ARCHIVES
of
FOUNDRY ENGINEERING

ISSN (1897-3310)
Volume 11
Issue 1/2011

5 – 8

1/1

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

Efficiency of additives of the polysaccharide type on physical properties of bentonite mixtures

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Received 16.02.2011; accepted in revised form 11.03.2011

Abstract

The addition of polysaccharide additives generally aims at improving some important physical properties of bentonite mixtures, above all the stability of moulds against the water loss and prevention of surface defects of castings. Polysaccharide products of inland and foreign production were checked in mixtures of two bentonites of the Czech provenance with the same montmorillonite content. The attention was paid in particular to the abrasion resistance of mixtures during storing them under constant climatic conditions.Conclusions have shown the substantial influence of: the amount of the added additive, the kind and structural composition of the additive (pH of the water extract, electric conductance).

Keywords: Product development; Green sand system; Dextrin; Additives

1. Introduction

In spite of intensive research and considerable progress in manufacture of moulds and cores the technology of bentonite moulding mixtures continues to be a dominant one for manufacturing them (e.g. more than 70 % of castings from graphitizing ferrous alloys) [1]. Generally, for improving the chosen physical-chemical properties different additions are added in mixtures as follows: carriers of pyrolysis carbon (PC), iron oxides, additives of a polysaccharide type (starches, saccharides, dextrins) with the aim of reducing the casting defects (penetrations, veining), improving the mixture flowing property, reducing the mixture erosion, improving the mechanical properties of mixtures etc. [2] – [5].

An independent question is development of polysaccharide based mixtures for core making (e.g. the starch-clay-dextrin system) that have technological properties comparable with commonly used core binders but they have better collapsibility after casting (sodium silicate) and they are more friendly to living environment (organic resins) [5] – [9].

In spite of a fact that the additives of the polysaccharide type are used for more than 40 years there doesn't exist unambiguous opinion on their effect. Individual authors are agreeing about positive effect of polysaccharide addition from the point of view of surface quality of castings [3]. Brümmer [12] in his extensive study compares the influence of polysaccharide type additives on chosen properties of bentonite moulding mixture. He compares the influence of starches and highly polymeric sugars with dextrins and low polymeric sugars and with swelling powders. All three types of additives with different solubility in water or hygroscopicity have positive influence on "staling" of mixtures, they increase the mixture resistance against rat tails and they are ecologic. In addition to it the dextrin and powders positively influence the stability of mould edges and they improve the wear resistance.

Dextrins (fig. 1.) have similar structure as starch (high-molecular polymer D-glucose) in which the monomeric units are connected with α(1 → 4) glycoside bonds in linear chains and branching is ensured by α(1 → 6) glycoside bonds. Based on a number of structural glucose units dextrins can be classed in oligosaccharides and/or polysaccharides. They are formed by starch splitting inside the chain, most frequently by α-amylase enzyme. Dextrins are industrially made by acidolysis or by high temperature effect (roasting, up to 220 °C). In dependence on the manufacturing method and the kind of initial starch the dextrins with diametrically opposite properties can be obtained (hydroscopicity, viscosity, stability, gelation, solubility, pH etc.).

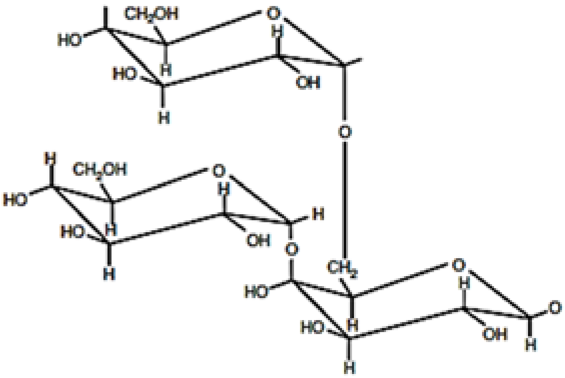

Fig. 1. Schematic depicting of the dextrin molecule [17]

Industrially made dextrins are divided to white ones and yellow ones; the white ones are less degraded, they have lower solubility; yellow dextrins have usually almost hundred-per-cent solubility [13] [16].

This contribution is aimed at evaluating the influence of the presence of different dextrins in bentonite moulding mixtures. Polysaccharide additives applicable in Czech foundries were chosen as model dextrins. Concentration interface was chosen based on experience from operating conditions of foundry production, and namely the addition of 0, 1, 2 weight % in the mixture.

2. Materials and methods

The addition of dextrin was studied in bentonite moulding mixture formed by quartz base sand of Šajdíkovy Humence Š 35 ŠH (d_{50} = 0.37 mm) and 8 weight parts of nitrified bentonite Keribent R (joint-stock company of Keramost, a.s.). It is a selectively mined mixture of bentonites from the North Bohemian and the Middle Slovakia regions with montmorillonite content of 67.57 % [18] and with ion-exchange capacity (CEC) of 66.87 mmol/100 g. The pH value of the bentonite suspension (1:10 – bentonite:water) was 10.16 and electric conductance of the given suspension was 675 μS/cm (WTW Inolab pH/Cond level 1).

Following dextrins are evaluated in the work:

„DB“ – yellow dextrin obtained by roasting of wheat starch

„DT“ – yellow dextrin from potato starch prepared by thermic splitting with polymerisation mean of 140 – 170 glucose units

„DN“ – the mixture of bentonite (>60.0 %) and starch (<40.0 %)

„DL1“ – yellow dextrin of high solubility obtained by continual preparation by roasting of potato starch and by effecting with strong acids

„DL2“ – yellow dextrin of high solubility obtained by continual preparation by roasting of wheat starch and by effecting with strong acids

„DL3“ – yellow dextrin of high solubility obtained by continual preparation by roasting of potato starch and by effecting with strong acids

3. Experimental results and discussion

3.1. Generally characterization of dextrines

Basic parameters of dextrins were determined in water suspension (1:10 ratio). Moisture was determined according to the CSN 44 1377 standard (under temperature of 105 ºC up to constant weight).

Moisture of bentonite moulding mixture was controlled according to compactibility (42 ± 1 %). The mixture was prepared on a MK 00 sand mill with mixing time of 5 min. after addition of forming water. Having achieved the required compactibility the mixture was hermetically enclosed for 2 h. for the purpose of moisture stabilization and properties of moulding mixture connected with it. Basic mechanical properties of moulding mixture were measured on standard cylinders Ø 50 x 50mm (green compression strength, splitting strength on equipment of the firm WADAP the LRU-1 type, tensile strength in water condensation zone +GF+, the SPNF type, compactibility), moisture and wear (loss in weight after 1 min/infra-red lamp) in time dependence of 0 – 2 h. in defined conditions (RV = 48 – 60 %, T = 20 – 24 °C) for the purpose of studying the mixture behaviour in real conditions on a moulding line. Influence of the dextrin presence in the mixture on collapsibility of bentonite mixtures or inclination to formation of lumps was simulated by measuring of secondary compression strength after thermal exposure (300 °C/1 h.) on cold samples. Temperature under which the secondary strength was determined resulted from preceding measurements of temperature field when it was determined that majority of the mould volume is heated just to this temperature.

Staling of the mixture was determined under increased temperature (160 °C) with drying ratio of 0.02 %/min.

Basic parameters of studied dextrins are summarized in tab. 1. Natural moisture of raw materials ranged in a wide interval of 0.67 – 8.65 % („DN“). This maximum is probably given by the additive composition (the bentonite – dextrin mixture). Similar behaviour was observed also during determination of pH (2.81 – 10.15) and electric conductance (89.1 – 622.0 μS/cm).

The pH value of the bentonite moulding mixture has a considerable influence on its physical (technological) properties. Generally it should range in the basic region (usually pH 9 – 10).

For that reason the strongly acid pH of all dextrins is startling, with the exception of the „DN“ additive, which with higher concentrations in the mixture can considerably decreased its technological properties. Low pH is probably given by the manufacturing process of dextrins (acid hydrolytic splitting of starch).

3.2. Physico – chemistry properties of foundry mixture with studied dextrines

In spite of the fact that the individual mixtures during their stabilization were hermetically enclosed the collapsibility considerably dropped (by 7 – 15 %) and the mixture moisture slightly too (0.16 – 0.37 %).

A probable cause of it is the presence of dextrin which decreases the amount of forming water for bentonite.

Table 1
General characterization of dextrines

Dextrin	Moisture [%]	pH	Conductivity [µS/cm]
DB	6,17	2,93	531
DT	4,29	2,81	523
DN	8,65	10,15	89,1
DL1	0,67	3,1	517
DL2	4,69	3,32	622
DL3	1,55	3,15	144,7

The mixture with bentonite only (with 0 % of dextrin) is indicated as a standard. During the experiment also the dextrin concentration was modified for the reason of considerable decrease of mixture strength (e.g. decrease of compression strength by 56 % in comparison with standard one) and the growth of its plasticity (during the strength tests the „barrels“ were formed); therefore the addition of 2 % of dextrin wasn’t further on studied.

Technological properties of moulding mixtures with addition of polysaccharide additives are depicted in fig. 2. The presence of dextrin in the moulding mixture influenced the decrease of compression strength (from 142 kPa for the standard down to 87.5 kPa for the „DL3“) and also of splitting strength (standard: 36.8 kPa, „DL3“: 23.7 kPa). In the case of strength test in water condensation zone the growth of strength (3.7 – 4.6 kPa) was observed for all dextrins with the exception of „DL2“ (3.4 kPa) in comparison with the standard (3.5 kPa) and with maximum for „DL1“. The presence of dextrin additives in the mixture was shown up also in the growth of toughness (ration of splitting strength and compression strength in %) which is a measure of mixture plasticity. Toughness of moulding mixture without dextrin was 25 %. „DN“ dextrin (23 %) was an exception, toughness of remaining mixtures ranged within 25 – 32 % („DT“).

If the residual compression strength is considered a measure of bentonite mixture collapsibility, then the addition of most dextrins has positive influence on the mixture collapsibility (tab. 2.). Their effect is in decreasing the residual strength under higher temperature, maximum is achieved for „DN“ and „DT“ dextrins. Loss of mixture moisture in natural conditions is a cause of increased mixture erosion

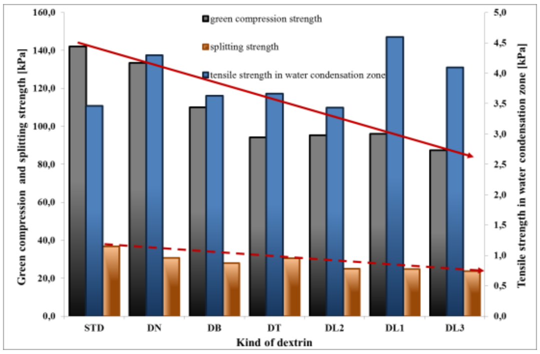

Fig. 2. Technological properties of foundry mixtures

Determination of loss of mixture moisture (under 160 °C) has shown that the mixtures with greatest inclination to staling are that ones with „DL3“, „DL1“ and „DT“ dextrins. An opposite conspicuous effect has the „DN“ dextrin; resulting moisture by ca. 0.4 % lower was determined for this mixture. The main aim of this contribution is to consolidate the opinion on the influence of dextrins presence in moulding mixture on wear resistance of the mould (stability of edges etc.). From the point of view of mixture wear resistance the dextrins have different effect. The standard cylinder samples were stored in defined laboratory conditions for such time that would simulate the placing of moulds on a line before the proper casting.

It is evident from figs. 3. and 4. that theoretical assumptions were met when the mixture wear was decreased immediately. Namely the loss of mixture (in %) ranged from 0.5 % (DN) up to 4.4 % (DB). When storing for a longer time (above 1 h.) the mixture behaviour was different. The loss of mixture with „DN“ and dextrins of the „DL“ series was higher than the standard one (without dextrin) and this difference increased with storing time increase. Maximum growth was observed in the case of „DN“ dextrin when after storing for two hours the growth of moulding mixture wear was 2.9 %.

Table 2.
Collapsibility of moulding mixture with chosen dextrins

	STD	DN	DB	DT	DL1	DL2	DL3
1 - green compression strength [kPa]	142,1	133,5	110,2	94,4	95,4	94,2	87,5
2 – residual compression strength (300°C) [kPa]	122,3	183,2	106,5	137,9	74,4	103	99,2
(1-2) [kPa]	19,8	-49,7	3,7	-43,5	21	-8,8	-11,7
(1-2) [%]	13,9	-37,2	3,4	-46,1	22,0	-9,3	-13,4

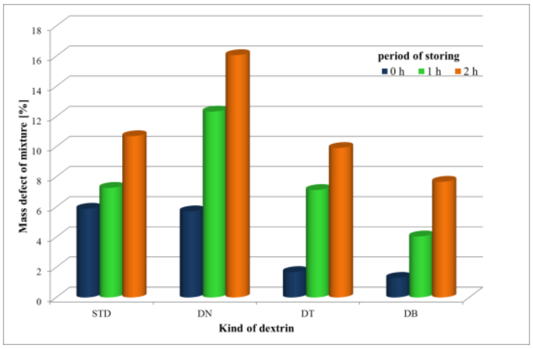

Fig. 3. Stability of the mixture against staling

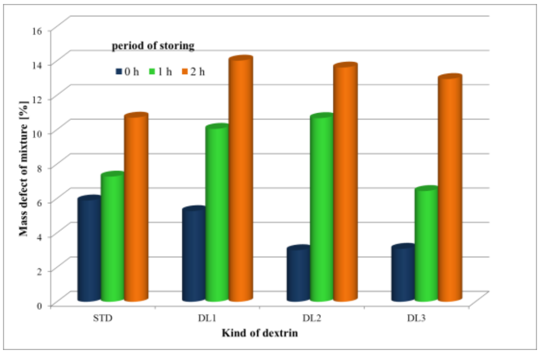

Fig. 4. Stability of the mixture against staling

4. Conclusion

This contribution is aimed at evaluating the use of dextrins as an additive for unit bentonite mixtures with the aim of improving the chosen physical-chemical properties of the moulding mixture. As most of dextrins has strongly acid pH it is probable that in the moment of moulding mixture circulation the concentration of those additives will be increased what could have a negative impact on chosen properties of moulding mixture (compression strength, splitting strength etc.). This fact was indicated by the loss of strength of pattern „circulationless“ mixture. In addition to it a considerable growth of mixture plasticity (toughness) was observed what would result in worse compacting of moulds what used to be the most frequent argument for decreasing the tendency of mixtures with saccharides to rat tails. Positive influence has the presence of dextrins in a mixture on its collapsibility. No additional strengthening of mixture resulting from higher temperatures wasn’t observed. From the point of view of mixture stability against wear (wear resistance) the addition of dextrins has a positive influence in a short time interval only. After storing of mixtures with chosen dextrins for a longer time their wear resistance decreases in comparison with moulding mixtures without presence of polysaccharide additives.

With regard to above mentioned results and more complicated preparation of moulding mixtures (achieving the required compactibility) the favourable effects of adding the mentioned dextrins in bentonite mixtures are considerably suppressed with their negative influences.

References

[1] Neudert, A. Trends of green sand systems *Slévárenství,* 2006, Vol. 54, No. 10/11, pp. 10 – 11(in Czech)

[2] Jelínek, P. Pojivové soustavy slévárenských formovacích směsí. 2004, Ostrava (in Czech)

[3] Gilson, D. M. et. al. Sand Additives – Past, Present and Future, *AFS Transactions*, 95-39, pp. 295 – 303

[4] Chang, Y, The flowability of bentonite bonded green molding sand. *J Mat Proces Tech,* 2001, 113, pp. 238-244
Brümmer, G. Die Vorteile von Einheitsgemischen aus Bentonit, Glanzkohlenstoffbildner und anderen Zusätzen. *Slévárenství,* 2000, Vol. 48, No. 2/3, pp. 102 – 109 (in Czech)

[5] Zhou, X. et. al. The high temperature resistant mechanism of a-starch composite binder for foundry. *J. Mat. Proc. Tech.*, 2009, 209,pp. 5394-5398

[6] Zhou, X. et. al. Adheisve bonding and Self-Curing Characteristics of a-Starch based composite binder for green sand mould/Core. *J Mat Sci Tech*, 2004, Vol. 20, pp. 617-621

[7] Zhou, X. et. al. Study on synthesis and properites of modified starch binder for foundry, *Journal of Materials Processing Technology*, 2007, 183, pp. 407-411

[8] Yu, W. et. al. Preparation and experiments for a novel kind of foundry core binder made from modified potato starch. *Materials and Design,* 2009, 30, pp. 210-213

[9] Makino, H. et. al. Molding simulation and experiments of new coremaking system with polysacharide-based binder. *AFS Transaction*, 2005, paper 05-039(04), pp. 1-8

[10] Effler, L. et.al. Slévárenství, 1964, Vol 12, pp. 481-483 (in Czech)

[11] Fosum, J., Vácha, L. Slévárenství, 1984, Vol. 32, No. 7, pp. 267-269 (in Czech)

[12] Brümmer, G. Organische Leime als sinnvolle ergänzung zum Formstoffbinder Bentonit, *Giesserei*, 2000, No. 3, pp. 62 – 68

[13] Kodíček, M. *Biochemické pojmy – výkladový slovník*. 1. VŠCHT Praha, 2004, 171 s. (in Czech)

[14] VODRÁŽKA, Zdeněk. *Biochemie*. 2. Praha : Academia, 2002. 191 s. (in Czech)

[15] White, D. R. et. al. Dextrin characterization by high-performance anion-exchange chromatography-pulsed amperometric detection and size-exclusion chromatography-multi-angle light scattering-refractive index detection. *Journal of Chromatography A,* 2003, 997, pp. 79 -85

[16] Ciesielski, W, Tomasik, P. Thermal properties of complexes of amaranthus starch with selected metal salts. *Thermochimca Acta*, 2003, 403, pp. 161-171

[17] Valdivieso, A.L. et. al. Dextrin as a non-toxic depressant for pyrite in flotation with xanthates as collector. *Minerals engineering*, 2004, Vol. 17, pp. 1001-1006

[18] HOLTZER, M. et.al. Methods pf the montmorillonite content determination in foundry bentonites. *AFE,* 2009, Vol. 9, No. 4, pp. 69 - 72