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The estimation of harmfulness for environment of moulding sand with biopolymer binder based on polylactide

K. Major-Gabryś*, St. M. Dobosz, J. Jakubski
Department of Moulding Materials, Mould Technology and Foundry of Non-ferrous Metals,
Faculty of Foundry Engineering, AGH University of Science and Technology,
ul. Reymonta 23, 30-059 Kraków, Poland
* Corresponding author. E–mail address: katmg@agh.edu.pl

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Abstract

The article takes into consideration technological and ecological aspects of IV generation moulding sands. Investigations concerning an application of biopolymer materials as binders for moulding sands are presented in the paper. These investigations are the continuation of examinations related to applications of various biopolymers as binding agents and to the properties of the moulding sands with biopolymer binders. In the paper there are the researches concerning analyzing gases emitted from moulding sands during heating.

Keywords: Moulding sand; Binding material; Biopolymer; Environment hazard

1. Introduction

Contemporary scientific researches are leading to progressive replacing the binders obtained from petrochemical materials with biopolymers coming from renewable resources. The idea is compact with a concept of sustainable development which is one of the main priorities for the European Union.

The artificial biopolymers are obtained as products of polymerization of substances coming from renewable resources. Most common are aliphatic polyesters obtained from monomers PHB, PGA, PLA or PHV. The artificial biopolymers are also called macromolecular compounds manufactured by petrochemical industry or from petrochemical polymers after inserting into them degradation factors to cause their biodegradability [1-2].

Increasing concern (intrest) of aliphatic polyesters such as polylactide, polycaprolactone, poly(hydroxyalkanoates) and aliphatic-aromatic polyesters is caused by the possibility of using them for producing biodegradable packaging and other short-time life products. The global usage of biodegradable polymers in packaging market (industry) in year 2006 was 43 thousand ton and 40% of that was the usage of polylactide [1-2]. PLA is presently one of the most important biopolymer available on the market of biodegradable polymers [3-9].

Effective biodegradation of PLA requires temperature near 60^{o}C and humidity near 95%. Such conditions require implementation of recycling and composting systems of used products. The results of authors researches [10-12] connected to technological usefulness of many biopolymer materials showed best strength properties of moulding sand with biopolymer binder PLGA and binder PLA2, both air hardening and hardening by microwaves. The strength properties of the moulding sands with chosen biopolymer binders predestine these binders for foundry practise usage.

The results of strength tests and taking into account availability of the examined materials, the PLA2 binder 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. Bio-Flex F 6510 is nearly odourless, insoluble in water and its melting point is in the range: 150-170^{o}C [13].

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

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 on figures 1-2.

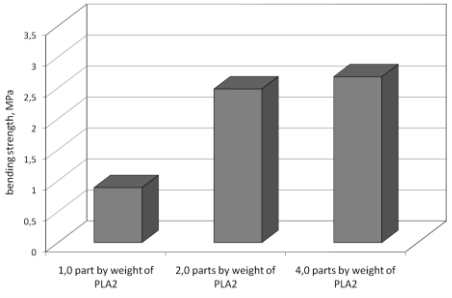

Fig. 1. The influence of the PLA2 binder amount on a bending strength of the tested moulding sands prepared in the self-hardening sands technology [14]

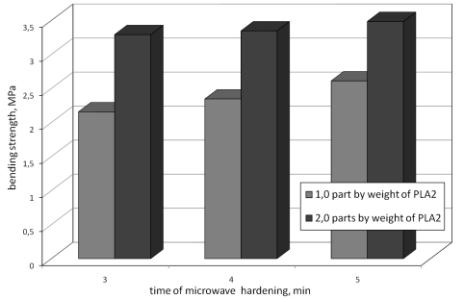

Fig. 2. The influence of the PLA2 binder amount and a hardening time on a bending strength of the tested moulding sands hardened by microwaves [14]

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[14].

2.2. Investigations of harmfulness for environment of moulding sands with the biopolymer binder PLA

The gas emission during the heating process is important from two reasons:

1. Gases emitted from the moulding sand and drifting toxic dusts can pollute human work environment, being hazardous for life and health.
2. Penetrating inside the mould they get to the metal-mould joint and can react with liquid metal, causing many surface defects of the cast.

The environment and health hazard is the topic of many scientific researches. A special attention is put on hydrocarbons from benzene group (BTEX) and on polycyclic aromatic hydrocarbons (PAH).

The article takes into consideration the researches concerning analyzing gases emitted from moulding sands during heating. The researches were taken in Foundry Research Institute in Krakow. There was used a multifunction device using to examine liquid alloys surface properties. The construction of the device let permanent registration of residual gases content aid of quadrupole mass analyzer Prisma QMS-200 made by Pfeiffer Co. the researches were taken in high vacuum conditions.

Moulding sand with the following composition was taken into elaboration:

Quartz sand - 100 parts by weight
Biopolymer PLA - 2 parts by weight.

For comparison, a typical self-hardening moulding sand with furfuryl resin (called furan moulding sand) was tested. The furan moulding sand composition was:

Quartz sand - 100 parts by weight
Phenol-furfuryl resin - 1,1 part by weight
Hardener (aqueous solution of PTS acid) - 0,55 parts by weight

Moulding sands were densified preparing cylindrical samples having size: Ø12x5mm. The sample mass was 0,933g. Some of the researches results are shown on the figures 3-6.

The applied researches proved that the concentration of gases emitted during heating the moulding sand with biopolymer binder is much lower than the concentration of gases from furan moulding sand.

From the moulding sand with biopolymer binder the following compounds (gases) are emitted:

- The range of atomic mass 0-3u – hydrogen,
- The range of atomic mass 3-16,5u – nitrogen, oxygen, methane,
- The range of atomic mass 16,5-18,5u – ammonia and water vapor,
- The range of atomic mass 18,5-28,5u – carbon monoxide, nitrogen,
- The range of atomic mass 28,5-45u – fluorine, argon, carbon dioxide, propane,

- The range of atomic mass 45-85u – chlorine,
- The range of atomic mass 85-100u – very low concentration of toluene,

The range of atomic mass 100-200u – no concentration of BTEX or PAH.

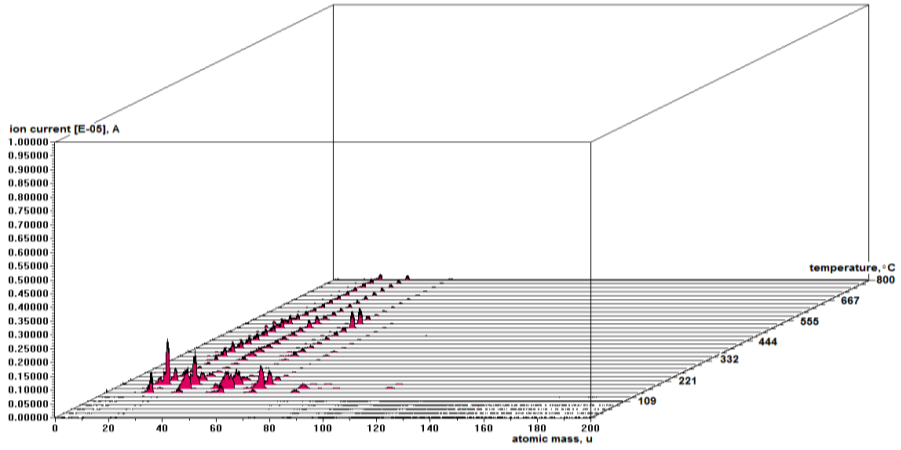

Fig. 3. The analysis of gases emitted during heating the moulding sand with biopolymer PLA

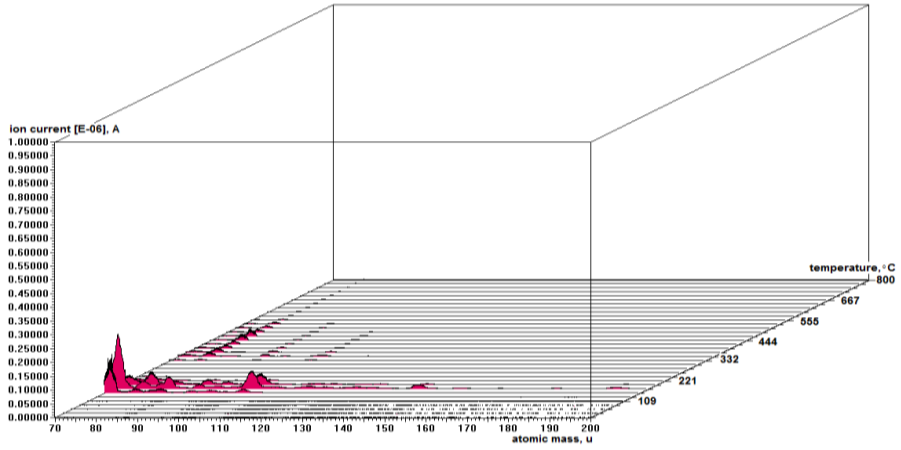

Fig. 4. The analysis of gases emitted during heating the moulding sand with biopolymer PLA in the range of atomic mass 70-200u

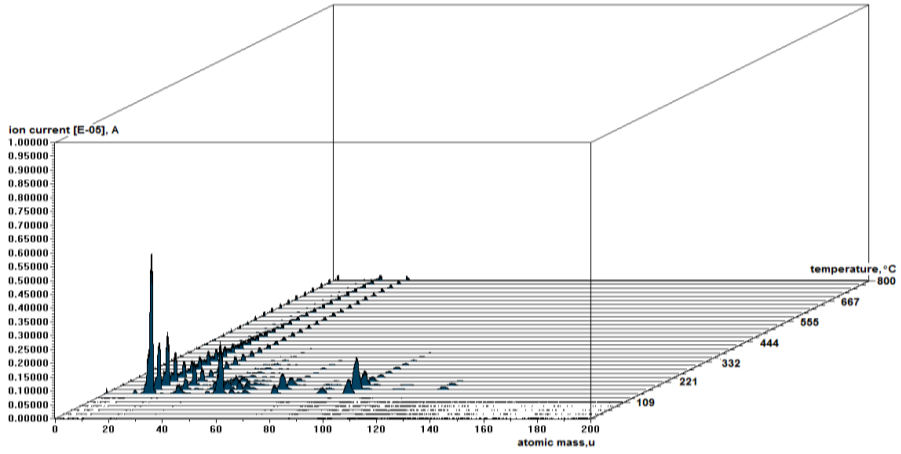

Fig. 5. The analysis of gases emitted during heating the furan moulding sand

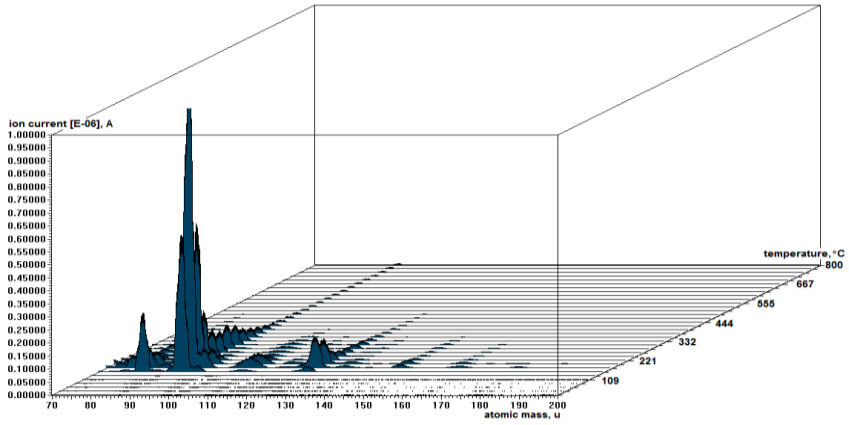

Fig. 6. The analysis of gases emitted during heating the furan moulding sand in the range of atomic mass 70-200u

From the moulding sand with furfuryl resin the following compounds (gases) are emitted:

- The range of atomic mass 0-3u – hydrogen,
- The range of atomic mass 3-16,5u – nitrogen, oxygen, methane,
- The range of atomic mass 16,5-18,5u – ammonia and water vapor,
- The range of atomic mass 18,5-28,5u – carbon monoxide, nitrogen,
- The range of atomic mass 28,5-45u – hydrogen sulfide, fluorine, argon, carbon dioxide, propane,
- The range of atomic mass 45-85u – sulfur dioxide, dinitrogen dioxide, benzene,
- The range of atomic mass 85-100u – toluene (BTEX),
- The range of atomic mass 100-200u –xylene (BTEX), naphthalene, acenaphthylene, fluorene, anthracene (PAH).

The concentration and the composition of emitted gases from the moulding sand with biopolymer proves its proper ecological character.

3. Conclusions

The applied researches and the detailed analysis of data prove that the moulding sand with biopolymer binder is much more ecological friendly than the typical self-hardening furan moulding sand. Considering its satisfying technological properties and high ability to mechanical reclamation – the subject of the future authors paper – this moulding sand may be a new, interesting alternative to moulding sands technologies being used presently.

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References

[1] Kuciel S., Liber-Kneć A., Zajchowski S., Biocomposites made of thermoplastic starch or of polylactide and starch mixture filled with natural fibers, POLIMERY, no 10 (2009) 667-673 (in Polish).
[2] Kuciel S., Kuźniar P., Liber-Kneć A., Polymer biocomposites with renewable sources, Archives of Foundry vol. 10, no 3 (2010) 53-56.
[3] Florjańczyk Z., Debowski M., Chwojnowska E., Łokaj K., Ostrowska J., Synthetic and natural polymers in present-day polymer materials, Part I – Polymers made of renewable resources and polymer nanocomposites, POLIMERY no 10 (2009) 611-625 (in Polish).
[4] Tackes G., Core Binders: A Look into the Future, Modern Casting Oct 1 (2001) 24-27.
[5] Eastman J., Protein – based binder update: Performance put to the Test, Modern Casting, no 10 (2000) 32 – 34.
[6] Kramářová D., Brandštetr J., Rusín K., Henzlová P., Biogenic polymer materials as foundry moulds and cores binders, Slévárenství vol. 60, no 2-3 (2003) 71-73 (in Czech).
[7] Pielichowski J., Puszyński A., Chemistry of polymers, WNT Teza, Kracow (2004) (in Polish).
[8] Błędzki A.K., Collective work, Recycling of polymer materials, WNT, Warsaw (1997) (in Polish).
[9] Połowiński S., Physical chemistry of polymers, Publishing House of Technical University of Lodz, Łódź (2001) (in Polish).
[10] Dobosz St.M, Major-Gabryś K., The selection of moulding sands with biopolymers, Technológ, vol. II, special number (2010) 17-22.
[11] Dobosz St.M., Major-Gabryś K., Biopolymers as IV generation moulding sands binders, Archives of Mechanical Technology and Automation, vol. 28, (2010) 11-18 (in Polish).
[12] Dobosz St.M, Major-Gabryś K., Strength properties of moulding sands with chosen biopolymer binders, Archives of Foundry, vol. 10, no 3 (2010) 17-20.
[13] Technical and safety data sheets – Bio-Flex F 6510.
[14] Major-Gabryś K., Dobosz St.M., Jakubski J.: Thermal deformation of moulding sands with biopolymer binders, Archives of Foundry Engineering, Vol. 10, no 4, (2010) 129-132

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