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Impact of the Moulding Parameters on Flowability of Bentonite-Bonded-Green Sand Mould

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Abstract

Compactability of the green sand, water content, and parameters of the moulding machine of the pressing speed, and compaction force have an influence on the sand moulding process. These parameters of the moulding machine and moulding material were examined to determine the appropriate factors to make bentonite-bonded green sand mould have a good flowability around the pattern. In the current work, flowability of the green sand was measured based on non-destructive flowability test using a new sand motion detection sensor flowability measurement during the pressing process of the green sand supports finding the optimal compaction time without wasting of the consumed energy for the compaction process. The results obtained of time-dependent-flowability shows that 26% compactability, and 4.17% water content gives highest flowability during compaction of the green sand by using 36 mm/s of the pressing speed. It was found that flowability of the green sand increases as a result of increasing of speed of the pressing machine.

Keywords: Green sand, Moulding material, Moulding machine, Time-dependent-flowability, Sand moulding

1. Introduction

Green sand refers to moulds made and filled with sand simply tempered with water [1]. Green sand mould is widely used because of availability of the sand on the Earth's crust and from another hand; the sand mould can be repeated used for moulding other patterns. Foundry sand is used for ferrous and nonferrous metal castings [2]. Bentonite is another type of binding material, which is added in a suitable amount to improve the strength of the sand mould [3]. The sand required for moulding process should have flowability around the pattern, and it must be deformed plastically without failure, so that the pattern can be easily separate [4]. Flowability allows green sand to fill the narrow cavities between the flask and pattern when compressed. Flowability is a necessary property to exceed the friction exists between model and sand [5]. Flowability is affected by sand grain size, bentonite and water content [6], as well as mixing process, uniform distribution of mixed green sand gives high flowability [7]. Flowability properties of green sand were investigated by many researchers over the years. Dietert, Hofmann [8, 9], Moore [10], Fisher [11], Kennedy [12], Vanier, Kyle, Buchanans [13, 14, 15], Orlov [16], Levelink [17], and Wiliiam [18] have introduced methods for measuring flowability of the green sand. These methods measure flowability of green sand based on the hardness ratio of the bottom level to hardness of the upper level, ratio of the extruded mass to the total mass, or ratio of the sample height reduction to the original height. Mais et.al [19] measured flowability of the green sand using TNO and Orlov methods. They found that there is less variation in flowability occurs at high levels of compactability and vice versa. The present new test of flowability method of the green sand takes into account variation of the sand density that usually occurs during the moulding process. Flowability measurement by this non-destructive method can be used for measuring flowability during compaction of the green sand over the complex pattern. Moulding machine parameters of pressing speed, and compaction force as well as moulding materials parameters of compactability, water content were investigated.

2. Methodology

The moulding sand used in this investigation is natural sand, and sand grain size distribution was listed in table 1. The constituents of sand, 8% bentonite and water are mixed together by an LM-2e type mixing machine.

Table. 1.
Distribution of Grain size of natural sand [20]

Mesh (mm)	0.315	0.2	0.16	0.125	0.1	0.08	0.063	0.063
(Residue / sieve) (g)	0.60	0.8	1.2	2.2	8.6	29.2	26.4	12

The prepared green sand is subjected to various tests to measure compactability, water content. Afterwards, flowability of the green sand is measured with a new flowability sensor. Hofmann method [9] was used to measure compactability of the prepared green sand. During this method, the tube test with 50mm diameter, and 100mm height is filled with the green sand, and subjected into 1Mpa pressure. Value of the measured reduced length represents the compactability percentage. Water content test involves weighting about 45g of green sand, then putting it into the evaporator. Percentage of water content that appears on the screen equipped with the evaporator is recorded.

3. Flowability measurement of the green sand

Flowability and other features [21], of green moulding sand were measured basis of a new sand motion detection sensor developed by Bast [22]. The sensor is installed in the graded pattern, tube test 140 mm high, and 80 mm diameter is placed on the stepped pattern, and filled with bentonite-bonded green sand. The sand is subjected to pressure through the pressing machine, and movement of the sand presses the sensor probe down and gives signals to the computer [20]. Wireless system is integrated into the flowability sensor for remote sand flowability measurement [23]. In this work, effect of water content, pressing speed, compactability, and compaction pressure on flowability of the bentonite-bonded green sand was investigated based on the sensor readings of a new flowability sensor. The Pressing machine has a maximum pressing speed of 36 mm/sec, and a maximum pressure of 0.4 MPa has been used to prepare sand samples to measure flowability through flowability sensor. Labview software was used to control movement of piston of the pressing machine, and the software is connected between flowability sensor and the pressing machine across an interface as shown in figure 1. The interface has another function, which is to obtain data from the sensors and sent it to the computer. Parameters of compaction process were regulated using Labview software by setting 7 seconds of compaction time, and 6 bar of air pressure.

Fig. 1. An interface connects a computer, pressing machine and sensor

Four experimental series were adopted to investigate the impact of different factors on flowability of the green sand mould. The first experimental series was used to examine the effect of the compactability ratio (26% and 50%) on the variance of the sensor readings, as shown in figures 2 and 3 respectively, where s_o, s_u are measurement values of the upper sensor, and the bottom sensor respectively. The sensor readings increase with the pressing time until the readings reach a constant value, the differences Δs between the sensor readings s_o and s_u give an idea of flowability of the green sand. It was found that the difference in the sensor readings for the examined sand samples containing 26% compactability are less than the difference in the sensor readings for the examined sand samples containing 50% compactability. This means that flowability of green sand sample with compactability of 26% is higher than that green sand sample with compactability of 50%. Observing behavior of the green sand through this non-destructive technique helps the foundry men to evaluate the moulding process.

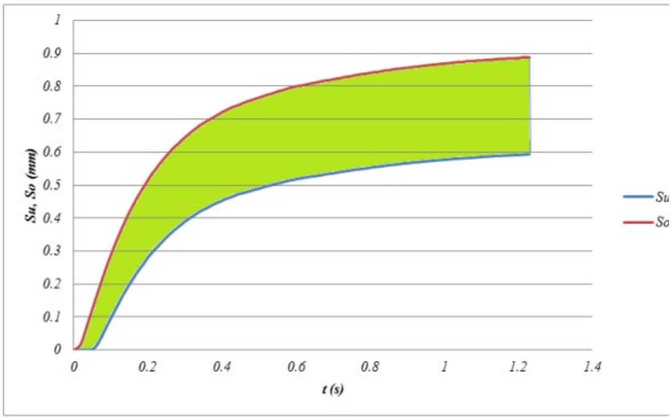

Fig. 2. Variation of the sensor signals for 26% Compactability of the sand sample

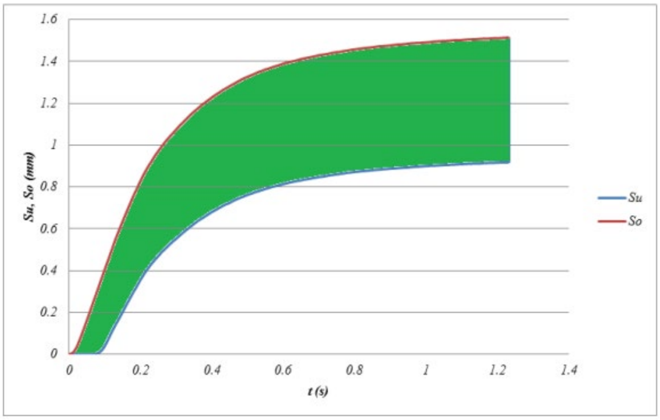

Fig. 3. Variation of the sensor signals for 50% Compactability of the sand sample

Several mathematical relationships have been developed to calculate flowability of green sand depending on the sensor readings. In the current work, flowability was calculated by the first developed equation which is based on the ratio of the sensor signal on the bottom level S_u of the stepped pattern to the sensor signal of the upper level S_o [20].

The second experimental series was used to study the impact of varying water content on flowability of green sand. Figure 4 shows the effect of various moisture contents on the flowability of green sand at a pressing speed of 36 mm/s, giving flowability of 68.25%, 53.88%, and 47.47% for the green sand with water content of 4.17%, 4.67%, and 4.81% respectively.

The third experimental series was used to evaluate the effect of different pressing speeds (17 mm/s, 23 mm/s, and 32 mm/s) on the flowability of green sand. The flowability of green sand increases as a result of increasing speed of the pressing machine, where the highest flowability of 60.27% was found for green sand with a compactability of 26% and a pressing speed of 32mm/sec, as shown in figure 5.

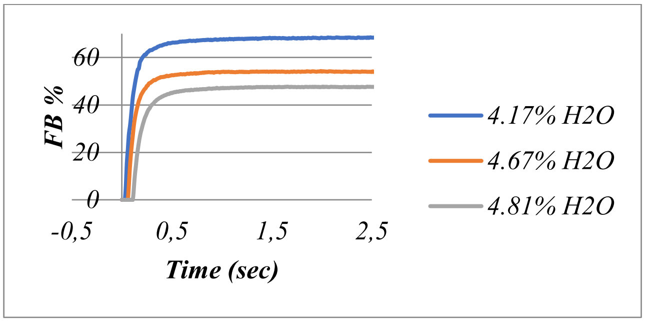

Fig. 4. Flowability percentage VS compaction time @ 36 mm/sec

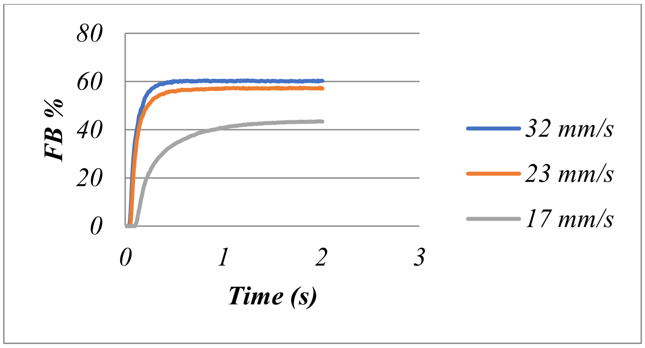

Fig. 5. Flowability percentage VS compaction time @ 26 % compactability

The fourth experimental series was used to predict the effect of two factors, compactability and compaction pressure, on the flowability of green sand simultaneously, each of these factors have three levels, the variables and their levels were listed in table 2. Design of experiments through multi-level factorial design, and the final responses of the flowability sensor were listed in table 3. Comparison of effect of the compaction pressure and compactability on the final values of flowability of the green sand is shown in figure 6. The obtained result of these experiments indicates that high compaction pressure 0.4MPa and low compactability 35% gives highest flowability of the green sand. Increase either pressing force or pressing speed or both of these parameters contributes to overcome the cohesive forces that exist between the sand particles, and the adhesive forces between the sand sample and the tube test. Exceeds of these cohesion forces and adhesion forces support flowability of green sand around the pattern. Decrease a flowability is related into behaviour of sand which become more viscous as a result of increase water content.

Variation of sand density during compaction process is connected with existing of internal friction between the sand particles, as well as the external friction between the green sand sample and the internal wall of the tube test and piston of the pressing machine. The new test measures flowability of green sand as a function of compaction time dynamically, where variation of sand density takes in to account.

Table. 2.
Variables and its levels

Factors		Compactability	Compaction Pressure
Symbol		*Co*	*P*
Units		%	*MPa*
Levels	Main level _ (0)	40	0.3
	Higher level_(+1)	45	0.4
	Lower level (-1)	35	0.2
Interval		5	0.1

Table. 3.
Design of experiments during compaction of the green sand

Number of experiments	Variables		Final Response by sensor	
	Co %	*P (MPa)*	S_u *(mm)*	S_o *(mm)*
1	-1	-1	0.469	0.930
2	0	-1	0.420	0.946
3	+1	-1	0.376	1.032
4	-1	0	0.584	1.037
5	0	0	0.637	1.201
6	+1	0	0.767	1.668
7	-1	+1	0.819	1.118
8	0	+1	0.817	1.326
9	+1	+1	0.834	1.547

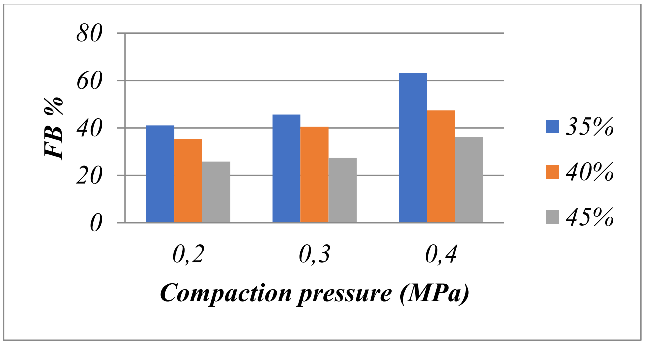

Fig. 6. Final values of flowability % VS compaction pressure

4. Conclusions

Time-dependent-flowability test of the green sand measured by this new technique is a dynamic non-destructive test. Online determining of flowability of the green sand enhance predicts the right moulding parameters for sand making process. Live surveillance of the moulding process contributes in reduce of compaction time and saves energy to get sand mould has good profile of the pattern.

The smallest value of flowability 45.48% was obtained during compaction of the green sand which had 50% compactability by using 32mm/sec of the pressing speed. Decrease a flowability is related into behaviour of sand which become more viscous as a result of increase water content. The final results of the flowability measured by a multi-level factorial design of experiments show that maximum value of the pressing force compaction pressure of 0.4MPa gives highest flowability of the green sand having 35% compactability. Increasing the pressing force or the pressing speed or these two parameters contribute to in improve flowability of green sand.

Conflict of interest

The author states that there is no conflict of interest.

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