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Impact of the Different Moulding Parameters on Properties of the Green Sand Mould

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Abstract

Sand Casting process depends mainly on properties of the green sand mould, sand casting requires producing green sand mould without failure and breakage during separation the mould from the model, transportation and handling. Production of the green sand mould corresponding to dimensions and form of the desired model without troubles depends on the properties of the green sand. Ratio of constituents, preparation method of the green sand, mixing and pressing processes determine properties of green sand. In the present work, study effect of the moulding parameters of bentonite content, mixing time, and compactability percentage on the properties of the green sand mould have been investigated. Design of experiments through Taguchi method was used to evaluate properties of permeability, compressive strength, and tensile strength of the green sand. It was found that 47% of compactability, 9(min) of mixing time, and 6% of bentonite content gives highest values of these properties simultaneously.

Keywords: Green sand, Compactability, Tensile strength, Permeability, Taguchi method

1. Introduction

Casting process was widely adopted method as manufacturing process instead of the other methods for making an expensive and complicated shapes [1]. More than 70% of the metal castings are produced by a sand-casting process [2]. Green sand casting has extensively applications in industry, due to the cost effectiveness of the available of sand and bentonite on the earth crust, the production process and simplicity of recycling of green sand, and automation [3-5]. Casting process involves pouring of the molten metal into cavity of the sand mould, makes it to solidify, and the obtained objects called castings [6]. The main constituents of the green sand mould are Silica sand mixed with 10-12% binder material of bentonite clay and 2- 5% water [7]. Water and the additives of bentonite binder which have properties like, ability of water absorption, viscosity, and swelling index make the sand possess high bonding strength [8]. There are many moulding parameters have an effect on the sand mould properties [1]. Quality or defects of the castings is based on properties of the green sand mould in terms of strength, and dimensional accuracy which depends on the constituent's type and ratio of water and bentonite to sand, and type of pressing process as well as the mixing time. [9-12].

Properties of the green sand like tensile strength, compressive strength, and permeability promoting the sand to be used for producing of ferrous and non-ferrous castings [13]. The property of Permeability referred to ability of the gas or liquid to be flow through the green sand. Permeability of the green sand is based on bentonite to water ratio, the sand grain size and shape [5]. Each permeability represents a continuous porosity which reduces the density of the green sand. The increase permeability contributed to the leakage of gases during the casting process. Whereas a lower permeability means enhanced density, so this contributes to better strength of the green sand. It is found that density of the green sand has directly proportional to young's modulus of elasticity [14]. Improving the tensile strength of the green sand mould helps to produce a sand mould without breaking while the sand mould is lifted from the model [15, 16].

A few researchers used the statistical approaches such as Taguchi method to determine the effective sand moulding factors. The method involves design of orthogonal array, as well as utilize S/N ratio (signal to noise ratio) [17, 18]. Pulivarti et.al, used analysis of variance (ANOVA) through Taguchi method to identify effect of moulding parameters on the properties of the green sand mould [19]. Desai et.al based on design of experiment, and Quality loss function for optimize of sand moulding parameters to obtain the best properties of green sand mould [6]. Gupta et.al focused on reducing defects of casting through controlling the sand mould properties using the design of experiment method [20].

The current work represents an attempt to use Design of Experiments through Taguchi method for determining the effective and appropriate moulding parameters for enhancing properties of tensile strength, compressive strength, and permeability of the green sand mould.

2. Design of Experiments

The main target of this work is practical finding of the required variables of the sand moulding process to get the best tensile strength, compressive strength, and permeability of the green sand mould.

Determining the optimum factors of compactability percentage, bentonite content, mixing time and their levels which have an influence on properties of the green sand mould usually depends on the experience of foundry men, and try and error method. Design of experiments was used to determine the effective parameters for the sand moulding process. Taguchi method based on four levels of three parameters of compactability percentage, mixing time, and bentonite content have been adopted.

Amount of the used Bentonite percentage in the current investigation are 6%, 8%, 10%, and 12%. The mixing time used in the present work are 3, 5, 7, and 9 minutes. The selected compactability levels are of 32%, 37%, 42% and 47%. The sand moulding parameters and their levels are listed in table 1.

The moulding materials used are BP- Quartz with irregular shape, and grain size of 0.25 mm , and BP-A bentonite containing 86% Montmorillonite. The sand used for this investigation is mixed through mixer machine type LM-2e with appropriate ratio of bentonite and water according into adopted plan of experiments listed in table 2 to prepare the required compactability of the green sand.

The tube test 50 mm diameter is filled with the mixed green sand, and the mixture is subjected into 1Mpa pressure through the pressing machine. The measured reduce length of the loss sand represents compactability percentage of the green sand. Compactability of the green sand listed in table 1 requires that the water content be controlled during the mixing process to get the desired values [21]. Four series of green sand mixture with different compactability (32%,37%, 42%, and 47%) were used to prepare the required standard samples with a height 50 mm, and a diameter 50 mm. Three standard samples from each adopted experiment in table 2 were prepared to measure the permeability, compressive strength and tensile strength.

The permeability test involves placing the compacted green sand in permeability gauge type LPiR-3e, and recording the measured value that appears on the gauge screen. The mechanical properties of tensile strength, and compressive strength were also investigated through placing the prepared sand samples in the universal sand strength testing machine. The samples were subjected to the load until failure occurred, and the the measured values are displayed on the instrument screen. Each experiment was repeated three times, and the dispersion characteristics were found less than 0.05.

Table 1.
Parameters of the sand moulding and their levels

Levels	**Parameters**		
	Bentonite content %	**Mixing Time (min)**	**Compactablity %**
1	6	3	32
2	8	5	37
3	10	7	42
4	12	9	47

Table 2.
Plan of Experiments

Ex. No	**Compactability %**	**Mixing Time (min)**	**Bentonite %**
1	1	1	1
2	1	2	2
3	1	3	3
4	1	4	4
5	2	1	2
6	2	2	1
7	2	3	4
8	2	4	3
9	3	1	3
10	3	2	4
11	3	3	1
12	3	4	2
13	4	1	4
14	4	2	3
15	4	3	2
16	4	4	1

Table 3.
Measured values for the monitored properties of the moulding mixture

Ex. No	Permeability *10^{-8} m^2/Pa . s*	Compressive strength *MPa*	Tensile strength *MPa*
1	4.998	0.0932	0.0014
2	4.826	0.103	0.0017
3	5.86	0.1373	0.0019
4	6.377	0.1618	0.0023
5	6.492	0.1128	0.0020
6	6.089	0.1079	0.0016
7	5.343	0.1765	0.0023
8	5.171	0.1667	0.0024
9	6.722	0.1275	0.0022
10	5.4	0.1226	0.0023
11	6.089	0.1177	0.0019
12	6.607	0.1373	0.0021
13	7.181	0.1275	0.0023
14	6.837	0.1373	0.0022
15	6.607	0.1618	0.0029
16	6.722	0.1767	0.0033

3. Results and Discussion

Table 3 has listed the measured properties of permeability, compression strength and tensile strength of the green sand which were measured based on approved experiments. Minitab software has been used for designing and analyze design of experiments.
The obtained results shown that permeability of the green sand has an influenced by compactability percentage, mixing time and bentonite content. Compactability of the green sand have an influenced by water content, there is an opportunity to evaporate exceeds content due to heat generation during the mixing process. This behavior contributes in leave voids between the sand grains which enhanced permeability property. Increase of bentonite content show an extremely constant effect on permeability of the green sand, figures 1 and 2 show surface plot and main effect of the moulding parameters on permeability respectively. The maximum permeability 7.181 (10^{-8} m^2/Pa.s) was achieved in experiment No. 13 and its levels 4, 1, and 4 of compactability percentage, mixing time, and bentonite content respectively. While experiment No. 2 and its levels 1, 2, and 2 of the moulding parameters gives 4.826 (10^{-8} m^2/Pa.s) the minimum value of permeability property of the green sand.

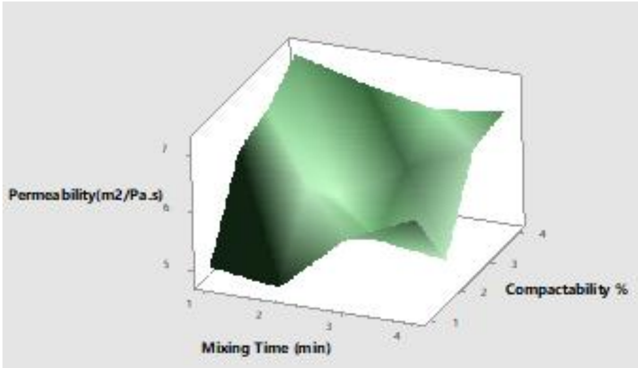

Fig. 1. Permeability Vs compactability & Mixing time

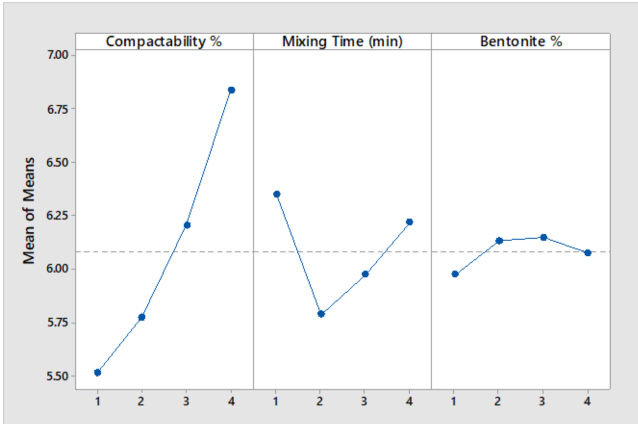

Fig. 2. Main effect of parameters on Permeability

The surface plot, and main effect shown in figures 3, and 4 display compressive strength change as a result of variation of the moulding parameters. The greatest value of compressive strength is 0.1767 MPa has been achieved with experiment No. 16 and its levels 47% of compactability, 9(min) of mixing time, and 6% of Bentonite content. Experiment No. 1 and its levels 1, 1 and 1 of the moulding parameters gives 0.0932 MPa the minimum value of compressive strength property of the green sand. Bentonite content, and mixing time have a great effect on the compressive strength of the green sand. While, compactability percentage has fluctuating effect on the compressive strength property. There is an increase of compressive strength during shift from the first level of compactability factor to the second level. Afterward it is found decrease of the compressive strength property during compactability shift from the second level to the third level. Then after, shift of the compactability factor to the fourth level enhances compressive strength of the green sand.

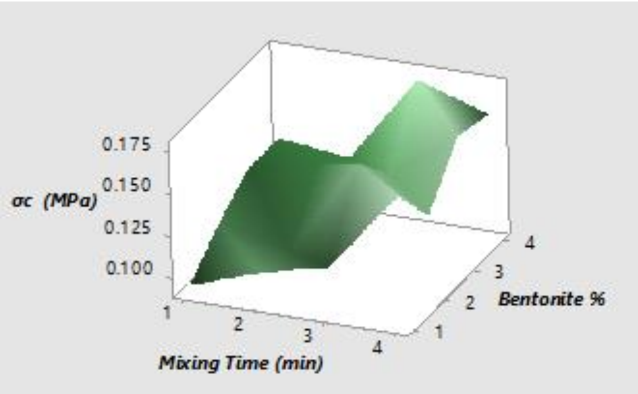

Fig. 3. Compressive strength Vs Bentonite & Mixing time

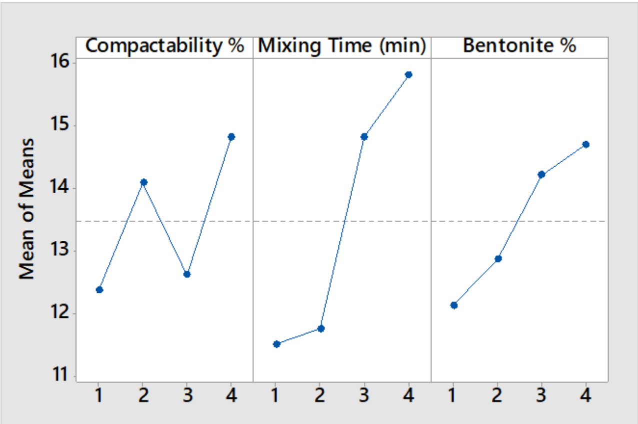

Fig. 4. Main effect of parameters on compressive strength

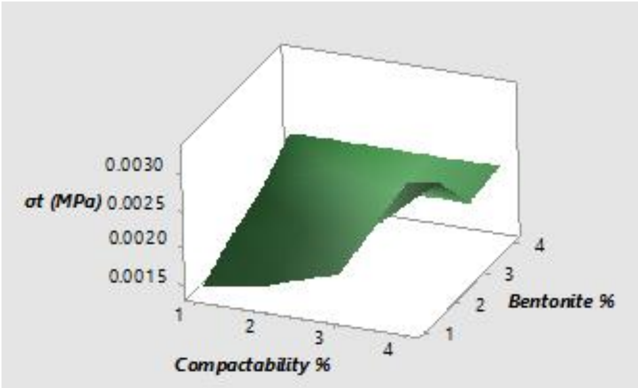

Fig. 5. Tensile strength Vs Compactability & Mixing time

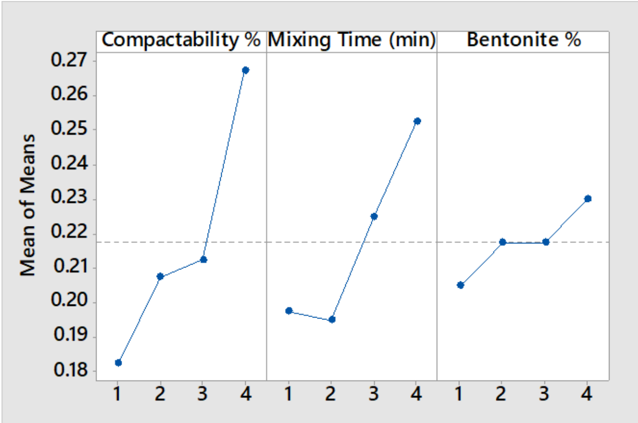

Fig. 6. Main effect of parameters on Tensile strength

Tensile strength of the green sand very necessary property to insure obtain sand mould without fracture during separation of the mould process from the model. Figures 5 and 6 of the surface plot and main effect respectively shown that increasing any of the moulding parameters of compactabilty, bentonite, and mixing time supports tensile strength property of the green sand.
The second and third levels of compactability and bentonite have approximately constant effect on the tensile strength. The levels 4, 4, and 1 of experiment No. 16 gives the maximum tensile strength 0.0033 MPa of the green sand. The lowest value of the tensile strength 0.0014 MPa was obtained in experiment No. 1 which have levels 32% compactability, 3(min) mixing time, and 6% bentonite content.

4. Conclusions

Appropriate parameters of the moulding process and their levels have been determined based on the Taguchi method for enhancing properties of the green sand. Properties of the bonding strength evaluate ability of the sand mould to withstand the further processing without failure. Permeability property is required to prompt outgassing after pouring the molten metal in the mould cavity. The highest values of these properties were obtained at the same time by using the 4th levels of compactability, and mixing time, and the 1st level of bentonite content. Bentonite content have an extremely constant effect on permeability of the green sand. The compressive strength of the green sand has an influenced by Bentonite content, and mixing time while compactability percentage has fluctuating effect. Increasing the moulding parameters of compactabilty, bentonite, and mixing time enhance tensile strength property of the green sand.

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