A Fuzzy-TOPSIS Method for Optimizing of Forging Problems

Dhiraj Kumar, Sharifuddin Mondal

Abstract: Forging industry consists of simple procedural steps, but a lots of problems are associated with the forging industries. This paper describes the major problems in forging industries along with their cause and effect that reduce the extent of profits. An attempt has also been made to apply Fuzzy multi-criteria combined with TOPSIS method in ranking the problems on the basis of various parameters. This approach improves the quality of manufacturing for forging goods, material availability & its price, fuel supply, technology upgradation, material wastage etc. The proposed approach is very useful due to its capability of providing optimal results with incomplete significant information. The study is the first of its type in forging industries. A numerical model is considered to indicate the effectiveness of the present technique.

Keywords: Fuzzy Logic, TOPSIS, Optimization Technique, Forging Industry

I. INTRODUCTION

Forging is a metal working process at elevated temperature in which metal deformed plastically under controlled condition. It is used to get a preset shape or size by exerting compressive force with mean of different type of die, hammer and press or an upsetting machine. Most commonly used metals include aluminum, brass & copper, carbon, very hard tool steels, alloy & stainless steel, titanium, and high temperature alloys which contain molybdenum, nickel or cobalt. Forging finds largest application in agriculture, aerospace, automotive, material handling & several industrial equipment, national defense, construction, mining. With the help of forging process, parts can be created stronger as compared to other metal working process but a lots of problems are associated with the forging industries. These problems along with their causes and effects are listed in table 1. Fuzzy-TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is being adopted by many researchers for evaluating performance of different manufacturing processes like EDM (Electric discharge machining) [1, 2,3], Laser drilling [4], Turning [5], Robust design [6], Milling [7], Welding [8], Product infant failure [9], Sustainable city logistic planning [10]. Organizations performance [11], Supplier evaluation and management [12, 13],

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Group decision making [14], Vehicle technologies [15], Electronics industry [16], Design (Cost Management) [17], Rapid prototyping [24] etc.

Dewangan et.al. [1] implemented Fuzzy-TOPSIS approach to analyze the effects of various process parameters of EDM. To find optimal parametric setting of AISI P20 tool steel, authors focused on the surface integrity and dimensional accuracy of workpiece. Sivapirakasam et.al. [2] utilized Taguchi method combined with Fuzzy-TOPSIS to explore and understanding the optimization problem of multi-response parameters in green EDM. Priyadarshini et.al. [4] used Fuzzy-TOPSIS method to analyze the heat affected zone (HAZ), HC (Hole Circularity), Material Removal Rate in pulsed Nd: YAG laser micro-drilling of High Carbon steel. It is also found that, optimization of process parameters depends upon the minimizing the HC & HAZ and maximizing the MRR. Gok [5] utilized Fuzzy-TOPSIS combined with GRA (Grey Relational Analysis) to analyze the turning of ductile iron to optimize the value of cutting parameters. Yang et.al. [6] adopted the Fuzzy-TOPSIS methodology to work on the remanufacturing product design. MS (Material Selection), MJM (Material Joining Method), SD (Structure Design) & SCM (Surface Coating Method) are the major design perspectives in remanufacturing. Hsieh et.al. [18] used HFACS (Human factors analysis and classification system), fuzzy TOPSIS, and AHP (analytic hierarchy process) to explore the important error factors of human being in Taiwan (Department of Emergency). (Surface Coating Method) are the major design perspectives in remanufacturing. Hsieh et.al. [18] used HFACS (Human factors analysis and classification system), fuzzy TOPSIS, and AHP (analytic hierarchy process)

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Table 1. Common problems in forging industries with their causes and effects

S.N.	Problems	Causes	Effects	Overcome
1	Lack of Technology Upgradation	Non-availability of new technology. Low interest of manufacturer. High upgradation cost.	Due to lack of technology upgradation, the forging process may loose the capability of satisfying the needs of new customers.	Low productivity, Low profitability
2	Lack of Automation	Initial investment is too high; Non-availability of automation system; Political pressure.	Lack of automation leads to increase workers fatigue and effort or labour intensive operation, increase product or material being damaged or destroyed, permit non-conforming product from shipping, decrease efficiency etc.	Low profit, Low productivity, Accident
3	High Material Cost	Less availability of source; High transportation cost; High labour cost.	Purchase of raw materials are costlier due to very less sources of material, high transportation and labour cost.	Low productivity, High price of finished product
4	Poor Maintenance Check	Irregular maintenance. Lack of trained labour.	Poor maintenance check causes is too much pressure, too wide pressure fluctuation, system extra dirty, extra oil cellar work, shortened bearing life, extra repair shop work etc. and so many problems are created which leads to damages and accidents in industry.	Low productivity, Higher Cost, Increased lead time, Accident and Damage
5	Lack of Marketing in International Market	Less production rate; High cost; Less support of government for international market.	Due to lack of marketing in international market opportunities for collaboration and mutual learning are missed. Also leads to face maximum direct competitive battles.	Low productivity, Lower brand value
6	Lack of Workers	Non-availability of trained workers. To cut cost, less workers requirement.	Due to low availability of workers, always extra work load comes on the available workers.	Low productivity, Accidents
7	Unskilled Workers	Lack of regular training. Low investment on training.	Due to limited training and education workers are mostly unskilled and inefficient. These workers have lack of basic skills, poor inter-personal communication skills.	Low productivity, Low turnover, Negative impact of customer service or inner-company communication
8	Product Defect	Low quality machine and equipment. Lack of quality checkup. Lack of skilled labour.	Defects such as unfilled section, cold shut, scale pits, die shift, flakes, surface cracking, improper grain growth, incomplete forging penetration, residual stresses in forging etc. appear.	Lower productivity, Poorer quality, Less price of finished product
9	Low Fuel Supply	Lack of resource; High transportation cost; Shortage of labour at mines.	Generally in forging, Coal is used as fuel. Continuous production are interrupted due to shortage of fuel supply.	Low productivity
10	Low Material Availability	Lack of resource. Lack of exploration.	Material availability is important in forging due to demand of forging parts especially in automobile. Continuous production are interrupted due to shortage of fuel material.	Low productivity, High price of finished product
11	Not follow the environmental policies completely	Negligence. Lack of awareness. Failure of implementing authority.	If we don't follow the environmental policies, pollution increases which cause allergies, disease, damage to crops, air pollution imbalances slowly aid in the depletion of the ozone layer etc.	Low productivity, Health issue, Safety issue
12	Lack of Pollution Control Initiatives	Negligence. Least priority is given by manufacturer. Lack of awareness.	Due to lack of pollution control initiatives, the source and implementing particles are increasing that increase the creation of pollutants which results pollution (air, water and soil pollution).	Low productivity, Health issue, Environmental issues (like air, water and soil pollution)

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Marbini & Kangi [20] applied Fuzzy-TOPSIS for analyzing the stock exchange in Tehran. It is found that, by agreement between risk & return in stock, this profit should be maximized within designed portfolio. Sirisawat & Kiatcharoenpol [21] utilized Fuzzy & AHP combined with TOPSIS to analyze the RLB (Reverse Logistics Barriers) in industry for electronics applications. In this study, authors mainly aimed on the categorization of RLB and ranking barriers & solution of RL implementation. Liu & Wei [22] investigated Fuzzy-TOPSIS to analyze the risk factors considering questionnaire survey and estimate the overall risk levels of EV (electric vehicle) charging infrastructure Public-Private Partnership (PPP) projects. Walczak & Rutkowska [23] adopted Fuzzy-TOPSIS for the personalized ranking of projects in a participatory budget (PB). But the researches on forging problems by Fuzzy-TOPSIS approach is negligible and need more studies. Fuzzy-TOPSIS approach is a powerful tool to find out optimal setting of process parameters in any manufacturing technique but still it is not applied to forging in literature.

In present paper, we select a Fuzzy-TOPSIS based approach for multi-criteria decision making. An attempt has been made to highlight the problems that are causing the most of the damage. In decision making, FST (Fuzzy Set Theory) is applied to find a pattern of vagueness & unpredictability. Linguistic terms are considered for representing the preferences of decision maker in FST. The decision makers give linguistic rankings for the forging problem to the concerned criteria and corresponding alternatives that are combined by using Fuzzy-TOPSIS, the main benefit is that it differentiate between the better (Benefit criteria) & less the better (Cost criteria). It also helps to select a solution that is near to positive ideal solution & away from negative ideal solution. Recommendation is made for procurement to the alternative with maximum score. Linguistic data are chosen to analyze forging criteria characteristics. Sensitivity analysis is also conducted to find out the best problem solver of forging problems. Various strategic recommendations were made to overcome the forging problems mentioned. Remaining part of the work is presented in following sequence as section 2, linguistic fuzzy set & Fuzzy-TOPSIS are discussed, section 3, a fuzzy multi-criteria method for forging problems is described, section 4, approach of numerical application, section 5, conclusions remarks of present work.

II. LINGUISTIC FUZZY SET AND FUZZY-TOPSIS

A. Linguistic fuzzy set

In FST, conversion scales are adopted to get fuzzy numbers from the linguistic term. In present work, we utilized the properties of two triangular Fuzzy numbers to estimate the criteria & alternatives. These properties are given below:

1: Property of addition

$$\tilde{B}(+)\tilde{E} = (B_1 + E_1, B_2 + E_2, B_3 + E_3) \qquad B_1 \geq 0, E$$

2: Property of subtraction

$$\tilde{B}(-)\tilde{E} = (B_1 - E_1, B_2 - E_2, B_3 - E_3) \qquad B_1 \geq 0, E_1 \geq 0$$

3: Property of multiplication

$$\tilde{B}(*)\tilde{E} = (B_1 * E_1, B_2 * E_2, B_3 * E_3) \qquad B_1 \geq 0, E_1 \geq 0$$

4: Property of division

$$\tilde{B}(/)\tilde{E} = (B_1/E_1, B_2/E_2, B_3/E_3) \qquad B_1 \geq 0, E_1 \geq 0$$

5: Property of inverse

$$\tilde{B}^{-1} = \left(\frac{1}{B_1}, \frac{1}{B_2}, \frac{1}{B_3}\right) \qquad B_1 \geq 0$$

6: Property of symmetric image

$$-\tilde{B} = (-B_1, -B_2, -B_3) \qquad B_1 \geq 0$$

7: Property of multiplication by a constant

$$k * \tilde{B} = (kB_1, kB_2, kB_3) \qquad B_1 \geq 0, k \geq 0$$

8: Property of division by a constant

$$k/\tilde{B} = (k/B_1, k/B_2, k/B_3) \qquad B_1 \geq 0, k \geq 0$$

9: Property of a constant division by fuzzy number

$$\tilde{B}\backslash k = (B_1\backslash k, B_2\backslash k, B_3\backslash k) \qquad B_1 \geq 0, k \geq 0$$

Fuzzy ratings & linguistic variables are applied for the alternatives. The linguistic variables & fuzzy ratings applied for the criteria are presented in table 2 and table 3 respectively.

Table 2. Linguistic membership function for alternatives with rating

Linguistic term	Membership function
Worse (WE)	(0.2,0.2,0.4)
Bad (BD)	(0.2,0.4,0.6)
Medium (ME)	(0.4,0.6,0.8)
Good (GD)	(0.6,0.8,1.0)
Better (BE)	(0.8,1.0,1.0)

Table 3. Linguistic membership function for criteria with rating

Linguistic term	Membership function
Very small (VS)	(0.2,0.2,0.4)
Small (S)	(0.2,0.4,0.6)
Medium (ME)	(0.4,0.6,0.8)
Much (MU)	(0.6,0.8,1.0)
More (MO)	(0.8,1.0,1.0)

B. Fuzzy-TOPSIS

Fuzzy-TOPSIS is one of the many approaches being used to determine the selected criteria against multiple alternatives. This approach, consist of nine steps is now explained below:

1. First, Criteria ratings and Alternatives ratings are assigned.

2. Then, Criteria and Alternatives aggregate fuzzy ratings are computed.

$$a = \min_k\{a_k\}, b = \frac{1}{K}\sum_{k=1}^{K} b_k, c = \max_k\{c_k\} \tag{1}$$

$$a_{ij} = \min_k\{a_{ijk}\}, b_{ij} = \frac{1}{K}\sum_{k=1}^{k} b_{ijk}, c_{ij} = \max_k\{c_{ijk}\} \tag{2}$$

Now, criteria aggregate fuzzy weights, $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$ where

$$w_{j1} = \min_k\{w_{jk1}\}, w_{j2} = \frac{1}{k}\sum_{k=1}^{k} w_{jk2}, w_{j3} = \max_k\{w_{jk3}\} \qquad (3)$$

3.

Now, we compute the decision matrix of Fuzzy.

$$\tilde{D} = \begin{matrix} & C_1 & C_2 & \cdots & C_n \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} \begin{bmatrix} \tilde{X}_{11} & X_{12} & \cdots & \tilde{X}_{1n} \\ \tilde{X}_{21} & X_{22} & \cdots & \tilde{X}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{X}_{m1} & X_{m2} & \cdots & \tilde{X}_{mn} \end{bmatrix}, \quad i = 1,2,...,m; j = 1,2,...,n \qquad (4)$$

$$\tilde{W} = (\tilde{w}_1, \tilde{w}_2, ..., \tilde{w}_n) \qquad (5)$$

4. Then, normalization of decision matrix of Fuzzy

$$\tilde{R} = [\tilde{r}_{ij}]_{mxn}, \qquad (6)$$
$$i = 1,2,...,m; j = 1,2,...,n$$

Where

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \text{ and } c_j^* = \max_i c_{ij} \quad \text{(Benefit Criteria)}$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \text{ and } a_j^- = \min_i a_{ij} \quad \text{(Cost Criteria)}$$

5. Now, we compute the matrix of weighted normalized.

$$\tilde{V} = [\tilde{v}_{ij}]_{mxn}, \quad i = 1,2,...,m; j = 1,2,...,n \text{ where } \tilde{v}_{ij} = \tilde{r}_{ij}(.)\tilde{w}_j$$

6. Then, we compute the FPIS & FNIS.

$$A^* = (\tilde{v}_1^*, \tilde{v}_2^*, ..., \tilde{v}_3^*) \text{ where } \tilde{v}_j^* = \max_i\{v_{ij3}\} \quad i = 1,2,...,m; j = 1,2,...,n$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, ..., \tilde{v}_3^-) \text{ where } v_j^- = \min_i\{v_{ij1}\} \quad i = 1,2,...,m; j = 1,2,...,n$$

7. Now, we compute the distances of each alternative from FPIS & distances of each alternative from FNIS.

$$d_i^* = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^*), \quad i = 1,2,...,m$$

$$d_i^- = \sum_{j=1}^{n} d_v(\tilde{v}_{ij}, \tilde{v}_j^-), \quad i = 1,2,...,m$$

8. Finally, we compute the each alternatives closeness coefficient(CC_i).

$$CC_i = \frac{d_i^-}{d_i^- + d_i^*}, \qquad i = 1,2,...,m \qquad (14)$$

9. Alternatives are ranked a/c to CC_i.

Where, Alternatives, A_j (j=1, 2… m); Criteria, C_i (i=1, 2… n); Aggregate Fuzzy weight ($\tilde{w}_j$), $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$;

$\tilde{D}$ = Alternatives decision matrix of Fuzzy; $\tilde{R}$ = Normalized decision matrix of Fuzzy; $\tilde{V}$ = Weighted normalized matrix if Fuzzy; A^* = FPIS; A^- = FNIS; d_i^* = Distances of each alternative from FPIS; d_i^- = Distances of each alternative from FNIS; CC_i = Closeness coefficient

III. FUZZY MULTI-CRITERIA METHOD FOR FORGING PROBLEMS: CRITERIA SELECTION

First of all, select the criteria for evaluating common problems of forging. After going through literature review on forging problems and from practical experience of working at Heavy Engineering Corporation Limited, Ranchi, India, the criteria are selected. The criteria used for selecting are chosen based on expert opinions to incorporate their possible working practices. They generally consider linguistic values to criteria rating & corresponding alternatives. Linguistics terms cannot be used to do mathematical operation, they are transformed into Fuzzy triangular number so that these can be used in Fuzzy-TOPSIS. Total 12 criteria are selected. These criteria are Technology Upgradation (C1), Need of Automation (C2), Material Cost (C3), Maintenance (C4), Need of Marketing in International Market (C5), Insufficient Workers (C6), Unskilled Workers (C7), Product Quality (C8), Fuel Supply (C9), Material Availability (C10), Adherence to environmental policies (C11), and Pollution Control Initiatives (C12). The different criteria are presented in table 4 in details.

Table 4. Selected criteria for common problems of forging with category

S.N.	Criteria	Id	Definition	Category
1	Technology Upgradation	C1	Technology upgradation refers to increase in new potential & skill to fulfill the customer need.	B
2	Need of Automation	C2	Automation is an apparatus making technique, automatically operates leading to the capability and the ability to fulfill new customer needs.	B
3	Material Cost	C3	Material cost is the amount of money invested in the purchase of raw material which is needed in production of product.	C
4	Maintenance	C4	Maintenance is defined as functional checking, servicing, restoring or checking of necessary device, equipment, machinery, building infrastructure and supporting utilities in industry.	B
5	Need of Marketing in International Market	C5	Need of marketing in international market refers to examine the step to opportunities maximization for collaborating & collective learning and at the same time minimizing the cause of direct cutthroat battles.	B
6	Insufficient Workers	C6	Insufficient workers means that fewer workers than they need to be.	C
7	Unskilled Workers	C7	Unskilled workers refers to the worker with limited training and less education.	C

8	Product Quality	C8	Product quality is ability of product that contribute to meet the customer's satisfaction.	B
9	Fuel Supply	C9	Fuel supply is defined as the abundant/sufficient fuel reached in the industry in time.	B
10	Material Availability	C10	Material availability refers to the material readily available and abundantly.	B
11	Adherence to environmental policies	C11	It means the understanding and adherence to environmental policies to improve its products, service and processes to minimize waste and improving recycling activities.	B
12	Pollution Control Initiatives	C12	Pollution control initiatives work on pollution source reduction and implementing particles that reduce or eliminate the creation of pollutants.	B

*B = Benefit Criteria, C = Cost Criteria

After the investigation & identification of best alternative using selected criteria, the analysis of sensitivity is performed to find the effect on decision making of criteria weight.

IV. NUMERICAL DEMONSTRATION

In this section, the implementation of proposed approach is illustrated to evaluate the forging problems. There are total four alternatives assumed such as A1, A2, A3 and A4. All alternatives are then assessed by executing the forging criteria presented in Table 4 with the help of three decision makers as D1, D2, and D3. All alternatives for every criteria from Table 2 are used to give linguistic rating to the criteria presented in Table 3 by the decision makers. All obtained ratings for criteria and alternatives are listed in Tab. 5 & Tab. 6 respectively.

The aggregated fuzzy weights ($\widetilde{w}_{ij}$) is determined for every criterion with the help of Eq. (3), e.g. for aggregated fuzzy weight criteria C1 is denoted by $\widetilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$ where

$w_{j1} = \min_k(0.6, 0.6, 0.4)$, $w_{j2} = \frac{1}{3}\sum_{k=1}^{3}(0.8, 0.8, 0.6)$, $w_{j3} = \max k(1.0, 1.0, 0.8)$

$= \widetilde{w}_j = (0.4, 0.733, 1.0)$

Similarly, the other criteria aggregate weights are determined.

Then, the alternatives aggregate fuzzy weights are determined based on Eq. (2), e.g. the aggregate rating for alternative A1 for criteria C1 is found out with the half of the rating supplied by the three decision makers as:

$a_{ij} = \min_k(0.2, 0.4, 0.2)$, $b_{ij} = \frac{1}{3}\sum_{k=1}^{3}(0.4, 0.6, 0.4)$, $c_{ij} = \max k(0.6, 0.8, 0.6)$

$= (0.2, 0.466, 0.8)$

Similarly, the other alternatives aggregate ratings with respect to the 12 criteria are calculated.

Table 5. Linguistic analysis for the 12 criteria

Criteria	Decision makers		
	D1	D2	D3
C1	MU	MU	ME
C2	S	MO	S
C3	ME	MO	MO
C4	MO	MO	MO
C5	VS	MO	ME
C6	MU	ME	MO
C7	MU	ME	ME
C8	S	MO	MU
C9	VS	ME	MO
C10	ME	MO	MO
C11	VS	S	S

Table 6. Linguistic analysis for the four alternatives (A1, A2, A3, and A4)

Criteria	A1 D1	A1 D2	A1 D3	A2 D1	A2 D2	A2 D3	A3 D1	A3 D2	A3 D3	A4 D1	A4 D2	A4 D3
C1	BD	ME	BD	WE	ME	BE	BE	GD	BE	WE	BE	BE
C2	BE	BE	GD	BE	ME	BD	BD	WE	GD	BE	BD	ME
C3	ME	GD	BE	WE	BD	BD	BD	BD	GD	BE	GD	ME
C4	BD	BE	BE	GD	ME	WE	GD	ME	BE	WE	WE	WE
C5	ME	GD	BE	BD	BD	BE	WE	WE	WE	ME	WE	BD
C6	BD	WE	ME	GD	ME	WE	BE	ME	ME	BD	WE	ME
C7	WE	GD	ME	BE	WE	BE	GD	BE	BE	BE	BD	BD
C8	WE	WE	GD	GD	BE	BE	ME	BE	WE	GD	GD	WE
C9	ME	BE	ME	WE	BE	BE	ME	ME	WE	BD	BE	BE
C10	GD	GD	BE	ME	WE	ME	ME	GD	WE	BD	GD	BD
C11	BD	BE	WE	GD	GD	GD	ME	ME	GD	GD	ME	GD
C12	GD	BD	BE	GD	GD	ME	ME	BD	BE	BE	BE	BE

Next, normalization is carried out for the fuzzy decision matrix of all alternatives with the half of Eq. (6–8), e.g. the alternative normalized rating A1 for criteria C1 is calculated as

$c_j^* = \max_i(0.8, 1.0, 1.0, 1.0) = 1.0$

$a_j^- = \min_i(0.2, 0.2, 0.6, 0.2) = 0.2$

While C1 is a benefit criteria,

$\tilde{r}_{ij} = \left(\frac{0.2}{1.0}, \frac{0.466}{1.0}, \frac{0.8}{1.0}\right) = (0.2, 0.466, 0.8)$

Similarly, the normalized values for all 12 criteria are determined for every alternative.

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The values of a_j^- & c_j^* are chosen as 1 and 1 respectively. The weighted decision matrix of fuzzy for all four alternatives is determined using Eq. (9). The weighted decision matrix of fuzzy for all alternatives are calculated by using equation (3), (7) & (8), e.g. criteria fuzzy weight C1 and alternative A1 is shown by

$\tilde{v}_{ij} = (0.2, 0.466, 0.8)(*)(0.4, 0.733, 1.0) = (0.08, 0.342, 0.8)$

Similarly, for all 12 criteria and their four alternatives, fuzzy weight are figure out. Then, we have determined the FPIS (A^*) and the FNIS (A^-) based on using Eq. (10) and (11) for every alternatives, e.g. for criteria C1, $A^- = 0.08$ and $A^* = 1.0$. In the same way, computations are completed for rest of the criteria. Then, the distance $d_v(*)$ of each alternative is calculated with the help of the fuzzy positive ideal matrix (A^*) and fuzzy negative ideal matrix (A^-) using Eq. (12) and (13). For e.g., for alternative A1 & criteria C1, the distances $d_v(A_1, A^*)$ & $d_v(A_1, A^-)$ are determined given below:

$d_v(A_1, A^-) =$

$\sqrt{\frac{1}{3}[(0.08 - 0.08)^2 + (0.342 - 0.08)^2 + (0.8 - 0.08)^2]} = 0.442$

$d_v(A_1, A^*) =$

$\sqrt{\frac{1}{3}[(0.08 - 1.0)^2 + (0.342 - 1.0)^2 + (0.8 - 1.0)^2]} = 0.663$

Likewise, the distances for rest of the criteria are computed for all the alternatives. Then, the distances d_i^* and d_i^- are determined respectively using Eq. (12) and (13). Closeness coefficient (CC_I) for the twelve criteria and four alternatives are computed and plotted in table 7 and 8 respectively.

Table 7. Closeness coefficient (CC_i) for the twelve criteria

Criteria	d_i^-	d_i^*	CC_i	Rank
C1	2.247	2.353	0.488	4
C2	2.384	2.566	0.481	5
C3	1.646	2.740	0.375	12
C4	1.873	2.225	0.457	8
C5	1.859	2.819	0.397	11
C6	1.925	2.669	0.419	10
C7	2.146	2.793	0.434	9
C8	2.441	2.509	0.493	2
C9	2.240	2.645	0.458	7
C10	2.268	2.334	0.492	3
C11	1.367	1.476	0.480	6
C12	2.546	2.345	0.520	1

By comparing the CC_i values of the twelve criteria (Table 7), it has been found out that C12 > C8 > C10 > C1 > C2 > C11 > C9 > C4 > C7 > C6 > C5 > C3 which indicates the criteria weight for solving the forging problems and improves the industrialization revolution in forging industries. By comparing the CC_i values of the four alternatives (Table 8), it can be seen that A2 > A1 > A3 > A4. Therefore, it can be said that supplier A2 has the best problems solver of common problem of forging as per the view of the decision making committee.

Table 8. Closeness coefficient (CC_i) for the four alternatives	Alternatives			
	A1	A2	A3	A4
d_i^-	6.421	6.613	5.966	5.945
d_i^*	7.203	7.248	7.475	7.548
CC_i	0.471	0.477	0.443	0.440
Rank	2	1	3	4

A. Analysis of Sensitivity

To evaluate the criteria impact, weights represented by W_{Ci} for criteria C_i (where $i = 1, 2, \ldots, n$) are determined to find out the best problem solver of common problems of forging. The sensitivity analysis is also conducted. Total 17 experiments were performed & details are shown in Table 9.

Table 9. Sensitivity analysis experiments

EX. No.	Definition	Overall Closeness Coefficient (CC_I)				Ranking
		A1	A2	A3	A4	
1	$W_{C1-C12} = (0.2,0.2,0.4)$	0.441	0.451	0.412	0.417	A2>A1>A4>A3
2	$W_{C1-C12} = (0.2,0.4,0.6)$	0.464	0.472	0.434	0.440	A2>A1>A4>A3
3	$W_{C1-C12} = (0.4,0.6,0.8)$	0.475	0.483	0.440	0.447	A2>A1>A4>A3
4	$W_{C1-C12} = (0.6,0.8,1.0)$	0.482	0.489	0.444	0.452	A2>A1>A4>A3
5	$W_{C1-C12} = (0.8,1.0,1.0)$	0.513	0.519	0.466	0.477	A2>A1>A4>A3
6	$W_{C1} = (0.8,1.0,1.0), W_{C2-C12} = (0.2,0.2,0.4)$	0.441	0.460	0.450	0.435	A2>A3>A1>A4
7	$W_{C2} = (0.8,1.0,1.0), W_{C1,C3-C12} = (0.2,0.2,0.4)$	0.476	0.463	0.421	0.432	A1>A2>A4>A3
8	$W_{C3} = (0.8,1.0,1.0), W_{C1-C2,C4-C12} = (0.2,0.2,0.4)$	0.422	0.464	0.418	0.400	A2>A1>A3>A4
9	$W_{C4} = (0.8,1.0,1.0), W_{C1-C3,C5-C12} = (0.2,0.2,0.4)$	0.456	0.458	0.438	0.394	A2>A1>A4>A3
10	$W_{C5} = (0.8,1.0,1.0), W_{C1-C4,C6-C12} = (0.2,0.2,0.4)$	0.464	0.460	0.389	0.417	A1>A2>A4>A3
11	$W_{C6} = (0.8,1.0,1.0), W_{C1-C5,C7-C12} = (0.2,0.2,0.4)$	0.449	0.453	0.396	0.428	A2>A1>A4>A3
12	$W_{C7} = (0.8,1.0,1.0), W_{C1-C6,C8-C12} = (0.2,0.2,0.4)$	0.444	0.450	0.416	0.421	A2>A1>A4>A3
13	$W_{C8} = (0.8,1.0,1.0), W_{C1-C7,C9-C12} = (0.2,0.2,0.4)$	0.445	0.484	0.426	0.430	A2>A1>A4>A3
14	$W_{C9} = (0.8,1.0,1.0), W_{C1-C8,C10-C12} = (0.2,0.2,0.4)$	0.462	0.456	0.415	0.437	A1>A2>A4>A3
15	$W_{C10} = (0.8,1.0,1.0), W_{C1-C9,C11-12} = (0.2,0.2,0.4)$	0.474	0.450	0.423	0.428	A1>A2>A4>A3
16	$W_{C11} = (0.8,1.0,1.0), W_{C1-C10,C12} = (0.2,0.2,0.4)$	0.449	0.480	0.433	0.440	A2>A1>A4>A3
17	$W_{C12} = (0.8,1.0,1.0), W_{C1-C11} = (0.2,0.2,0.4)$	0.456	0.471	0.428	0.464	A2>A4>A1>A3

It can be observed from Table 9, all criteria weights for first five experiments are set equal to (0.2,0.2,0.4), (0.2,0.4,0.6), (0.4,0.6,0.8), (0.6,0.8,1.0), and (0.8,1.0,1.0). The weight of each criteria for experiment 6–17 is set as highest (0.8,1.0,1.0) in successive experiment and lowest value (0.2,0.2,0.4) for the remaining criteria. The objective is to observe the criteria influencing highly the decision making process. As an illustration, the criteria C1 has the highest weight (0.8,1.0,1.0) for experiment 6, whereas the weight (0.2,0.2,0.4) for remaining criteria. The analysis of sensitivity is carried out and its result are presented in Fig. 1. It is observed from Fig. 1 & Table 9 that, alternative A2 score highest in 13 experiments (Expt. No. 1–6, 8–9, 11–13, 16-17) out of 17 experiments while alternative A1 score 4 votes for remaining experiments. Hence, we can conclude that alternative A2 emerging as the winner with a majority of votes (76.47%) and relatively insensitive to criteria weights for our decision making process.

B. Recommendations

There are following various strategic recommendations made to deal with the forging problem.

(1) Procurement of raw material is the fundamental item and required serious attention. The dimension (length & diameter) of the raw material should be selected such that there is minimum wastage of material during further operation. This will result in increment of maximum raw material availability & ultimately decrease the raw material wastage.

(2) Proper layout is always encourageable. The proper process layout helps in easy movement of material and the workforce required to movement of material. This will be not increasing production rate only but also save the wastage of time and money.

(4) The management play a very significant role in development of any industries. Employee should always be motivated by their management. The employee can be motivated by either by developing personnel or by increasing their financial growth. The proper awareness regarding security & safety also enhance employee's morale.

(5) Some important control measures of pollutions are as follows:

(a) Control at Source: It helps in the choice of raw materials and treatment of exhaust gases before final discharge and stock height increase up to 38 meters for proper mixing of the discharged pollutants.

(b) Industry Site Selection: The site of an industry should be selected by considering weather & topographical characteristics at that location.

(c) Industrial Waste Treatment: The industrial waste must be discharged after proper treatment.

(d) Plantation: To control the level of dust, smoke & pollutants in the atmosphere, there should be intensive plantation in that region.

(e) Government Regulation Act: Government should set a monitoring committee to regulate the level prescribed by pollution control board against the industry not confirming the prescribed level.

(f) Environmental Impacts Assessment: This assessment should be carried out on regular basis to evaluate and identify the hazardous and severe effects of pollutant disposed by industries on natural eco-system.

(g) Stringent Implementation & Environmental Protection Act: Environment Protection Act should be followed strictly and there should be provision of punishment for concerned person.

V. CONCLUSIONS

The degree of proper project selection has been highly affecting the rate of success for any project of industries particularly in forging industry. In this aspect, the Fuzzy-TOPSIS which is one of the hybrid approach to select the problem and also estimating all influencing parameter's weightage to select the alternatives. A number of alternatives have been looked over by considering the various criteria, which are highly responsible for different types of problems. The Fuzzy-TOPSIS approach is being used to get order of priority among the alternatives.

The proposed approach has three steps. In step1, the evaluating criteria of forging problems are noticed. These criteria are Technology Upgradation, Need of Automation, Material Cost, Maintenance, Need of Marketing in International Market, Insufficient Workers, Unskilled Workers, Product Quality, Fuel Supply, Material Availability, Adherence to environmental policies, and Pollution Control Initiatives. In step 2, Linguistic ratings to the alternatives & criteria provided by the experts as (a) Fuzzy-TOPSIS approach has been used to aggregate the ratings and generation of an overall closeness coefficient score for every alternatives to measure the forging problem solver.
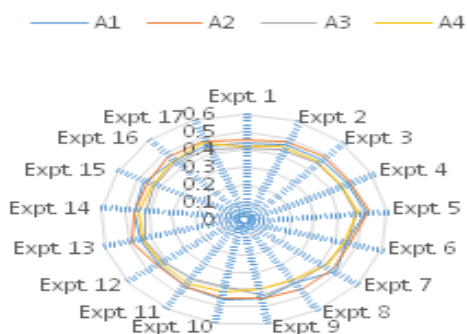

Fig. 1 Result of sensitivity analysis

(b) The forging problem solver having highest score is the best among alternatives.

In step 3, the influence of criteria on weights in decision making process is determined by performing sensitivity analysis.

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