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# Appraisement of Advanced Machine Tool Using Dominance

C. D. Singh[1] and Dr.Dilip Sen[2]

[1]*M-tech Research Scholar, Department of Mechanical Engineering, Vindhya Institute of Technology & Science, Satna, India.*
[2]*Faculty, Department of Mechanical Engineering, Vindhya Institute of Technology & Science, Satna, India.*

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A B S T R A C T

The milling CNC machines are the workhorses of the precision machining industry. CNC machines stands for Computer Numeric Control. CNC is an industry standard programming language designed specifically for controlling high-precision mills, Millings, cutting and grinding machines. It's the progeny of the marriage between Computer Aided Design (CAD) and Computer Aided Machining (CAM). Recently, CNC machines evaluation-selection for advanced manufacturing system problem has rosen. In the present reporting, Milling CNC machines (Computer Numerical Control) machine tool has been evaluated on by exploring the concept of fuzzy set with dominance approach.

Keywords: Multi-Criteria Decision Making (MCDM), CNC Milling machine tool and Benchmarking.

## I. INTRODUCTION

CNC machine tool is valuable for precision industry that uses programs to automatically execute a series of machining operations. CNC machines offer increased productivity and flexibility (Onut et al. 2008).

Computer Numerical Control (CNC) is one in which the functions and motions of a machine tools are controlled by means of a prepared program containing coded alphanumeric data.

CNC can control the motions of the work piece or tool, the input parameters such as feed, depth of cut, speed, and the functions such as turning spindle on/off, turning coolant on/off.

The selection of a CNC machine tool among the alternatives is a multi-criteria decision-making (MCDM) problem including both qualitative and quantitative criteria. In conventional approaches, the CNC machine tool selection problem tends to consider quantitative criteria that less effectively dealing with the impreciseness or vagueness nature of the linguistic assessment.

Under many situations, the qualitative measures of the alternatives such productivity, working automation; precision, accuracy etc are considered which often imprecisely defined by experts panel judgment 'linguistic assessment. Fig. 1 showed the CNC machine tool. The core *objective* of presented is to evaluate the best CNC machine tool amongst preferred under CNC machine tool multi indices appraisement module (tackle criterion undertook uncertainty).

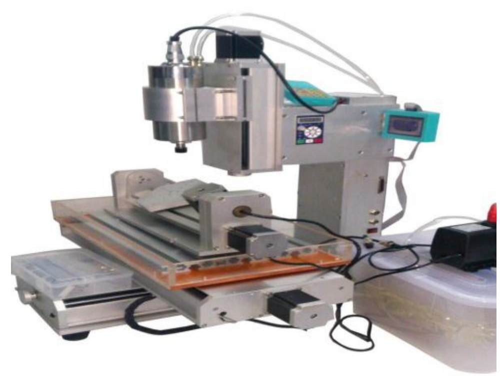

Fig: 1 CNC machine tool

An option that you make about what you think should be done or about which is the best of various alternatives. Decision making is regarded as the mental processes (cognitive process) resulting in the selection of a course of action among several alternative scenarios. Every decision making process produces a final choice. The output can be an action or an opinion of choice. Prof. Zadeh proposed the concept of fuzzy logic in 1965. Fuzzy logic theory is a control tool and technique, which encompasses the data by allowing partial set membership rather than crisp set membership or non-membership.

## 2. FUZZY SET THEORY

Prof. Zadeh proposed the concept of fuzzy logic in 1965. Fuzzy logic theory is a control tool and technique, which encompasses the data by allowing partial set membership rather than crisp set membership or non-membership. Fuzzy logic deals with the concept of partial truth, where the truth value may range between completely true and completely false. Fuzzy logic found their application where the valuable information is neither completely true nor completely false, or which are partly true and partly false, Brauers and Ginevicius (2010); Chakraborty (2011); Dadios and Jr (2002); Gadakh (2011);Kala (2010); Kalibatas and Turskis (2008); Karsak (2008); Kracka et al., (2010).

### 3. DOMINANCE METHODS

$$defuzz(\widehat{A}) = \frac{\int x \cdot \mu(x)dx}{\int \mu(x)dx} \quad \text{..........(1)}$$

$$= \frac{\int_{a_1}^{a_2}\left(\frac{x-a_1}{a_2-a_1}\right)\cdot xdx + \int_{a_2}^{a_3} xdx + \int_{a_3}^{a_4}\left(\frac{a_4-x}{a_4-a_3}\right)\cdot xdx}{\int_{a_1}^{a_2}\left(\frac{x-a_1}{a_2-a_1}\right)dx + \int_{a_2}^{a_3} dx + \int_{a_3}^{a_4}\left(\frac{a_4-x}{a_4-a_3}\right)dx}$$

$$= \frac{-a_1a_2 + a_3a_4 + \frac{1}{3}(a_4-a_3)^2 - \frac{1}{3}(a_2-a_1)^2}{-a_1-a_2+a_3+a_4}.$$

### 4. THE RATIO SYSTEM

Ratio System defines data normalization by comparing alternative of an objective to all values of the objective:

$$x_{ij}^{*} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{2}}} \quad \text{..........................(2)}$$

$$U_i' = A_i - B_i \quad \text{..........................(3)}$$

$$U_i' = \frac{A_i}{B_i} \quad \text{..........................(4)}$$

$$y_i^{*} = \frac{\sum_{j=1}^{g} w_j x_{ij}^{*}}{\sum_{j=g+1}^{n} w_j x_{ij}^{*}} \quad j = 1, 2, ..., n. \quad \text{........(5)}$$

Here

$$A_i = \prod_{j=1}^{g} x_{ij}; i = 1,2,...,m$$

denotes the product of objectives of the $i_{th}$ alternative to be maximized with $g = 1,2,...,n$ being the number of objectives to be maximized and where

$$B_i = \prod_{j=g+1}^{n} x_{ij}; i = 1,2,...,m$$

Denotes the product of objectives of the $i_{th}$ alternative to be minimized with $n-g$ being the number of objectives (indicators) to be minimized. Thus MULT-IMOORA summarizes ratio system analysis and full multiplicative form.

### 5. EMPIRICAL RESEARCH: EVALUATION OF MILLING CNC MACHINE TOOL

A Milling CNC machine tool evaluation appraisement module against OI and SI has been constructed via literature survey (Sun, 2002; Duran and Aguilo, 2008; Qi, 2010; Sahu et al., 2014; Sahu et al., 2015, Sahu et al., 2016). CNC Milling machine tool evaluation appraisement module is shown in Table 1. Objective data is shown in Table 2.

Trapezoidal fuzzy number operator are used by (Duran and Aguilo, 2008; Qi, 2010), is explored to aggregate the fuzzy numbers, then Equation 1 is used to covert rating and weight against criterion into crisp value shown in Table 3-9. Finally normalization is carried out by Equation 2 and ranking is obtained by Equation 3-4-5, shown in Table 10.

Table.1: CNC milling machine tool appraisement module

| | ***Information*** | Objectives | Sources |
|---|---|---|---|
| **Appraisement of milling CNC machine tool** | ***OI*** | Price, INR, $(C_1)$ | (Sun,2002) |
| | | Tool capacity, No. $(C_2)$ | (Sun,2002) |
| | | Necessity of space , Inch $(C_3)$ | (Duran and Aguilo,2008) |
| | | Maintenance cost, INR/Year, $(C_4)$ | (Qi,2010) |
| | | Degradation with time, Year, $(C_5)$ | (Sahu et al., 2014) |
| | | Power requirement, Unit/hrs $(C_6)$ | (Sahu eta l., 2015) |

| | | | |
|---|---|---|---|
| | | Scheduled utilization,($C_7$) | (Duran and Aguilo,2008) |
| | | Fitness for worker , ($C_8$) | (Sun,2002) |
| | ***SI*** | Flexibility against goods ($C_9$) | (Duran and Aguilo,2008) |
| | | Chances of element failure, ($C_{10}$) | (Sahu et al., 2014) |
| | | Ease for making clean, ($C_{11}$) | (Qi,2010) |
| | | Coding flexibility, M/S, ($C_{12}$) | (Sahu et al., 2015) |

Table. 2: Technical and Cost (objective) information against CNC Milling machine tool measures

| **Evaluation of CNC Milling machine tools** | ($C_1$) | ($C_2$) | ($C_3$) | ($C_4$) | ($C_5$) | ($C_6$) |
|---|---|---|---|---|---|---|
| **Milling CNC-1** | 16000000 | 6 | 49 | 51000 | 16 | 2 |
| **Milling CNC-2** | 15000000 | 5 | 50 | 52000 | 14 | 3 |
| **Milling CNC-3** | 17000000 | 6 | 50 | 50000 | 17 | 2 |
| **Milling CNC-4** | 18000000 | 8 | 47 | 53000 | 18 | 3 |
| **Milling CNC-5** | 19000000 | 7 | 50 | 50000 | 19 | 2 |
| **Milling CNC-6** | 19000000 | 7 | 50 | 50000 | 19 | 4 |
| **Milling CNC-7** | 12000000 | 8 | 52 | 54000 | 10 | 2 |
| **Milling CNC-8** | 10000000 | 8 | 50 | 50000 | 11 | 3 |
| **Milling CNC-9** | 18000000 | 8 | 52 | 50000 | 17 | 3 |
| **Milling CNC-10** | 18000000 | 7 | 50 | 42000 | 16 | 3 |

Table 3: Weights against CNC Milling machine tool measures as assigned by DMs and corresponding aggregated fuzzy weights (AFW)

| **Evaluation of CNC Milling machine tools** | Importance weight expressed in linguistic terms | | | | | AFW |
|---|---|---|---|---|---|---|
| | DM1 | DM2 | DM3 | DM4 | DM5 | |
| **$C_1$** | H | H | M | H | H | (0.640,0.740,0.740,0.840) |
| **$C_2$** | VH | VH | VH | H | H | (0.760,0.860,0.920,0.960) |
| **$C_3$** | H | H | MH | H | MH | (0.620,0.720,0.760,0.860) |
| **$C_4$** | M | VH | H | H | H | (0.660,0.760,0.780,0.860) |
| **$C_5$** | VH | H | VH | H | H | (0.740,0.840,0.880,0.940) |
| **$C_6$** | VH | VH | VH | H | H | (0.760,0.860,0.920,0.960) |
| **$C_7$** | H | H | MH | H | MH | (0.620,0.720,0.760,0.860) |
| **$C_8$** | M | VH | H | H | H | (0.660,0.760,0.780,0.860) |
| **$C_9$** | VH | H | VH | H | H | (0.740,0.840,0.880,0.940) |
| **$C_{10}$** | VH | VH | VH | H | H | (0.760,0.860,0.920,0.960) |
| **$C_{11}$** | VH | VH | VH | H | H | (0.760,0.860,0.920,0.960) |
| **$C_{12}$** | H | H | MH | H | MH | (0.620,0.720,0.760,0.860) |

Table.4 Appropriateness rating against subjective CNC Milling machine tool measure, ($C_7$)

| **Evaluation of CNC Milling machine tools** | Appropriateness rating against individual 1st level evaluation measures | | | | | AFR |
|---|---|---|---|---|---|---|
| | DM1 | DM2 | DM3 | DM4 | DM5 | |
| **Milling CNC-1** | G | MP | F | F | MP | (3.800,4.800,5.400,6.400) |
| **Milling CNC-2** | G | G | VG | G | VG | (7.800,8.800,9.400,10.00) |
| **Milling CNC-3** | VG | VG | VG | G | G | (8.200,9.200,9.600,10.00) |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Milling CNC-4** | VG | G | VG | VG | VG | (8.600,9.600,9.800,10.00) |
| **Milling CNC-5** | VG | MG | G | G | G | (7.000,8.000,8.800,9.600) |
| **Milling CNC-6** | MG | F | G | MG | VG | (6.000,7.000,7.600,8.400) |
| **Milling CNC-7** | F | G | MG | F | G | (5.400,6.400,7.000,8.000) |
| **Milling CNC-8** | F | G | G | G | F | (5.800,6.800,7.400,8.400) |
| **Milling CNC-9** | F | G | G | G | G | (6.400,7.400,8.200,9.200) |
| **Milling CNC-10** | G | MG | F | VG | MG | (6.000,7.000,7.600,8.400) |

Table.5 Appropriateness rating against subjective CNC Milling machine tool measure, ($C_8$)

| **Evaluation of CNC Milling machine tools** | Appropriateness rating against individual 1st level measures | | | | | AFR |
|---|---|---|---|---|---|---|
| | DM1 | DM2 | DM3 | DM4 | DM5 | |
| **Milling CNC-1** | MG | F | G | MG | VG | (6.000,7.000,7.600,8.400) |
| **Milling CNC-2** | F | G | MG | F | G | (5.400,6.400,7.000,8.000) |
| **Milling CNC-3** | F | G | G | G | F | (5.800,6.800,7.400,8.400) |
| **Milling CNC-4** | F | G | G | G | G | (6.400,7.400,8.200,9.200) |
| **Milling CNC-5** | G | MG | F | VG | MG | (6.000,7.000,7.600,8.400) |
| **Milling CNC-6** | VG | VG | G | G | G | (7.800,8.800,9.400,10.00) |
| **Milling CNC-7** | MG | VG | G | F | G | (6.400,7.400,8.000,8.800) |
| **Milling CNC-8** | G | VG | MG | VG | VG | (7.800,8.800,9.200,9.600) |
| **Milling CNC-9** | MG | G | MG | G | VG | (6.600,7.600,8.400,9.200) |
| **Milling CNC-10** | F | VG | F | MP | VG | (5.600,6.600,6.800,7.400) |

Table.6 Appropriateness rating against subjective CNC Milling machine tool measure, ($C_9$)

| **Evaluation of CNC Milling machine tools** | Appropriateness rating against individual 1st level evaluation measures | | | | | AFR |
|---|---|---|---|---|---|---|
| | DM1 | DM2 | DM3 | DM4 | DM5 | |
| **Milling CNC-1** | VG | VG | G | G | G | (7.800,8.800,9.400,10.00) |
| **Milling CNC-2** | MG | VG | G | F | G | (6.400,7.400,8.000,8.800) |
| **Milling CNC-3** | G | VG | MG | VG | VG | (7.800,8.800,9.200,9.600) |
| **Milling CNC-4** | MG | G | MG | G | VG | (6.600,7.600,8.400,9.200) |
| **Milling CNC-5** | F | VG | F | MP | VG | (5.600,6.600,6.800,7.400) |
| **Milling CNC-6** | MG | F | G | MG | VG | (6.000,7.000,7.600,8.400) |
| **Milling CNC-7** | F | G | MG | F | G | (5.400,6.400,7.000,8.000) |
| **Milling CNC-8** | F | G | G | G | F | (5.800,6.800,7.400,8.400) |
| **Milling CNC-9** | F | G | G | G | G | (6.400,7.400,8.200,9.200) |
| **Milling CNC-10** | G | MG | F | VG | MG | (6.000,7.000,7.600,8.400) |

Table.7 Appropriateness rating against subjective CNC Milling machine tool measure, ($C_{10}$)

| **Evaluation of CNC Milling machine tools** | Appropriateness rating against individual 1st level evaluation measures | | | | | AFR |
|---|---|---|---|---|---|---|
| | DM1 | DM2 | DM3 | DM4 | DM5 | |
| **Milling CNC-1** | G | MG | MG | MG | G | (5.800,6.800,7.800,8.800) |
| **Milling CNC-2** | VG | MG | MG | MG | MG | (5.800,6.800,7.600,8.400) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Milling CNC-3 | G | MP | MG | MP | G | (4.600,5.600,6.600,7.600) |
| Milling CNC-4 | VG | G | MG | VG | VG | (7.800,8.800,9.200,9.600) |
| Milling CNC-5 | F | G | G | MP | MP | (4.400,5.400,6.200,7.200) |
| Milling CNC-6 | MG | F | G | MG | VG | (6.000,7.000,7.600,8.400) |
| Milling CNC-7 | F | G | MG | F | G | (5.400,6.400,7.000,8.000) |
| Milling CNC-8 | F | G | G | G | F | (5.800,6.800,7.400,8.400) |
| Milling CNC-9 | F | G | G | G | G | (6.400,7.400,8.200,9.200) |
| Milling CNC-10 | G | MG | F | VG | MG | (6.000,7.000,7.600,8.400) |

Table.8 Appropriateness rating against subjective CNC Milling machine tool measure, ($C_{11}$)

| **Evaluation of CNC Milling machine tools** | Appropriateness rating against individual 1st level evaluation indices | | | | | AFR |
|---|---|---|---|---|---|---|
| | DM1 | DM2 | DM3 | DM4 | DM5 | |
| Milling CNC-1 | G | MP | F | F | MP | (3.800,4.800,5.400,6.400) |
| Milling CNC-2 | G | G | VG | G | VG | (7.800,8.800,9.400,10.00) |
| Milling CNC-3 | VG | VG | VG | G | G | (8.200,9.200,9.600,10.00) |
| Milling CNC-4 | VG | G | VG | VG | VG | (8.600,9.600,9.800,10.00) |
| Milling CNC-5 | VG | MG | G | G | G | (7.000,8.000,8.800,9.600) |
| Milling CNC-6 | MG | F | G | MG | VG | (6.000,7.000,7.600,8.400) |
| Milling CNC-7 | F | G | MG | F | G | (5.400,6.400,7.000,8.000) |
| Milling CNC-8 | F | G | G | G | F | (5.800,6.800,7.400,8.400) |
| Milling CNC-9 | F | G | G | G | G | (6.400,7.400,8.200,9.200) |
| Milling CNC-10 | G | MG | F | VG | MG | (6.000,7.000,7.600,8.400) |

Table.9 Appropriateness rating against subjective CNC Milling machine tool measure, ($C_{12}$)

| **Evaluation of CNC Milling machine tools** | Appropriateness rating against individual 1st level evaluation measures | | | | | AFR |
|---|---|---|---|---|---|---|
| | DM1 | DM2 | DM3 | DM4 | DM5 | |
| Milling CNC-1 | G | G | VG | VG | G | (7.800,8.800,9.400,10.00) |
| Milling CNC-2 | MG | VG | MG | VG | MG | (6.600,7.600,8.200,8.800) |
| Milling CNC-3 | MG | VG | MG | G | VG | (7.000,8.000,8.600,9.200) |
| Milling CNC-4 | G | G | F | MG | MG | (5.600,6.600,7.400,8.400) |
| Milling CNC-5 | G | G | MG | VG | MG | (6.600,7.600,8.400,9.200) |
| Milling CNC-6 | MG | F | G | MG | VG | (6.000,7.000,7.600,8.400) |
| Milling CNC-7 | F | G | MG | F | G | (5.400,6.400,7.000,8.000) |
| Milling CNC-8 | F | G | G | G | F | (5.800,6.800,7.400,8.400) |
| Milling CNC-9 | F | G | G | G | G | (6.400,7.400,8.200,9.200) |
| Milling CNC-10 | G | MG | F | VG | MG | (6.000,7.000,7.600,8.400) |

Table.10 Evaluation of CNC milling machine tool

| **Evaluation of CNC milling machine tool** | Ranking by dominance technique |
|---|---|
| Milling CNC-1 | 9 |
| Milling CNC-2 | 7 |

 

| | |
|---|---|
| **Milling CNC-3** | **1** |
| **Milling CNC-4** | 5 |
| **Milling CNC-5** | 3 |
| **Milling CNC-6** | 8 |
| **Milling CNC-7** | 2 |
| **Milling CNC-8** | 4 |
| **Milling CNC-9** | 6 |
| **Milling CNC-10** | 10 |

## 6. CONCLUSION

After applying the dominance approach, it is found that Milling CNC-3 is the optimum alternative than others. The summarized preference orders against different CNC Milling machine tools have been depicted in Table. 10. Moreover, module for crisp or subjective objectives can be segregated with respect to their interrelated metrics/ dimensions and can also be solved for benchmarking problems.

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