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Preparation and experiments for a novel kind of foundry core binder made from modified potato starch

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ABSTRACT

In order to be used as an alternative binder of sand core in foundry, a liquid water-soluble modified starch binder (WMSB) was developed. Laboratory testing results showed that the dry strength of WMSB core sand could reach 2.0 MPa and be controlled by the additions of WMSB and bentonite. Moisture absorption character, gas forming property and breakdown capacity of WMSB core sand were proved to be acceptable by comparison tests with some common core binders. Batch production experiments of WMSB were conducted to make sand cores of various castings and testified that the utilization of WMSB was feasible and valuable in foundry application.

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1. Introduction

In foundry practice, sand cores are most extensively used to form various complicated cavities of castings corresponding for a great amount of resource consumption and a considerable production costs. A feasible core binder is the key to obtain optimal sand cores with high strength and desired performance, so that it has top effects on production technology and manufacturing cost of castings [1,2]. Presently, there are several kinds of foundry core binders extensively used as follow: clay, core oil, water glass and synthetic resin, etc. Any of them has its advantages and disadvantages. Clay is cheap, facile and convenient for core preparation, but it is mainly applied in making sand moulds and seldom used in making cores due to its low adhering strength; Core oils and synthetic resins have high strength and good moisture resistance, but their expensive cost, high gas forming property and non-recycling feature restrict their widespread application; In despite of the superiorities in strength and cost, water glass is still limited for making sand cores due to its unsolved undesirable breakdown capacity and difficulty for reuse. Therefore, producers and researchers pay great attention all the while to select and develop optimum binders which can correspond well with various demanded properties of sand cores. In recent yeas, natural water-soluble organic foundry binders were developed rapidly for their particular superiorities of performance and low cost, as well as renewable resource and less environmental pollution [3–7]. Nevertheless, there are few reports about the successful application of water-soluble organic foundry binders in production thus far.

Starch is made from corn, especially maize and potato, which can be used as a kind of natural water-soluble organic binders with the superiorities of extensive resource and regeneration. However, without modification, starch can not be applied in foundry as main binder of cores due to the low strength in both solid and liquid states [8]. Dextrin which is made of starch has much higher strength to use in foundry coats, but it has not been used in making sand cores because of the high moisture absorption and severe mold adhesiveness.

For the purpose of developing a new core binder, we considered to exploit potato starch which is abundant and cheap as the main adhering component of a new core binder. In the present work, the preparation process, technological experiments and batch application for a water-soluble modified starch binder (WMSB) was performed and reported.

2. Experimental

2.1. Preparation

WMSB was prepared under following technologic procedure. First, an adequate amount of formaldehyde and phosphoric acid was mixed with water by stirring, and then urea and polyethylene alcohol solution with 10 wt% was added in and dissolved uniformly at the ambient temperature. Secondly, the solution was heated to 60–80 °C and the potato starch was added gradually with continuous stirring to avoid aggregation, then the temperature was kept at 80 °C and the solution was held to be stirred for 20–40 min to dissolve the starch sufficiently. Finally, the PH value was examined and adjusted with 1% NaOH solution to about 7.0. The optimal applying ingredient of the binder is shown in Table 1.

The modifying principle of WMSB is probably that acidic hydrolyzation occurs in potato starch at the definite temperature in the test condition. Some acid reacts with starch on the surface of starch grains, the additives, such as formaldehyde, urea and polyethylene alcohol, was combined with starch or causes the grains break down and connect again [9,10]. So cohesion of the starch binder was strengthened and its moisture absorption resistance was improved.

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Table 1
Components and ingredient of WMSB (wt%)

Components	Potato starch	Formaldehyde	Phosphoric acid	Polyvinyl alcohol	Urea	Water
Content	28–30	1	0.1	2	1	Balance

Table 2
Physical properties of WMSB

Color	Specific density (g/cm^3)	Viscidity ($N\ s/m^2$)	PH value	Content of solid (wt%)	Odor
Lucidity	1.15–1.2	1.52	7.0	29–31	Slight

Table 3
Ingredients of technological experiments of WMSB core sands (wt%)

Test no.	Bentonite	Binder	Water	Base sand
1	2	4	1	Balance
2	2	5	0	Balance
3	2	6	0	Balance
4	2	7	0	Balance
5	3	5	1	Balance
6	3	6	0	Balance
7	3	7	0	Balance

The physical properties of WMSB were measured and shown in Table 2. There appeared no undesired phenomena such as mildew, ferment or reduction in adhesive strength during storage in summer for 3 months.

2.2. Technological experimental

The aim of technological experiments is to examine the main service performance and to investigate specific characteristics of the core sands adhered by WMSB. The raw materials used in technological experiments are essential silica sand (particle size 0.1–0.25 mm), natural calcium base bentonite, water and WMSB prepared up front. The controlling parameters include the additions of WMSB, bentonite and water. Core sands were blended in a SHN-5 type sand miller according to the ingredients of testing scheme given in Table 3. The examination items contain dry-tensile strength (dry strength), wet-compress strength (green strength), moisture content and moisture absorption character, gas forming property and breakdown capacity of the WMSB bonded core sand.

The dogbone specimens for tensile test and the cylindrical specimens for pressure test were prepared after milling, and then the dogbone specimens were baked for 1 h at 150 °C to remove the moisture. The dry-tensile strength and wet-compress strength examination was performed by using a SQY hydraulic testing machine with a measurement error about 5%. All data for strengths were tested five times and the average was used in the study. Moisture absorption character and breakdown capacity of core sands was examined by comparison with other common binder core sands on the same conditions. Gas forming property was measured by using a SFL type mould materials gas forming measuring apparatus with a measurement error about 2%. Breakdown capacity was determined by testing the pressure strength of samples which had been held at designated temperatures for 4 h in a box type electric furnace [11,12].

3. Results and discussion

3.1. Experimental results

3.1.1. Dry-tensile strength and wet-pressure strength

Fig. 1 shows the testing results of dry-tensile strengths and wet-pressure strengths of WMSB bonded core sands in technological experiments. It is apparent that the dry-tensile strengths increase with the increasing contents of WMSB and decreased with the increasing contents of bentonite. Wet-pressure strengths increase with the increasing contents of bentonite and show an optimum WMSB addition corresponding to any definite content of betonite, as shown in Fig. 2. To obtain adequate wet-pressure strength, the moisture of core sands should be kept between 3.5% and 4.5% and correspond to an optimal binder content with constant bentonite. In case of selected binder content, since wet-pressure strength increase and dry-tensile strength decrease with the increase of bentonite additions, it is necessary to choose appropriate content of bentonite in core sands to ensure high synthetically properties.

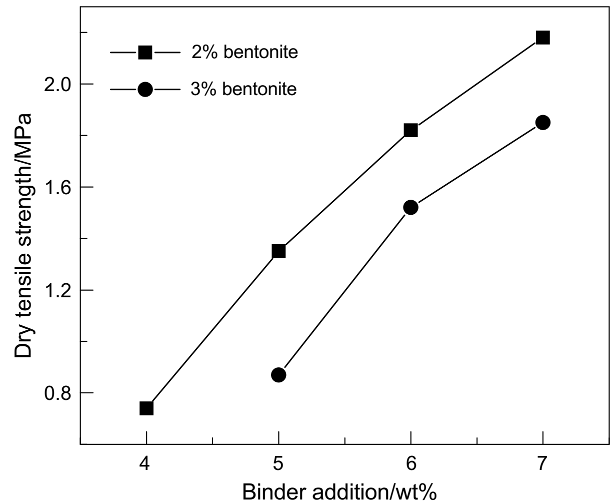

Fig. 1. Effects of binder content on the dry-tensile strength of the core sands.

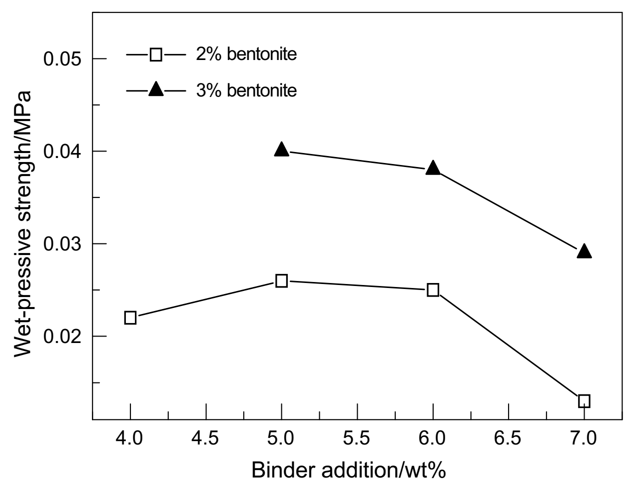

Fig. 2. Effects of binder content on the wet-pressure strength of the core sands.

3.1.2. Moisture absorption character

The moisture absorption tests of WMSB core sands were conducted by using contrastive method with some common foundry binders including core oil, water glass hardened by baking and by carbon dioxide, cold-setting furan resin, clay and dextrin. The dogbone specimens of investigated core sands were baked to remove moisture thoroughly and weighed exactly with an electronic balance, then part samples were placed in a closed container with saturate humidity holding for 2 and 8 h, respectively, the others were exposed under natural humidity for 1, 2 and 3 days. Then the tested samples were weighed again and calculated their moistures which denoted the respective moisture absorption contents at saturate humidity and under natural humidity, respectively. The experimental results are shown in Fig. 3. The moisture absorption contents of WMSB core sands in both two testing conditions are lower than that of all water glass sands, clay sand and dextrin sand, close to the level of core oil sand and furan resin self-hardening sand. It is suggested that WMSB core sand has substantially acceptable moisture absorption resistance.

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