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Research Paper

Application of Taguchi and Analysis Hierarcy Process Methods for Furan Design on Metal Casting Industry

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Abstract

In the preparation of furan the raw material used are, Silica Sand, Resin, and Catalyst. Some problem that occurs are high level of water, high level of sour, high level of clay, unsuitable distribution, and low permeability. All those problems above make the power of furan not suitable with the target that has been stated, so that furan can easily be broken, cracked, and do not stand with high temperature and its power becomes weak. The result of this research is that the optimal combination based on the highest TOPSIS score is A1 B2 C3 with the composition of Resin 1.3%, Catalyst 22.5% and new sand 15% + reclaim sand 85%. The coefficient of loss function compression strength is 4.611,11 and 10.375 for the shear strength. The raising quality based on the confirmation experiment is 0.1018 for the compression strength and 0.2339 for the shear strength. The value of S/N in the confirmation experiment for the compression strength is 20.5817 and 23.0480, in which both numbers are in the trust interval limitation that has been decided. It shows that TOPSIS procedure is able to increase furan quality for both responses, that is compression strength response, and shear strength response all at once in one parameter setting.

Keywords: *Compression Strength, Shear Strength of Furan, AHP Method, Taguchi*

1. Introduction

The foundry industry in Indonesia is growing quite rapidly. This is evidenced by the manufacture of machines and objects castings/products that are local and export[1]–[3]. Due to the varying demand for the use of castings from the consumer side, the casting industry strives to meet the demand in accordance with the specified specifications and the guaranteed quality in order to achieve the target and can compete with foreign-made cast products. In realizing the reality there are several factors that affect the quality of castings such as furan[4]–[6]. Furan is silica sand having high SiO2 content and high melting point and has undergone treatment process to achieve low acidity, low clay, low balance, LOI (Loss On Ignition), suitable distribution size, clean and low moisture content.

Some problems experienced by Metal Casting Industry is the emergence of defects from castings. The cause of the defect is the furan used in addition to the pattern/pattern created, melting, getting system, pouring, operator performance and the machines used. It is also caused by the improper use of the Resin, Catalyst and Silica sand, so that the furan becomes brittle or falls easily due to its low strength. Other defects that occur in furan are the emergence of air cavities, cracks, low permeability[7]–[9]. This is due to high water content, high acid content, high clay levels and unsuitable distribution. Furan defects caused by this furan an average of 2-10%.[10], [11] In order for the quality of the product to be of high quality, the Metal Casting Industry makes the standard of silica sand used as a reference for molding is SiO2: 95%, Fe2O3: 1% (maximum), Al2O3: 2% (maximum), CaO: 1% (maximum), MgO: 1% (maximum). In addition there are also some content/levels of elements or other substances with a small percentage that includes Clay: 0.5% (maximum), Moisture: 0.5% (maximum), Acid demand value: 4 ml H2SO4/100gr and Loss on Ignition (LOI): 2.7 - 35%.

A. Formulation problem

"What are the criteria and settings of furan parameters that have high performance and what is the optimal estimated value that can be achieved to get compression strength and Shear Strength furan simultaneously by suppressing loss function"?

B. Research purposes

1) Finding factors affecting compression strength and shear strength (furan)
2) Evaluate the selection process of furan combination alternatives in order to build furan performance
3) Determining the appropriate parameter setting so as to optimize compressive strength (Compression Strength) and Shear Strength simultaneously

4) Finding the optimum estimated value of compressive strength (Compression Strength) and shear strength (Shear Strength)

2. Literature Review

Furan

Quality furan is silica sand which has high SiO2 and melting point and has undergone treatment process to achieve low acidity, low clay, low balance, LOI (Loss on Ignition), suitable distribution size, clean and low moisture content. This furan is used to make molds or moldings on objects to be cast.[12]–[14]

The most common furans are mountain sand, beach sand, river sand and silica sand provided by nature. In its use can be done directly and some are done splitting into grains with a suitable size. Mountain sand, generally dug from the old layer. This sand contains clay and most can be used after water mixing. Sand with 10-20% clay content can be taken for granted. Silica sand, in some ways is derived from the mountain in its natural state. They all have a major part of SiO2, and they contain dirt like mica. Sand beaches and river sand mainly contains dirt like many organic bonds. Dirt is expected as small as possible.

Sand beaches, river sand, natural silica sand and artificial silica sand are not self-attached, therefore bindings are required to bind the grains to one another and only be used after mixing.

Form of grains of sand from furan classified into several types of round grains of sand, grains of sand partly angled, grain sand corner, grain sand crystals and so on. The type of rounded sand grit is good as furan, because it requires less amount of binder to obtain strength (Strength) and certain permeability, and is able to flow very well. In the crystal sand grains are less good for furan, because it will break into small grains of mixing and provide fire resistance and poor permeability to the mold, and furthermore requires a large amount of binding.

Furan is usually a collection of grains of varying sizes. But sometimes it consists of filtered grains that have a uniform size. The desired grain size is such that 2/3 of the sand grains have the size of 3 mesh sequentially, and the remainder of the next mesh-mesh size.

Clay Ground (Tonus) is the oldest binder used, natural sand and clay today is used in traditional casting. The most widely used type of tone is betonies, which is one type of clay consisting of fine grains of 10 - 0.01 where the main constituent phase is monmorillonite (Al2O3.4SiO2.H2O). Compared with other types of tone, betonies has more sources and has a stronger binding strength. The higher the content of betonies, the higher the ability to press and the ability of the furan form. Conversely, flow ability and gas flow ability will decrease.

Quartz sand (SiO2) is a natural sand commonly used in the world of metal casting as a molding base material. In large grains are usually used as a mold for gray iron castings, granules between 0.25 - 0.35 mm. As for steel, heavy metals and light metals will use fine grains to medium with a diameter < 0.2 mm. The chemical composition of this sand is SiO2 at least 98%. This quartz sand is used as sand mold for all types of castings, except the casting of Hard Manganese Steels.

Analysis Hierarhcy Process (AHP)

The Analysis Hierarchy Process is a process of "systematic rationality" to consider an issue as a whole and examine the simultaneous interaction of its various components within a hierarchy. The Analysis Hierarchy Process can synthesize the assessments into a comprehensive estimate with the relative priorities of various action alternatives.[15], [16] The priority generated by the Analysis Hierarchy Process is the basic unit used in all types of analysis and stimulates the emergence of ideas for carrying out creative actions and for evaluating the effectiveness of those actions. In addition, the Analysis Hierarchy Process can also track inconsistencies in the considerations and preferences of participants/respondents. The methods used in the Analysis Hierarcy Process in solving the problem are:

- Preparation of hierarchy; Hierarchical analysis is used to specify a complex or framed state into its components, then organize the component parts in a hierarchical form. An important step in hierarchy is the pairwise comparison of the criteria of a hierarchy.
- Priority setting; Priority setting is a step to synthesize the results of paired comparison assessment from the previous stage and to determine which criteria have the highest and lowest priority as a result of the analysis.
- Consistency testing; In testing the consistency of data priority setting results, information and data are very limited can be completed quickly and easily.

Steps of Analysis Hierarchy Process

1) Preparation of a hierarchical structure; Problems are broken down into components, then parts of the components are arranged in a hierarchical form. The top hierarchy is broken down into several supporting elements, then the elements are described to make the elements more specific.
2) Profit Loss Analysis; At this stage it begins with the dissemination and completion of a questionnaire containing questions about the order of priority level criteria and choosing the level of importance based on the level of priority that has been selected. The order of priority level of this criterion is used to determine the criteria weights used in the evaluation matrix analysis phase[7], [17].
3) Pairwise Comparative Assessment; Pairwise comparison is done on elements at a hierarchical level. Assessment is done by assigning numerical weights based on paired comparisons between elements with other elements. The result of the comparison is formed into a square matrix with an order corresponding to the number of elements at the hierarchical level.
4) Calculating Eigenvectors and Eigenvalue; The elements in each row of the matched pair matrix matrix are cumulatively multiplied, then the result is multiplied by the root with the degree corresponding to the number of elements in the matrix row. The result of this process is a column matrix, while the eigenvector is obtained by dividing the column matrix by the number of cumulative elements in the column matrix. Multiplication of pairwise matrix with eigenvector will result in a new column matrix. Eigenvalue is the result of the corresponding element of the new column matrix with the eigenvector. The maximum eigenvalue is the average of the elements in the eigenvalue matrix.
5) Testing Data Consistency; Consistency of data is known from the Consistency Ratio (CR) value which is the result between Consistency Index (CI) and Random Index (RI) The complete 3^k factorial design is the factorial arrangement for each factor k consisting of 3 levels. Generally denoted for 3 levels as low, medium and high level. Factorial Design Part 3^{k-p}. If the number of factors in the complete factorial design increases, then the number of experiments to be performed also increases. To reduce the number of experiments that have to be done then can be used partially factorial design. The factorial design partly includes only the main effects and low order interactions, whereas high order interactions are ignored.[18]–[20]. A partially 3^k factorial design is an experimental design consisting of $(1/3)^p\, 3^k$ design portions for $p < k$. for example 3^{k-2} is an experimental design consisting of 1/9 parts of 3^k design

3. Methodology

The Taguchi method was introduced by Genechi Taguchi in 1940 aimed at optimizing the experimental process. The taguchi method evolves on an overall, different approach to conventional methods of quality engineering. The target of Taguchi method is to make the product robust to noise, because it is often referred to as Robust Design.

1) Signal to Noise Ratio

Taguchi introduced the S/N ratio approach to examine the effect of noise factors on the variations that arise. The type of S/N ratio depends on the desired characteristics (Ross, 1996: 208-209), namely:

a. Smaller-the-Better (STB): the lower the value, the better the quality
b. Larger-the-Better (LTB): the greater the value, the better the quality
c. Nominal-the-Better (NTB): set a certain nominal value, if the value is close to the nominal value the quality is better

2) Controlled Factors and Noise Factors

Taguchi develops design and product development factors into two groups: controlled factors and noise factors (Ross, 1996: 34 and 204).

An orthogonal array is a matrix whose elements are arranged according to rows and columns. A column is a factor or condition that can be changed in an experiment. Lines are the state of the factor. Arrays are called orthogonal because the levels of the factors are balanced and can be separated from the influence of other factors in the experiment. So the Orthogonal Array (OA) is a balanced matrix of factors and levels, so that the influence of a factor or level is not coincident with the influence of other factors or levels. OA requires fewer experiments in evaluating several factors to provide more efficient experiments while still not losing information from observed experiments.

After determining the number of factors, the number of levels of each factor and the interaction between factors, then in the preparation of orthogonal arrays required calculation of the total number of degrees freely. The total number of degrees of freedom is a minimal line in OA, or at least equal to the number of experiments to be performed. So the selection of OA corresponding to the line should not be less than the total number of degrees of freedom. The corresponding OA can be seen from one of the standard OAs provided by Taguchi. In OA for two levels consisting of L4, L8, L12, L16, L32 and for three levels consisting of L9, L18, L27. L notation shows the number of experiments to be performed.

3) Designing Taguchi Experiments

The design of an experiment is a simultaneous evaluation of two or more factors (parameters) on the ability to influence the average or variability of the combined results of certain product or process characteristics.

A. Collection and Data Processing

1) Data Collection On Analysis Hierarchy Process Method

The information phase is an early stage to explore the data and information needed based on the questions on the work plan. Furan to be discussed is a furan that has a compressive strength of at least 3.8 kg/cm2 and a minimum shear strength of 1.2 kg/cm2. This furan has the composition of materials such as Resin, Catalyst and sand. Resins and catalysts commonly used are Foseco types. While the sand used is sand reclaim. The initial design of furan used as standard and potential for development is sand, Catalyst 26% by weight of Resin and using reclaimed sand (old sand). Types of Resins and Catalysts used in the furan-making process are Foseco. The Occurrence phase This creativity will be done in the form of development of alternative products as much as possible then selected against alternatives that have potential cost efficiency. In the design of furan there are some material composition that is Resin, Catalyst and Sand. The types of Resins and Catalysts are Foseco, Indocerra and Uniprima. While the sand used consists of reclaimed sand, new sand and mixed sand. An alternative combination that has the potential to be proposed as a furan design can be seen in Table 1.

Table 1: Furan Combination Alternatives

Alternatives	Resin	Catalyst	Sand
1	Foseco	Foseco	New Sand
2	Foseco	Indocerra	New Sand
3	Foseco	Uniprima	New Sand
4	Foseco	Foseco	Reclaim Sand
5	Foseco	Indocerra	Reclaim Sand
6	Foseco	Uniprima	Reclaim Sand
7	Foseco	Foseco	Mixed Sand
8	Foseco	Indocerra	Mixed Sand
9	Foseco	Uniprima	Mixed Sand
10	Indocerra	Foseco	New Sand
11	Indocerra	Indocerra	New Sand
12	Indocerra	Uniprima	New Sand
13	Indocerra	Foseco	Reclaim Sand
14	Indocerra	Indocerra	Reclaim Sand
15	Indocerra	Uniprima	Reclaim Sand
16	Indocerra	Foseco	Mixed Sand
17	Indocerra	Indocerra	Mixed Sand
18	Indocerra	Uniprima	Mixed Sand
19	Uniprima	Foseco	New Sand
20	Uniprima	Indocerra	New Sand
21	Uniprima	Uniprima	New Sand
22	Uniprima	Foseco	Reclaim Sand
23	Uniprima	Indocerra	Reclaim Sand
24	Uniprima	Uniprima	Reclaim Sand
25	Uniprima	Foseco	Mixed Sand
26	Uniprima	Indocerra	Mixed Sand
27	Uniprima	Uniprima	Mixed Sand

B. Data Processing

1) Profit-Loss Analysis

Profit-loss analysis is used to analyze the function of alternatives developed at the creative stage. Criteria used as consideration are moisture content, ease of operation, operating time, clay level, operating cost, material price and suitable distribution.

2) Eligibility Matrix

The feasibility matrix is used to select alternative combinations. Assessment for each alternative combination is done by assigning value.

3) Evaluation Matrix

Alternative selected in the previous stage and added one initial design. These criteria are production cost, moisture content, ease of operation, operating time, clay level, and suitable distribution.

4) Weighting Criteria

Weighting for each criterion is done using pairwise comparison method based on importance level, so the importance level of a criterion relative to other criterion can be stated clearly.

5) Results of Matched Comparison Matrices

The pairwise comparison of these elements takes into account the effect of the elements on the upper level.

6) Sensitivity Analysis

This sensitivity analysis is conducted to see the effect of the change of criteria weight on the alternative arrangement. This sensitivity analysis can also be used for other elements of criteria so that the established hierarchy is more dynamic and can capture the apparent symptoms of change.

7) Summary of Criteria and Alternative Weights

The weights generated from paired comparison calculations on both the objective and alternative criteria against the criteria.

8) Performance Calculation

Performance calculations for each of these alternatives and initial designs are done by multiplying the value of each row by its weight. It aims to determine which alternatives have the highest performance values that are the basis of the development stage.

9) Development Stage

This stage aims to select an alternative from selected alternatives in the previous stages by providing final recommendations in writing for selected alternatives to be implemented, including the full consideration of technical and economic factors to be implemented. Based on synthesis, sensitivity analysis, and performance calculation, alternatives (Foseco Resin, Foseco Catalyst, Mixed sand) can be implemented referring to levels and factors, orthogonal arrays used in the Taguchi method.

C. *Data Collection and Processing for Taguchi Method*

The collection of this furanic design data is based on a combination of selected alternatives: Foseco Resin, Foseco Catalyst and mixed sand from the Analysis Hierarchy Process method.

D. Experiment Variables

In this experiment the variables used include:

a. Independent Variable (Independent Variable); which affect the compressive strength (Compression Strength) and shear strength (Shear Strength), based on literature study and questionnaire are Resin, Catalyst and Silica sand.
b. Factor levels; Resin Factor, the level used consists of three levels of factors: 1.3% Resin; 1.5% Resin; Resin 1.7%. Catalyst Factor, the level used consisted of three levels of factors: Resin 20%; Resin 22.5%; Resin 25%. Sand factor, the level used consists of three levels of factors, namely sand reclaim 95% + new sand 5%; sand reclaim 90% + new sand 10%; sand reclaim 85% + new sand 15%.
c. Variable Response; In this furan design the response variable is compressive strength (Compression Strength) and shear strength (Shear Strength). Characteristics of calculi for compressive strength (Compression Strength) and shear strength (Shear Strength) are larger the better.

E. Trial Data

This furanic design trial data comprises Compression Strength and Shear Strength data, performed by direct experiments based on selected orthogonal arrays with replication of three times each. This experiment data consists of a primary trial and a confirmation experiment.

F. Selection of Orthogonal Array of Main Experiments

In this experiment the main significant factors were Resin (A), Catalyst (B) and Sand (C). The interaction between two significant main factors based on reference is the interaction between Resin and Sand or A x C. Determining the location of the factors used in the main experiments are Resin (A), Catalyst (B), Sand (C) and interaction between Resin and Sand (A x C).

G. Data Processing with Taguchi Method

Data relating to factors affecting compressive strength and shear strength, calculated by ANOVA where data has been transformed in the form of signal to noise ratio S/N. The next step in each response is calculation by pooling procedure, percent contribution, and optimum condition, residual analysis with IIDN assumption, TOPSIS procedure (Technique for Order Preference by Similarity to Ideal Solution), interest rate transformation, quality loss, optimum combination and experiment confirmation.

H. Influence Factor against Response Strength Furan Press

The compression strength response (Furan compression strength) is expressed by the magnitude of kg / cm2. This variable has the greater quality characteristics better (Larger the better) which means the greater the compression strength of furan is favored.

I. ANOVA Response Strength Furan Press

To know the main factor and the interaction between two factors that influence significantly to the variable of compressive strength response then used analysis of variance (ANOVA) two way. The data used in two-way ANOVA analysis is data that has been transformed in the form of signal to noise ratio S/N. Factors to be tested using this two-way ANOVA are Resin (A), Catalyst (B), Silica Sand (C) and Resin and Silica Sand (A x C) interactions.

Table 2: Anova Ratio S/N Strength Furan Press

Source variations	Df	F_{count}	F_{table}
Resin (A)	2	2059.11	2.67
Catalyst (B)	2	36.00	2.67
Silica Sand(C)	2	106.94	2.67
AxC	4	128.80	2.67
Error	16		
Total	26		

J. Percent Contribution Strength Furan Press

Percentage of contribution was obtained to know the amount of major factor contribution and significant interaction to furan compressive force response. Percentage contribution of each factor is shown in table 3.

Table 3: Percent Contribution Strength Furan Press

Source variations	SS	Df	MS	SS'	Contribution (%)
Resin (A)	102.800	2	51.400	102.75	83.4037
Catalyst (B)	1.797	2	0.899	1.747	1.4181
	5.339	2	2.670	5.289	4.2932
Silica Sand (C)					
AxC	12.861	4	3.215	12.761	10.3583
Error	0.399	16	0.025		0.5268
Total	123.196	26			100.00

Table 3 shows that the strength of furan press is influenced by Resin, Catalyst, Silica Sand respectively by 83.4%, 1.4%, 4.3% and the interaction between Resin and Silica Sand is 10.3%.

Table 4: ANOVA The Power of Furan Shear

Source variations	Df	F_{count}	F_{table}
Resin (A)	2	14.94	2.67
Catalyst (B)	2	5.49	2.67
Silica Sand (C)	2	5.22	2.67
AXC	4	2.70	2.67
Error	16		
Total	26		

Table 5: Percent Contribution Strength Tap Slide Furan

Source variations	SS	Df	MS	SS'	Contribution (%)
Resin (A)	2	643.82	321.91	600.22	35.69
Catalyst (B)	2	236.70	118.35	193.60	11.50
Silica Sand (C)	2	225.14	112.57	182.04	10.83
AXC					
Error	4	232.46	58.11	146.26	8.69
	16	344.78	21.55		33.59
Total	26	1682.91			100.00

K. Implementation of TOPSIS Procedure on Furan Design

By using TOPSIS procedure will be obtained Resin level, Catalyst and Silica Sand that can optimize both response. Characteristics of quality for the compressive strength response and shear strength is greater is better (Larger is better), then the form of loss function to be used is as follows:

$L_{ij} = K\ (1/r)\ \Sigma\ (1/\ y^2_{ijk})$

The above equation shows that K is the coefficient of loss function obtained based on calculations made by the company. The calculation of the loss coefficient is as follows:

1) To achieve the compressive strength of 3.8 kg/cm2 in the furan making process is done for 20 minutes. while the cost of manufacture amounted to Rp 415.
2) From the manufacture result usually reaches shear strength of 4.8 k cm2, then the difference resulting from target is 1 kg/cm2.
3) With the formula $K = L/\Delta^2$ then the loss function coefficient is obtained:

$$K = 415 / (1)^2 = 415$$

4) Desired shear strength of 1.2 kg/cm2 was the usual shear strength of 1.4 kg/cm2, with the duration of making furan 20 minutes and the cost of Rp. 415 so the loss coefficient is 288.2.

Table 6: The Influence of Major Factors On TOPSIS Value

Level	Factor		
	A	B	C
1	0.9613	0.8393	0.7174
2	0.7887	0.8609	0.8455
3	0.7013	0.7511	0.8885
Max-Min	0.2600	0.1098	0.1711

Based on table 6, the highest TOPSIS value describes good quality with combination of factor A1 B2 C3 and parameter setting is 1.3% Resin; 15% catalyst and new Sand 15% + Sand reclaim 85%. Resin Factor has the greatest contribution to TOPSIS value, followed by mixed sand and catalyst.

Table 7: Confirmation Trial Results

Response	Initial Condition	CI Confirm	Optimum Condition	Growth
Compressive strength	S/N opt. = 20.47989 MSD = 0.0089 Varians = 1.183	20.47989 ± 0.1680	S/N opt = 20.5817 MSD = 0.0087 Varians = 0.165	0.1018
shear strength.	S/N opt = 22.81409 MSD = 0.0052 Varians = 1.08	22.81409 ± 4.9310	S/N opt = 23.0480 MSD = 0.0050 Varians = 0.2129	0.2339

Based on calculation result in table 7 there is improvement of quality at S/N ratio for response of compressive strength equal to 01018 and shear strength equal to 0.2339. The magnitude of the S/N ratio obtained from the confirmation experiment was within the limits of the interval. Thus, the optimum combination obtained by Taguchi method with TOPSIS procedure approach has been able to improve the quality of furan making for both responses simultaneously with setting A1 B2 C3, ie 1.3% Resin; Catalyst 22.5% and new Sand 15% + Sand reclaim 85%.

Analysis and Interpretation of Analytical Hierarchy Process Method (AHP)

a. The magnitude of inconsistent ratio in the five furanic design criteria were moisture content (0.05), ease of operation (0.09), operating cost (0.09), clay level (0.07) and suitable distribution (0.09). This means that respondents are consistent enough in providing answers and pairwise comparison assessment on the furan design criteria.
b. The magnitude of the weight of the furan design criteria is operating cost (0.353), moisture content (0.284), suitable distribution (0.182), ease of operation (0.104) and clay level (0.078) with CR 0.04.
c. Alternative 7 (Foseco Resin, Foseco Catalyst and Mixed Sand) is the chosen alternative that has the highest performance compared to the original design and other alternatives.

Analysis and Interpretation Taguchi Method

a. Based on ANOVA Resin factor, Catalyst, Silica sand and interaction between Resin and Silica Sand have Fcount > F (10% 2,16) means that each factor has an influence of level difference to the compressive strength response and shear strength.
b. The largest percentage of furan compressive strength is achieved on the Resin factor of 83.4%, meaning that Resin has the strongest influence on the compressive strength and strength of Resin to reduce the total variation is 83.4%. While for shear strength is achieved on Resin factor of 35.69%, Mean Resin has the strongest influence on shear strength and strength of Resin to reduce the total variation is 35.69%.
c. Based on residual analysis on compressive strength or shear strength, the assumption of IIDN (0, σ2) is fulfilled. This means that the model is valid enough because the residual (the difference between the observed and expected values) is independent of one another, has zero mean and constant variant (identical) and normal distribution.
d. The amount of S/N of the optimum condition in the confirmation experiment for the compressive strength response is 20.5817 at the interval limit determined by the 90% confidence level that is between 20.3119 up to 20.6478. As for the shear force response of magnitude S/N is 23.0480 which is at the interval limit is determined with 90% confidence level that is between 17.8831 to 27.7451.
e. On TOPSIS procedure obtained coefficient of loss function 4.611.11 for compressive strength and 10,375 for shear strength. The optimum condition was obtained A1 B2 C3. This means that the combination of Resin (1.3%), Catalyst (22.5%) and new sand 15% + sand reclaim 85% is a parameter setting that can optimize compressive strength and shear strength simultaneously.
f. Improved furan quality of confirmatory experiments for compressive strength is 0.1018 or 10.18% and 0.2339 or 23.39% for shear strength.

4. Conclusion

a. Mixed Sand) is the chosen alternative with the highest weight (0.130) and the performance of 61.262.
b. Factors that affect the compressive strength and furan shear strength are Resin, Catalyst, Silica Sand and the interaction between Resin and Sand Silica.
c. The optimum combination of TOPSIS procedure is A1 B2 C3 that is 1.3% Resin, Catalyst 22.5% and new sand 15% + sand reclaim 85%The optimum conditions of the confirmatory experiments for the compressive strength response and shear strength are within the prescribed interval limits and quality improvement of 0.1018 for compressive strength and 0.2339 for the shear force response.

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