Thermal deformation of moulding sands with biopolymer binders

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Abstract

Investigations concerning an application of biopolymer materials as binders for moulding sands are presented in the paper. These investigations constitute the continuation of examinations related to applications of various biopolymers as binding agents. The results of strength tests, obtained for the investigated sands (with the PLA2 biopolymer binder) prepared in a self-hardening sands technology and air as well as microwave hardened, are presented. Examinations of sand thermal deformations based on the hot distortion measurements and on the basis of thermogravimetric investigations of sands with selected biopolymer binders were performed.

Keywords: Moulding sand, Binding material, Biopolymer

1. Introduction

In times of increasing requirements concerning environment protection looking for environmentally friendly materials as binders for moulding sands becomes necessary.

Applied up till now organic binding materials, on the basis of synthetic resins are characterised by good technological properties, but cause high emission of harmful substances. Therefore contemporary scientific investigations are aimed at a gradual substitution of binders obtained from petrochemical raw materials by biopolymers originated from renewable sources.

Investigations presented in this paper concern moulding sands of the IV generation, it means sands with biotechnological binders (according to Jelinek [1]). Biopolymers were applied as binding materials. Biopolymers being renewable natural polymers are characterised by several desirable physicochemical properties, including biodegradability. They constitute more and more interesting raw material used in various industrial applications, including environmentally friendly binding material for moulding sands.

Previous investigations of the authors concerned selecting the biopolymer material satisfying the requirements, which are to be met by moulding sands binders [2-4].

On the basis of the results of strength tests and taking into account availability of the examined materials, the PLA2 biopolymer was selected for further investigations.

PLA2 is a material sold under the trade name Bio-Flex F 6510, produced by the FKuR Kuststoff GmbH Company in a form of cylindrical granules. This is a biodegradable polymer based on polylactid acid (PLA), containing co-polyester and additions.

Applications:
- Foils,
- Products cast by injection moulding,
- Admissible for contact with food.

Bio-Flex F 6510 is nearly odourless, insoluble in water and its melting point is in the range: 150-170°C [5].
2. Authors own research

2.1. Examinations of technological properties of moulding sands with the biopolymer binder PLA2

Determination of strength properties of the tested sands was the first stage of investigations concerning the new biopolymer binder. Sands were of the following composition:

- Quartz sand: 100 parts by weight
- PLA2 binder: 2-4 parts by weight
- Solvent (CH2Cl2): to complete solving of a binder.

Moulding sands were prepared in the technology of self-hardening sands. Strength properties were measured after 24 hours of air hardening and hardening by microwaves, immediately after compacting and cooling to an ambient temperature. The obtained results are presented in Figures 1-3.

The performed examinations indicate that application of 2.0 parts by weight of the PLA2 binder is optimal. Moulding sands containing such amount of a binder have sufficient – from the point of view of foundry practice - strength properties. Strength properties of moulding sands hardened by microwaves are higher than those of air hardened sands.

Fig. 1. Influence of the PLA2 binder amount on a bending strength of the tested moulding sands prepared in the self-hardening sands technology

Fig. 2. Influence of the PLA2 binder amount on a tensile strength of the tested moulding sands prepared in the self-hardening sands technology

Fig. 3. Influence of the PLA2 binder amount and a hardening time on a bending strength of the tested moulding sands hardened by microwaves

2.2. Hot distortion measurements – investigations of thermal deformations of moulding sands with the PLA2 binder

Measuring the hot distortion parameter is used for the determination of the moulding sand thermal deformation. The detailed description of the method and the results characterizing thermal deformation of moulding sands with binders being currently used in foundry practice, were presented in previous publications of the authors [6 – 13]. Ignaszak [14] also presented same interesting investigation according to hot distortion tests and modification of DMA apparatus.

In this paper hot distortion curves are presented as a function of time. Temperature was also registered. As the thermocouple is placed next to the lower surface of the sample, the temperature inside the sample differs in a measure. This differences were investigated by authors [8] and by Ignaszak [14], who also proves different temperature fields on the cross-section of the sample.

Hot distortion curves for air hardened sands of various content of the PLA2 binder are presented in Figure 4. These sands are characterised by a small degree of a thermal deformation - an upper deformation as compared to the initial location is quite small reaching maximum 0.26 mm.

However, differences in a thermal deformation resistance occur and moulds of larger binder content have a higher resistance.

Fig. 4. Influence of the PLA2 binder amount on the thermal deformation of the air hardened sand, heating up temperature range - 120 – 135°C, measurement next to the lower surface of the sample, NiCr-CuAl thermocouple (jacket ø 3 mm)
...ich shaped casts were deformed did not exceed 20 s.

Fig. 5. Influence of the PLA2 binder amount on the thermal deformation of the microwave hardened sand; heating up temperature range - 125 – 135°C, measurement next to the lower surface of the sample, NiCr-CuAl thermocouple (jacket ø 3 mm)

The character of thermal deformation curves of sands with the PLA2 binder resembles curves obtained for moulding sands made in the cold box technology [8, 9].

The results of the thermal deformations of moulds hardened by microwaves are presented in Figure 5. The time of hardening by microwaves had influence on the thermal deformation. Hardening moulding sands by microwaves in 4 min. time caused an increase of the thermal deformation resistance.

Moulding sands containing 1 part by weight of the binder – hardened under various conditions – are compared in Figure 6. In this case, microwaves hardening allowed obtaining sand of a higher resistance to the thermal deformation.

Fig. 6. Thermal deformation of sands containing 1 part by weight of the PLA2 binder – hardened under various conditions; heating up temperature range - 120 – 130°C, measurement next to the lower surface of the sample, NiCr-CuAl thermocouple (jacket ø 3 mm)

Sands containing more binder (2 parts by weight) behave differently (Figure 7). The air hardened sand has the same resistance to the thermal deformation as 4 min microwave hardened moulds.

The performed examinations of the hot distortion parameter indicate that better properties during heating, are exhibited by sands containing 2 parts by weight of the binder, regardless of the applied hardening method. However, the attention should be directed to the time range (and temperature connecting to that time), at which shaped casts were deformed. In every investigated case a time at which shaped casts were deformed did not exceed 20 s.

Fig. 7. Thermal deformation of sands containing 2 parts by weight of the PLA2 binder – hardened under various conditions; heating up temperature range - 125 – 135°C, measurement next to the lower surface of the sample, NiCr-CuAl thermocouple (jacket ø 3 mm)

However, an assessment and practical implications of this deformation can be discussed only after performing investigations on the thermal destruction of moulding sands.

2.3. Thermogravimetric examinations of moulding sands containing biopolymer binders

In order to assess the thermal degradation effect of moulding sands with biopolymer binders their derivatographic examinations were carried out. Examinations comprised thermogravimetric analyses of moulding sands with biopolymer binders. Moulding sands containing 1.5 parts by weight of PLGA, PCL and CA prepared in the self-hardening technology and air hardened were examined. Materials selected for tests were described in detail in the previous references [2-4].

Examinations were carried out on the Erdley-Paulik-Paulik derivatograph. Samples were heated with a rate of 10⁷/min. The obtained TG and dTA curves are presented in Figures 8-10.

The TG curves for the examined sands are very similar. They show the mass decrement of app. 1.0% for sands with PLGA and PCL (Fig. 8-9), while 0.8% for sands with CA (Fig. 10).

Fig. 8. The TG and dTA curves for moulding sands with PLGA as a binder
In the case of sand with PLGA the decrement starts at a temperature of 238°C, while later on continues more gently up to a temperature of app. 493°C. Two endothermic peaks are seen on dTA curves for all examined sands. The first large peak, which occurs at a temperature of 493°C, is originated by the polymorphic quartz transformation, $\beta \rightarrow \alpha$. Derivatographic examinations carried out by the authors [9] for moulding sands prepared in the cold-box technology exhibited the mass decrement starting at a temperature of app. 100°C (loss of physically bond water), destruction of a binder majority in a temperature range 400-570°C and finish of the mass decrement at a temperature of 573°C – is originated by the polymorphic transformation, $\beta \rightarrow \alpha$.

Examinations of the hot distortion parameter indicate a small deformation degree, and also a favourable assessment of sands flexibility.

Further investigations should assess the ability to reclamation of spent moulding sands with those binders in an aspect of their biodegradability.

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References