribute Decision- Making (MADM) methods such as Simple Additive Weighting (SAW) and Weighted Product Method (WPM) use for a case study of tool insert selection for better surface finish in CNC (Computer Numerical Control) turning operation. In these methods their relative performance are compared with respect to ranking of alternative and from ranking we have selected best tool insert for better surface quality during turning operation on alloy steel using CNC turning centre.

Key words: MADM, SAW, WPM, Surface roughness

I. INTRODUCTION

Metal cutting processes are industrial processes in which metal parts are shaped or removal of unwanted material. It is one of the most important and widely used manufacturing processes in engineering industries. In the study of metal cutting, the output quality is rather important. A significant improvement in output quality may be obtained by proper tool and work piece combination, optimizing the cutting parameters. Tool insert is not only improves output quality, but also ensures low cost manufacturing. Tool insert include tool insert geometry such as nose radius, approach angle, rake angle, angle of inclination, clearance angle etc. Cutting parameters include feed rate, cutting speed, depth of cut, cutting fluids and so on. In turning process, selection of proper tool insert play critical roles for better surface finish of work piece.

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Lathe machine is the oldest machine tool that is still the most common used machine in the manufacturing industry to produce cylindrical parts but now days CNC machines are widely used for good quality, accuracy and high productivity. It is widely used in variety of manufacturing industries including aerospace and automotive sectors, where quality of surface plays a very important role in the performance of turning as good-quality turned surface is significant in improving quality. Surface roughness also affects several functional attributes of parts, such as wearing, heat transmission, and ability of holding a lubricant, coating, or resisting fatigue.

The product quality depends very much on surface roughness. Decrease of surface roughness quality also leads to decrease of product quality. In field of manufacture, especially in engineering, the surface finish quality can be a considerable importance that can affects the functioning of a component, and possibly its cost. However, In turning process the quality is affected by different parameters like tool geometry, work piece material, machining conditions and operating parameters. Among all of them tool geometry is one of the important parameter for better surface roughness. In the CNC turning operation many alternative tools say inserts are available. The selection of the proper tool insert is most critical step to obtain the desire surface finish. Among the number of available and applicable tool insert, on can be selected based on the MADM (multiple attribute and decision making method) methods. The final selection of tool insert and work material combination can provide the required surface finish for turning operation using CNC turning machine.

II. LITERATURE REVIEW

Mannan et al. have studied the effect of inserts shapes (round and square), cutting edges; inserts rake types and nose radius on surface roughness and residual stresses. . The cutting speed, feed and depth of cut were maintained constant. They conclude that, round inserts generate lower surface finish than square inserts. The positive rake produces lower values when coolant is used and high value in dry cutting. The surface roughness increasing with nose radius increases and use of coolant generate lower values of surface roughness [1]. Gokkeya and Nalbant studied about the effect of tool geometry (insert radius: 1.2mm, 0.8mm, and 0.4mm) and process parameter such as depth of cut, feed rate on surface roughness of AISI 1030 steel on CNC lathe machine. They conclude that, A good combination among the insert radius, speed rate and depth of cut can provide better surface qualities [2]. Neseli et al.

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have find out the influence of tool geometry (nose radius, approach angle and rake angle) on the surface finish obtained in turning of AISI 1040 steel on lathe machine by using AL2O3 coated tool inserts CNMG 120404-BF, CNMG 120408-BF, CNMG 120412-BF for finishing operation. They conclude that rake angle has the highest effect in reducing surface roughness and the effect of tool nose radius and approach angle increases with increases surface roughness [3]. Dogra et al. studied about the effect of tool geometry i.e. tool nose radius, rake angle, variable edge geometry and their effect on tool wear, surface roughness and surface integrity of the machined surface during turning. They conclude that, the large edge hone produce higher force and higher surface roughness than small edge hone. The large tool nose radius gives good surface finish than small tool nose radius and both are generate equal tool wear. The greater negative rake angle gives higher compressive stress which deeper affected zone below machined surface [4]. Guddat et al. investigated the effect of wiper PCBN inserts geometry (nose radius, edge radius, chamfer angle) on surface integrity. Wiper inserts produce smoother surfaces within the range of the experiments conducted and are more stable when it comes to changes in feed and nose radius [5]. Vijay Athawale and Shankar chakraborty have applied the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method for selection of best CNC machine from alternative machine in terms of specification and cost of machine [6]. Rao et al. have worked on the selection of material for wind turbine blade from the alternative material. They applied MADM (Multiple attribute decision making method) such as TOPSIS and fuzzy set theory and From the analysis they observed that if the wind turbine blades are made out of composite materials using carbon fibers, then they possess the high stiffness, low density and long fatigue life [7]. Abhang et al. studied about selection of best lubricant in turning operation from alternative lubricants by using MADM methods. They applied TOPSIS and AHP model and conclude that lubricant index evaluate and ranks best lubricant during steel turning operation and combined TOPSIS and AHP method provides a convenient approach for solving complex MADM problems in manufacturing domains [8]. Manshadi et al. proposed a numerical method for solving problem of material selection for cryogenic storage tank for transportation of liquid nitrogen from seven alternative materials. They used different MADM methods and from their results they provide rank and decided material number 3 SS 301-FH is the best and right choice for the tank [9]. B. Savant et al. have solved the problem of the selection of automated guided vehicle by using MADM methods. They applied Preference selection index (PSI) and TOPSIS MADM methods. From PSI and TOPSIS ranking results, they compared methods and average of the methods selects best AGV for the industrial application [10].

In the literature review, many researchers have worked on tool geometry effect on surface roughness in turning operation and also studied of MADM methods which are useful for solving selection problem in manufacturing environment. Here, MADM methods are apply for the selection of best tool insert from alternative tool insert for better surface roughness in CNC turning operation.

III. MULTIPLE ATTRIBUTE DECISION- MAKING METHODS

A. *Simple Additive Weighting (SAW) Method*

This is also called the weighted sum method and is the simplest and still the widest used MADM method. Here, each attribute is given a weight, and the sum of all weights must be 1. Each alternative is assessed with regard to every attribute. The overall or composite performance score of an alternative is given by Equation 1.

$$P_i = \sum_{j=1}^{M} w_j m_{ij} \tag{1}$$

Previously, it was argued that SAW should be used only when the decision attributes can be expressed in identical units of measure (e.g., only dollars, only pounds, only seconds, etc.). However, if all the elements of the decision table are normalized, then SAW can be used for any type and any number of attributes. In that case, Equation1will take the following form:

$$P_i = \sum_{j=1}^{M} w_j \left(m_{ij}\right)_{normal} \tag{2}$$

Where (m_{ij}) normal represents the normalized value of m_{ij}, and P_i is the overall or composite score of the alternative A_i. The alternative with the highest value of P_i is considered as the best alternative.

B. *Weighted Product Method (WPM)*

This method is similar to SAW. The main difference is that, instead of addition in the model, There is multiplication. The overall or composite performance score of an alternative is given by Equation 3.

$$P_i = \prod_{j=1}^{M} [(m_{ij})_{normal}]^{wj} \tag{3}$$

The normalized values are calculated as explained under the SAW method. Each normalized value of an alternative with respect to an attribute, i.e., (m_{ij}) normal, is raised to the power of the relative weight of the corresponding attribute. The alternative with the highest P_i value is considered the best alternative [11].

IV. STRATEGY CASE STUDY

Table 1: Attributes for CNC turning tool insert

Tool insert No.	Nose radius (mm)	Approach angle (Degree)	Rake angle (Deg.)	Clearance angle (Degree)	Angle of inclin-ation (Deg.)
1	0.2	95	0	7	0
2	0.2	93	0	5	0
3	1.2	107.5	-6	0	-7
4	0.8	91	-6	0	-6
5	0.4	45	0	7	0

Tool insert 1: CCMT 09 T3 02 PF, Tool insert 2: VBMT 16 04 02 PF, Tool insert 3: DNMG 15 04 12 PF, Tool insert 4: TNMG 22 04 08 PF, Tool insert 5: SCMT 09 T3 04 PF

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Here, the strategy case study is explained in the form of example. This example problem is related with selection of a suitable tool insert for work tool combination of machining operation. The tool insert selection problem considers five alternative inserts and five attributes and the data are given in table 1.

A. *Simple Additive Weighting Method*

As explain in SAW methods theory, value of these five attributes are normalized and weights ($w_1, w_2 \ldots w_5$) of attributes such as nose radius, approach angle, rake angle, clearance angle and angle of inclination are 0.40, 0.25, 0.20, 0.10, and 0.05.Table 2 shows the normalized values of tool inserts selection attributes.

Table-2: Normalize data for tool insert selection attributes

Tool insert No.	Nose radius (mm)	Approach angle (Degree)	Rake angle (Degree)	Clearance angle (Deg.)	Angle of inclin-ation (Deg.)
1	0.166	0.883	0	1	0
2	0.166	0.865	0	0.7142	0
3	1	1	1	0	1
4	0.666	0.846	1	0	0.8571
5	0.333	0.418	0	1	0

SAW Method:

For Tool insert 1:

$P_1 = w_1m_{11} + w_2m_{12} + w_3m_{13} + w_4m_{14} + w_5m_{15}$

$= (0.40\times0.166) + (0.25\times0.883) + (0.20\times0) + (0.10\times1) + (0.05\times0)$

$= 0.0664+0.2207+0+0.1+0$

$= 0.3871$

Similarly for all material results are,

Tool insert-2, $P_2 = 0.3507$

Tool insert-3, $P_3 = 0.90$

Tool insert-4, $P_4 = 0.72075$

Tool insert-5, $P_5 = 0.3377$

By arranging in descending order, the tool insert selection index is 3-4-1-2-5. It may be observed that the above ranking is for the given preferences of the decision maker. The ranking depends upon the judgment of relative importance of attributes made by the decision maker. The ranking of material based on Tool insert selection index given by SAW method is 3-4-1-2-5.

The SAW method also suggests the Tool insert designated as 3, i.e. DNMG 15 04 12 PF as the right choice for the given problem of selection of a suitable Tool insert for work tool combination of machinery operation. The second choice is the material 1, i.e. TiAI6V4 and the last choice is the material designated as 5, i.e. SCMT 09 T3 04 PF.

B. *Weighted Product Methods:*

The overall performance score (i.e. material selection index, in this problem) for each material is calculated using the normalized data of the attribute given in Table 2 for the given weights of the attributes.

For Tool insert: 1

$P_1 = (m_{11})w_1 + (m_{12})w_2 + (m_{13})w_3 + (m_{14})w_4 + (m_{15})w_5$

$= (0.166)0.4 + (0.883)0.25 + (0)0.20 + (1)0.10 + (0)0.05$

$= 0.4875 + 0.9693 + 0 + 1 + 0$

$= 2.4565$

Similarly for all Tool inserts, the results are,

Tool insert-2 $P_2 = 2.4187$

Tool insert-3 $P_3 = 4$

Tool insert-4 $P_4 = 3.8012$

Tool insert-5 $P_5 = 2.4481$

The values of P_i are arranged in the descending order as 3-4-1-5-2. Here WPM suggests the tool insert designated as 3. i.e. DNMG 15 04 12 PF as the right choice of the given tool insert selection problem, the second choice is TNMG 22 04 08 PF, and the last choice of tool insert is designated as 2, i.e. VBMT 16 04 02 PF.

V. CONCLUSION

The proposed MADM method, the Simple additive Weighted (SAW) and Weighted Product Method (WPM) applied for selection of a suitable tool insert from number of alternatives. The ranking of tool insert based on its performance score (i.e. tool insert selection index) for SAW methods is 3-4-1-2-5. Whereas given by WPM is 3-4-1-5-2. Hence from the ranking of SAW and WPM we found that first three rank of tool index is same but last two 5 and 2 are change but from the literature review of past researchers we found that tool nose radius is most effective parameter for surface roughness and as value of tool nose radius increases the value of surface roughness decreases so selection of 5 number insert is most logical than insert number 2. But in our case from comparing of these two methods tool insert 3 i.e. DNMG 15 04 12 PF is the best tool insert for better surface roughness in turning of alloy steel.

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