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Materials Today: Proceedings 5 (2018) 4615–4620

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ICMPC 2017

Multi Criteria Decision Making For Selection Of Material Composition For Powder Metallurgy Process

Shrikrushna B. Bhosale[a,b]*, Sumit Bhowmik[b], Amitava Ray[c]

[a]*Department of Mechanical Engineering, SVERI's College of Engineering, Pandharpur-413304, Maharashtra, India*
[b]*Department of Mechanical Engineering, National Institute of Technology, Silchar-788010, Assam, India*
[c]*Training and placement cell, Jalpaiguri Govt. Engineering College, Jalpaiguri, West-Bengal, India*

Abstract

Selection of appropriate material composition in the field of powder metallurgy is often difficult task as alloying element has greater effect on material properties. The paper reports the procedure for selection of material composition for powder metallurgy process. Proper material composition is observed to be a multi-criterion decision-making problem with conflicting and different objectives. For this purpose the TOPSIS (Technique for order performance by similarity to ideal solution) method is used which gives ranking of the alternatives. To find optimum composition, the two number of alternative alloying martial and four criteria for material selection is used. The result from the research shows that 0.8% Carbon and 2% Copper is best composition form selected data. The procedure is illustrated using a case study.

Selection and/or Peer-review under responsibility of 7th International Conference of Materials Processing and Characterization.

Keywords: Selection of material; TOPSIS; powder metallurgy.

1. Introduction

Powder metallurgy (P/M) forms close net shapes segments which minimizes the assembling steps. In powder metallurgy, pieces was delivered by blending distinctive metal powders, compaction and sintering at hoisted

* Corresponding author. Tel.: +91-9890921661; fax: +91-2186-225082
E-mail address: shrikrushna82@gmail.com

2214-7853
Selection and/or Peer-review under responsibility of 7th International Conference of Materials Processing and Characterization.

temperature. Likewise, unique powders can be effortlessly added to each other that gives plentiful shot for advancement of materials. For product development the material selection play vital role. Improper selection of material may result in failure to fulfil customer and manufacturer requirements [1]. Proper selection the materials give best performance with minimum cost [2]. Blends of essential iron and graphite powders has ordinarily utilized for P/M application. The expanding graphite content growths pearlite volume part in iron powder metallurgy [3]. A little measure of copper powder was included in blend to reinforce the sintered compounds. The expansion of copper and graphite brought about great quality and hardness which was seen in microstructural advancement [4]. Additionally, copper gives better dimensional security after sintering [5]. The increment in carbon brought about expanding hardness with decreasing elasticity [6]. Copper is the essential alloying component because of its solidifying impact [7] and somewhat decreases the strength because of presence of austenite in the quenched steel [8]. Due to such different effect of alloying material, it’s hard to select proper composition in powder metallurgy. Various researchers proposed different material selection theories such as technique of order preference by similarity to ideal solution (TOPSIS) , gray relational analysis (GRA), ELECTRE (Elimination Et Choix Traduisant la REalite), VIKOR (VIsekriterijumska optimizacija Kompromisno Resenje), and COPRAS (Complex PRoportional Assessment). Dagdeviren et al. [9] suggested the TOPSIS for the selection of optimal weapon. Prasenjit et al. [10] used Preferential Ranking Methods to solve material selection problem. R. Khorshidi et al. [11] carried out comparative analysis for materials selection in Al-SiC composite by using TOPSIS and PSI Methods. Deng Y-M et al. [12] explained the role of materials identification and selection with multi criteria decision method. R. kumar et.al [13] selected of nitride steel as best material for required application by using TOPSIS method.
In this paper TOPSIS method is used for proper selection of percentage of carbon and copper for powder metallurgy process using technique of order preference by similarity to ideal solution from the available alternatives. The aim of this paper is to propose a method to select material composition for industrial application. Tensile Strength (TS), Hardness (HD), Dimensional Change (DC) and percentage Elongation (EL) are the criteria for material composition selection for different carbon and copper percentages.

2. Multi Criteria Decision making TOPSIS method

The multi criteria decision making TOPSIS was developed by Yoon and Hwang [14]. The comparison of the output variables is not possible considering individual measurement unit. So to achieve the general optimum condition by considering all response parameters, multi-objective optimization method is used for further analysis. For this purpose, the TOPSIS method is used to find single optimum condition. TOPSIS method ranks the experiments based on the relative closeness to the ideal solution. Each of these variables has different measurement unit that quantify the performance of the process individually as shown in below Fig 1.

1	To evaluate the all alternatives
2	The attributes in the form of a decision matrix.
3	Calculate the normalized decision matrix
4	Decide weights by AHP method
5	Calculate weighted normalized matrix
6	Obtain the ideal (best) and negative ideal (worst) solution
7	Obtain the separation measures
8	Rank the relative closeness of a particular alternative

Figure. 1 Steps of TOPSIS methods.

Step 1: The objective is to evaluate the all alternatives, and the attributes are: density, hardness, crushing strength and porosity. For this particular problem, hardness and crushing strength are considered as beneficial attribute (i.e. higher values); While density and porosity are considered as non-beneficial (i.e. smaller values).

Step 2: The next step is to represent all the information available for the attributes in the form of a decision matrix.

Step 3: The quantitative values of the process performance selection factors, which are given in D matrix are normalized and the normalized matrix. Calculate the normalized decision matrix. The normalized value calculated as-

$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$ Where i=1, 2, 3…m; j=1, 2, 3…..n; R= $[r_{ij}]_{m\times n}$

Step 4: Relative importance of attributes (Rij) can be assigned the values and the weights considered are equal to all response parameters.

Step 5: The weighted normalized matrix, W_{ij} is calculated from normalised matrix multiply with weights.

Step 6: Determine the positive ideal solution (PIS) A+ by using equation 1 and negative ideal solution (NIS) A- by using equation 2.

$A^+ = \{(\max i\, V_{ij} \vert\, j \in J),\ (min\, i\, V_{ij} \vert\, j \in J), i = 1,\ 2, \ldots\ldots m\} = \{V_1^+, V_2^+ \ldots\ldots V_n^+\}$----equ.1

$A^- = \{(\min i\, V_{ij} \vert\, j \in J'),\ (\max i\, V_{ij} \vert\, j \in J'), i = 1,\ 2, \ldots\ldots m\} = \{V_1^-, V_2^- \ldots\ldots V_n^-\}$-----equ.s2

Where J is a set of beneficial attributes and J' is a set of non-beneficial attributes.

Step 7: The next step is to obtain the separation measures, and these are calculated by using the n-dimensional Euclidean distance.

The separation of each alternative from the positive ideal solution was calculated by using equation 3.

$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}$ ------equ. 3 Where i=1, 2, 3 ….m

The separation of each alternative from the negative ideal solution was calculated by using equation 4.

$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}$ ----------equ.4 Where i=1, 2, 3 ….m

Step 8: The relative closeness of a particular alternative to the ideal solution is calculated by using equation 5.

$C_i = \frac{S_i^-}{S_i^+ + S_i^-}$ -------------equ. 5 Where i=1, 2, 3 ….m; $0 \leq C_i \geq 1$

This relative closeness to ideal solution can be considered as the performance index for considering optimum composition for powder metallurgy process.

Step 9. Rank the alternatives with respect to *Ci* in descending order. The preferred alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution, where a higher *Ci* would mean higher preference.

3. Validation of the proposed methodology for selection of material composition

For this material composition, the iron powder ASC 100.29 is selected as base metal due to high compressibility [15]. For this example two alternative alloying material that is carbon and copper with criteria of material which shown in Table-1 and Table-2 respectively. From the material data handbook, the decision matrix which is shown in Table-3.

Table-1 Alternative alloying composition and criteria of material for carbon

Sr. No.	% of carbon	Tensile Strength (TS) MPa	Hardness (HD) Hv10	% Dimensional Change (DC)	% Elongation (EL)
1	0.2	200	60	0.15	6
2	0.5	265	80	0.06	4.2
3	0.8	300	105	0	3.8

Table-2 Alternative alloying composition and criteria of material for Copper

Sr. No.	% of copper	Tensile Strength (TS) MPa	Hardness (HD) Hv10	% Dimensional Change (DC)	% Elongation (EL)
1	2	220	68	0.3	6.2
2	4	200	63	1.5	2.2

Table-3 Decision Matrix for Carbon and Copper

For Carbon			
TS	HD	DC	EL
200	60	0.15	6
265	80	0.06	4.2
300	105	0	3.8
For Copper			
220	68	0.3	6.2
200	63	1.5	2.2

4. Result and Discussion

In order to solve the material composition selection problem, the decision matrix is considered from powder metallurgy data handbook (Table-3). For each criteria the same weight 0.25 is considered.

Table-4 Normalize decision matrix

For Carbon			
TS	HD	DC	EL
0.447	0.414	0.928	0.727
0.592	0.552	0.575	0.509
0.670	0.724	0.000	0.461
For Copper			
0.747	0.734	0.196	0.942
0.673	0.680	0.981	0.334

The Normalize decision matrix and Weighted Normalize decision matrix are represented in Table-4 and Table-5. The positive ideal solution (PIS) A+ and negative ideal solution (NIS) A- are calculated by using equation 1 and equation 2 respectively. Also, the separation of each alternative from the positive ideal solution (S+) and negative ideal solution (S-) are calculated by using equation 3 and equation4 respectively. Finally the relative closeness (C*i*) of a particular alternative to the ideal solution is calculated by using equation 5. Table-6 shows the positive ideal solution (S+) and negative ideal solution (S-) along with relative closeness (C*i*) and ranking of alternatives.

Table-5 Weighted Normalize decision matrix

TS	HD	DC	EL
For Carbon			
0.112	0.103	0.232	0.182
0.148	0.138	0.144	0.127
0.168	0.181	0.000	0.115
For Copper			
0.374	0.367	0.098	0.471
0.336	0.340	0.490	0.167

The positive ideal solution (PIS) A+ and negative ideal solution (NIS) A- are calculated by using equation 1 and equation 2 respectively. Also, the separation of each alternative from the positive ideal solution (S+) and negative ideal solution (S-) are calculated by using equation 3 and equation4 respectively. Finally the relative closeness (C*i*) of a particular alternative to the ideal solution is calculated by using equation 5. Table-6 shows the positive ideal solution (S+) and negative ideal solution (S-) along with relative closeness (C*i*) and ranking of alternatives.

Table-6 Relative closeness (C*i*) and ranking of alternatives.

S+	S-	Ci	Rank
For Carbon			
0.2597	0.0000	0.0000	3
0.1518	0.1153	0.4318	2
0.0000	0.2597	**1.0000**	**1**
For Copper			
0.3922	0.3949	**0.5017**	**1**
0.3071	0.3040	0.4975	2

Technique for order preference by similarity to ideal solution method is used to determine best material composition from alternative material composition. The ranking of material composition is shown in Table-6.

5. Conclusions

The multi criteria decision making TOPSIS method is applied for selection of material composition in powder metallurgy process. By this method 0.8% carbon and 2% copper are the best material composition among the other alternative material composition.

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