Optimization of Aluminum Sand Casting process parameters on RSM and ANN methods

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ABSTRACT

Sand casting is one of the best processes to produce a product to satisfy the customer requirements. The prime advantages of choosing the sand casting technique are perfect dimensional geometry, development of pattern is easy, production rate is high, and solidification time is low when compared to other casting techniques. The main purpose of sand casting is to produce a product with better quality in low cost. The properties of the green sand are based on the sand composition and the most important parameters in the preparation of moulding sand are green strength, moisture content and clay content. In this work, the silica oxide is blended in green sand with various compositions for cope box. The various compositions of sand parameters are experimentally investigated by using Response Surface Methodology (RSM). The results of sand parameters are compared with Artificial Neural Network (ANN) analysis. The blending of 9.2% SiO_2 with green sand is very suitable for this casting process. The blending of 9.2% SiO_2 with green sand is very suitable for this casting process. The effect of SiO2 blending with green sand, the initial raw material is reduced up to 25% of volume without casting defects. The hardness value increased up to 22% and the surface roughness decreased up to 12% by varying the percentage of SiO2 in green sand.

Keywords: SiO_2; Green sand; RSM; ANN

INTRODUCTION

Moisture content is one of the most important properties of sand preparation. The moulding sand property plays an important role of escaping the gases during the solidification process. The foundry industries produces aluminum, cast iron, brass and gun metal in a huge volumes. The researchers are discussed for improving sand casting process with respect to sand parameters, riser design, optimization techniques etc. Priyank et al [1] were investigated the sand casting process parameters by using DOE and ANN and also reported that the vent holes play crucial role in evasion of exhaust gasses during solidification of casting. The possession of the moisture content and properties of yola sand were determined by Paul [2]. Investigation of the yola natural sand was done for the variations in range of moisture content from 1 to 9%. For this experimental investigation, the author concluded that optimum results were moisture content of 5% and 118.6 KN/m^2 compressive strength. In sand casting process, the thermal behavior of casting/chill material was investigated by Farzaneh et al [3] and concluded that the role of temperature in sand casting process has a major impact. The optimization of CO_2 casting process was calculated by Noorul Haq et al [4], with the usage of Taguchi method. To obtain final products with high quality, optimization of input parameters were done and it is shows that the various defects that may arise were investigated and the optimum results of the defects were also recommended. In addition to the sand mix at weight percentage components like bentonite clay properties and zircon were selected. The aluminium alloy casting's sand mould properties are the targets of the research. For silica sand, the compositions and the physical properties were evaluated by Saliu et al [5] in various industries. The variation in amounts of ingredients, additives and the types of additives influences the properties of the molding sand. Additives like corn flour, coal dust and clay are also included in water and binders.

Mohsen et al [6] investigated the nano composites of aluminum-Al_2O_3 in gravity casting. The various fracture tests were conducted experimentally. Ganesh et al [7] investigated the nano silica particles, plays a vital role of casting quality in sand casting process. In this research work, the various optimization techniques like Taguchi and Grey rational analysis result have been analyzed. Mohd Moiz Khan et al [8] discussed the characteristics of green sand. The major mechanical analyses of universal testing compression, shear and impact test are analyzed. The grain finesses number of sand also experimentally investigated by using scanning electron microscope. Production units like Foundry industries in Nigeria Charnnarong Saikew [9] mostly used synthetic sand and imported binders. It has also stated that the foundries use various types of sand for manufacturing mold. The wide use of green sand which is easily available, and shell molding sand, cement bounded sand, dry sand and core sand which are forms of green sand used for special purposes are also analyzed. Factors like permeability, mould hardness, moisture, shatter index, green compressive strength and compatibility control the casting's quality in both the types of molding sands and this was investigated by Himanshu Khandelwal [10]. The above mentioned factors are again dependent on parameters like the grain size, amount of water used and the properties of the binder.

The use of regression equation was developed and optimized in GA and PSO by Surekha [11], the properties like percentage of clay, grain fineness number, and percentage of water of the green sand were analyzed. The control factors like permeability, harness, green compression strength were also considered. John et al [12] determined the main parameters such as pouring temperature, mold temperature and runner size of the aluminum alloy, the impact energy and the hardness of the aluminium alloy , and the optimum results were carried out by using the Taguchi experimental design method. Mekonnen et al [13] investigated the casting yield and the surface defects and studied the single blank and double blank aluminium. The chemical compositions of moisture content, clay content, grain size, sprue size, riser size, ramming and thickness and diameter ratio of the blank were considered. Better results for the aluminium blank of this work were obtained with the use of the Taguchi robust method. The environmental conditions on the sand mold properties were investigated by Ramin Meshkabadi [14]. The considered input parameters were mould hardness, permeability and clay content, and the compressive strength was considered as the output parameter. By neuro fuzzy modeling, from day 1 to day 3 with different compositions of the output parameters, the temperature and humidity are calculated and the best compressive strength is obtained while the green sand is recycled. The reused green sand was analyzed by Birru et al [15, 16] and a good strength was exhibited with the addition of alumina. The mechanical properties were improved considering the permeability, green and dry compression strength and bentonite content.

Based on the literature review, it is clearly observed that the sand parameters are the important role in sand casting. The various compositions are experimentally analyzed. But the composition of silica with various percentages is not analyzed so far. In this work, the various levels of volume of silica are blended with green sand.

METHODOLOGY

Experimental

The mould boxes divided into two portions such as drag and cope. The drag is in down position and cope is on over the drag box. The drag box is covered with mould cavity and gating system and the cope box is covered with sprue pin and riser. The geometry of mould cavity should solidify faster than the riser. Generally, the SiO_2 is one of the best thermal insulators and it will reduce the heat transfer through the green sand. Because of this property, the experimental work is designed by the standard composition of green sand , is prepared for drag box and blended SiO_2 with green sand is prepared for cope box. It is clear that the heat transfer rate of drag box is higher than the heat transfer rate of cope box. In this experimentation, the volume and geometry of riser will reduce because of slow heat transfer. The two experimental methods like combination green sand with SiO_2 and the design of riser geometry are involved in this work as follows. The major composition of green sand such as moisture and clay content blending with SiO_2 are selected with various levels and factors of independent variables. The RSM is selected for this investigation. The RSM designed the input parameters and output responses are shown in the Table 1.

Table 1. Factors and levels of independent variables using RSM

Factors	Symbol	Levels		
		1	2	3
Moisture Content%	A	6	7	8
Clay Content %	B	4	5	6
Silica Oxide(SiO_2) %	C	3	6	9

The amount of clay content (bentonite binder) of 4-6% and SiO_2 should be maintained from 3-9% in the green sand as shown in Figure 1(a). Generally SiO_2 has 1743ºC of melting point and very less thermal conductivity of 1.4 W/(m.K). The concentration of moisture content in the green sand should be within 6-8% as shown in the Figure 1(b). The experimental work of aluminum cast material with suitable riser conducted by 17 runs is shown in Figure 2. The geometry of mould cube is 50mm square is selected for this investigation. The hardness test was taken from Brinell hardness machine and surface roughness test have been carried out from surface roughness tester are shown in Figure 3(a&b).

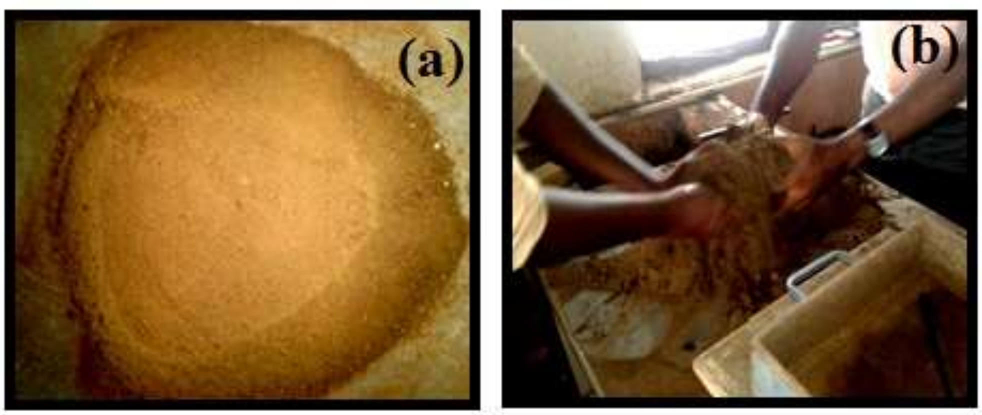

Figure 1. (a) Clay and SiO_2 mixer (b) Mixing of moisture content

Figure 2. Cast materials for RSM techniques

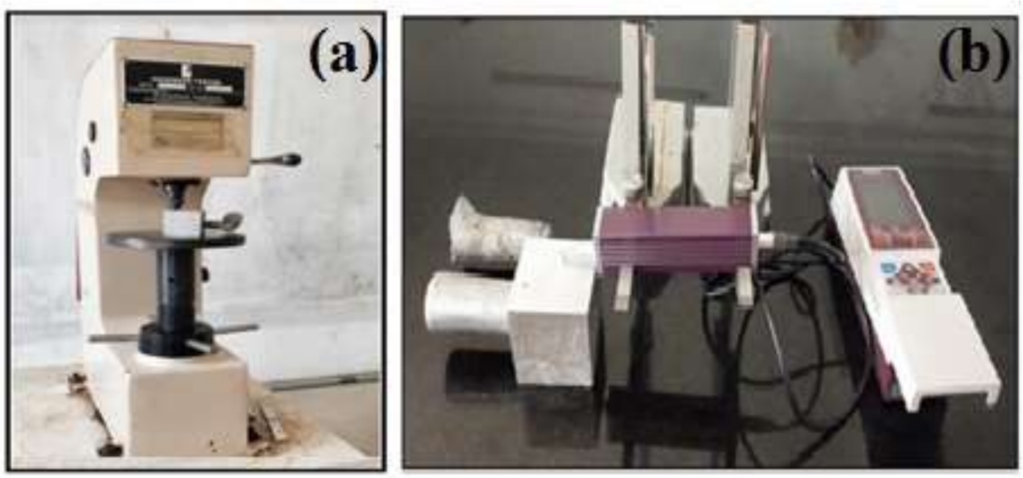

Figure 3. (a) Brinell hardness test machine (b) Surface roughness tester

Modelling of ANN:

The design of expert recommended seventeen sets of experiments on the basis of three factorial designs. The detailed design layout for these experiments is given in the Table 2. It shows various sand compositions such as moisture content, clay content and SiO_2.

Table 2. Design layouts for sand parameters

Run	Moisture Content (%)	Clay Content(%)	SiO_2 Content (%)
1	8	5	6
2	6	4	6
3	8	5	9
4	6	5	3
5	7	5	9
6	7	5	9
7	7	5	9
8	7	5	6
9	7	4	3
10	7	6	9

11	7	4	9
12	7	6	3
13	6	5	6
14	8	5	6
15	7	6	9
16	8	6	3
17	7	6	3

RESULTS AND DISCUSSION

The input parameters of and output responses are conducted experimental work and it is mentioned Table 3. The output responses of hardness and surface roughness are varied with various input parameters levels. From this technique, the best parameters of the sand preparation are identified. The best optimization techniques of RSM are selected for this investigation. The experimental analysis is on the composition of the moisture content, clay content, SiO_2, hardness and surface roughness. This experimentation is carried out for seventeen sets and also suitable riser was implemented as shown in Table 3.

Table 3. Experiment runs for aluminium of various input and output responses

Run	**Moisture Content (%)**	**Clay Content (%)**	**SiO_2 Content (%)**	**Hardness (BHN)**	**Surface Roughness (Microns)**
1	8	4	6	79	2.133
2	7	5	6	74	2.477
3	8	6	9	81	2.199
4	7	5	3	75	2.586
5	7	4	9	89	2.022
6	7	6	9	87	2.099
7	7	5	9	84	2.086
8	7	5	6	84	2.466
9	8	5	3	83	2.244
10	7	5	9	87	2.086

11	7	6	9	85	2.155
12	6	5	3	67	2.466
13	6	6	6	68	2.466
14	7	4	6	81	2.187
15	8	5	9	89	2.053
16	6	5	3	69	2.577
17	6	4	3	69	2.353

The lowest percentage of SiO_2 in sand parameter is achieved 67BHN hardness and 2.466 micron surface roughness. The highest thermal insulator of SiO_2 content is in cope box only. It is clear that the heat transfer rate of drag box is better than the cope box. The highest percentage of SiO_2 in sand parameters are achieved good hardness and low surface roughness. The SiO_2 content plays an important role in determining the properties of green sand. For this investigation, the input parameters are moisture content, clay content and SiO_2 and the selected output results are hardness and surface roughness applied in ANN techniques. The three dimensional structure of ANN consists of 3 input layers, 4 hidden layers and 2 output layers as shown in Figure 4.

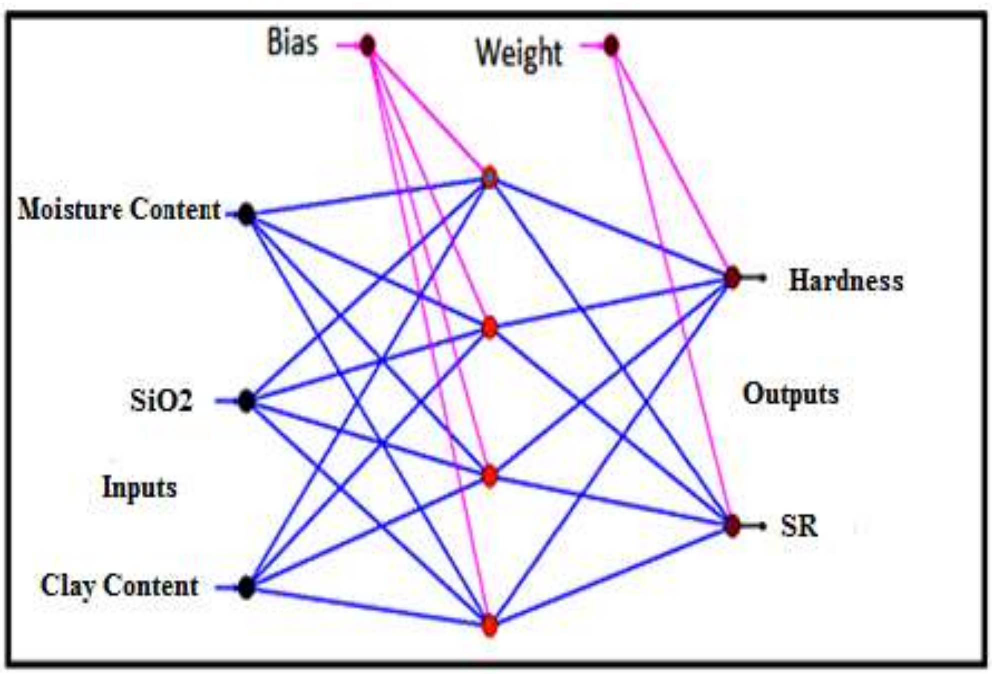

Figure 4. Architecture of ANN for sand parameters

The curve fitting for the hardness and surface roughness of aluminum can be acknowledged as shown in Figure 5. The achieved R value for hardness is 0.988 and the achieved R value for the surface roughness is 0.993 respectively.

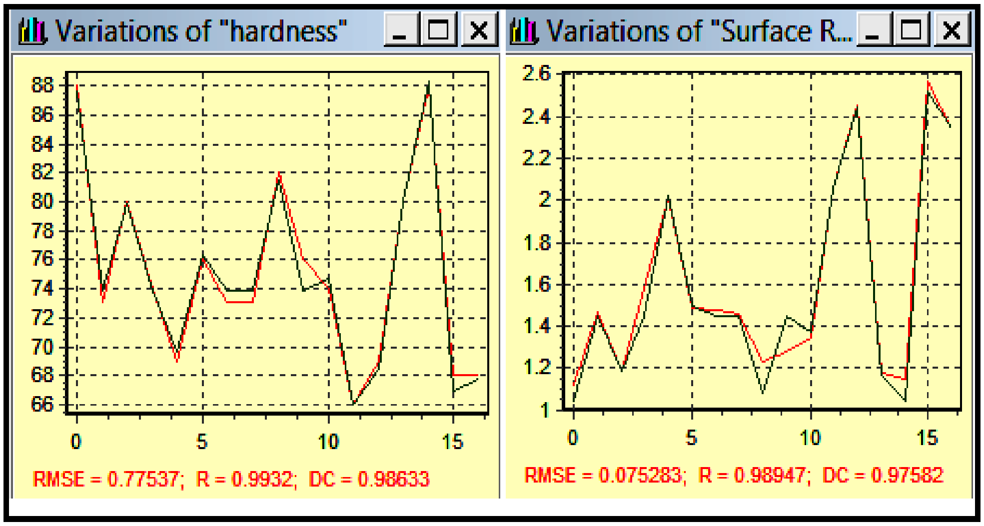

Figure 5. Curve fitting of hardness and Surface roughness for Aluminum

The Figure 6 shows the outcome of moisture content and SiO_2 on hardness and surface roughness of aluminum . In the commencement, the hardness is extremely small percentage of moisture content is 6-7 %. The hardness is improved with respect to boost in moisture content and increase in SiO_2. In surface roughness, it is low percentage of moisture content 7.5% . the surface roughness gets varation in moisture content.

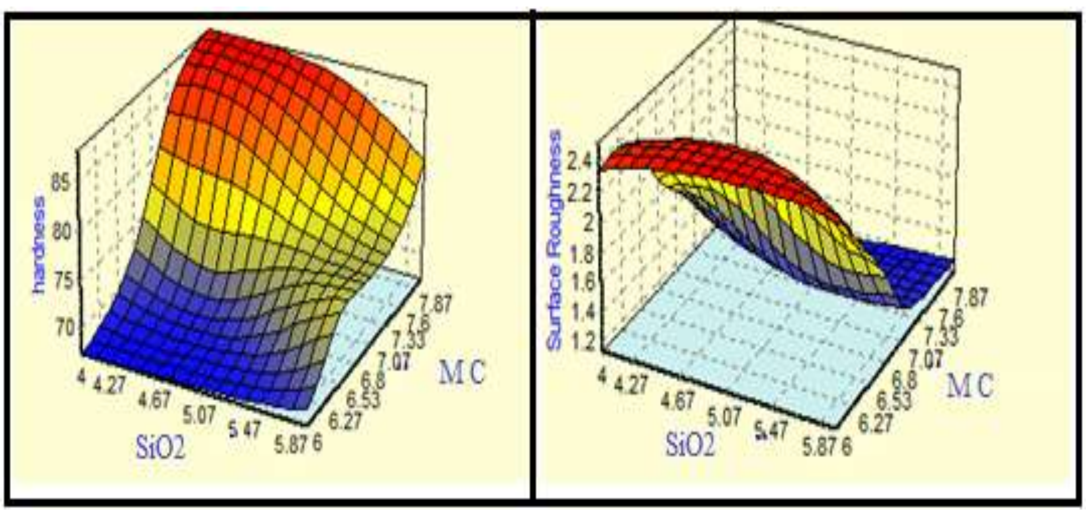

Figure 6. Result of moisture content and SiO_2 on hardness and surface roughness of Aluminum

The optimum green sand parameters of hardness and surface roughness are shown in Table 4. The result of ANN shows that the maximum SiO_2 content should be in 9.2 % and the moisture content should be in 7.8%. The optimum results of sand parameters are applied in cope box and analyzed best geometry of the riser by ANSYS simulation software. The best result of riser geometry is conducted experimental work.

Table 4. Optimum Results of Sand Parameters for Hardness and Surface Roughness of Aluminum

S.No	Name of the material	Moisture Content (%)	Clay Content (%)	SiO_2 Content (%)	Hardness (BHN)	Surface Roughness (Micron)
1	Aluminum	7.9	4.2	9.2	95	1.821

The various sand parameters of aluminum for RSM, ANN and best riser geometry are compared. The various methods of RSM, ANN hardness which are increases given in Figure 7(a). The other properties of Surface roughness are calculated from RSM, ANN and as shown in Figure 7(b). It is clear that the roughness values are gradually decreased from 2.022 micron to 1.756 micron based on the hardness.

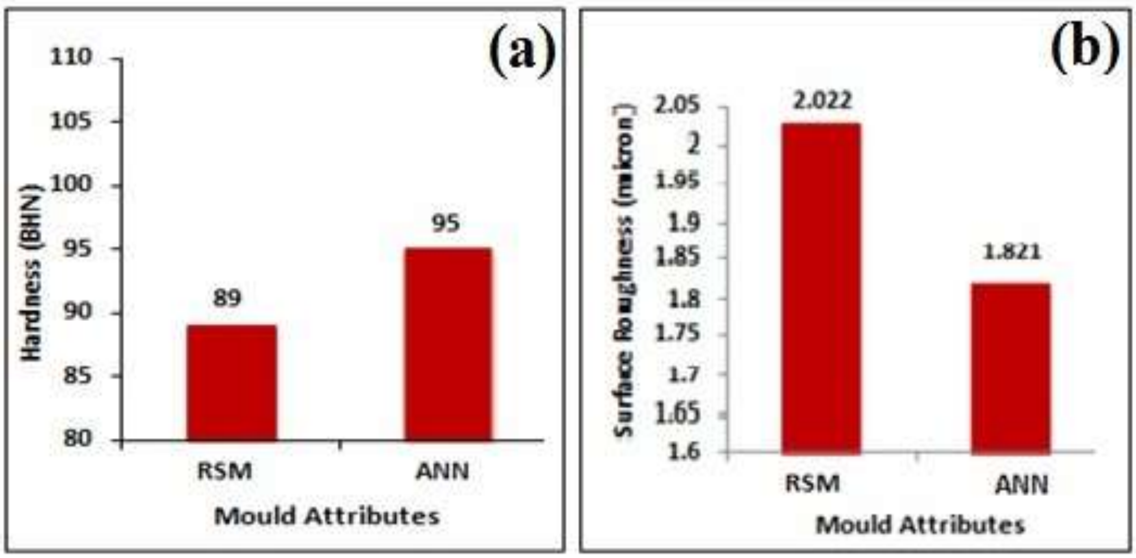

Figure 7. Comparison Results of (a) Hardness (b) Surface Roughness for Aluminum

CONCLUSION

Green sand is a very important role of heat transfer from the mould cavity and the riser zone in sand casting process. The various combinations of SiO_2 with green sand were experimentally investigated. The results of Taguchi orthogonal array, RSM and the nontraditional techniques of ANN were analyzed. These methods were used to reduce the cost and time of experiments. The conclusion are derived based on the results and follows

1. It is strongly recommended by the blending of 9.2% SiO_2 with green sand is very suitable for this casting process.
2. The effect of SiO_2 blending with green sand, the initial raw material is reduced up to 25% of volume without casting defects.
3. The hardness value increased up to 22% and the surface roughness decreased up to 12% by varying the percentage of SiO_2 in green sand.
4. The predicting competence and the accuracy create ANN analytically more practicable tool for foundry industry applications.
5. By mixing of SiO_2 with green sand, the riser volume is reduced up to 32% from raw material.

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