The estimation of ability to reclame of moduling sands with biopolymer binders

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Abstract

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. That’s why contemporary scientific researches are leading to progressive replacing the binders obtained from petrochemical materials with polymer biocomposites coming from renewable resources. Increasing concern of aliphatic polyesters such as polylactide, polycaprolactone, poly(hydroxyalkanoates) and aliphatic-aromatic polyesters is caused by the possibility of using them for producing many biodegradable products. In that context it is important to expand the researches connected to using biopolymers as moulding sands binders. Contemporary authors’ papers were focused on technological properties and harmfulness for the environment of this ecological moulding sands. This article takes into consideration the ability to reclamation of moulding sands with biopolymer binders.

Key words: Moulding sand, Biopolymer binders, Reclamation

1. Introduction

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. That’s why 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.

Despite having many advantages, the biopolymers and biocomposites market is relatively small comparing to the petrochemical materials market. However biodegradable polymers have the potential to capture app. 10% of the word polyolefines resin market used in agriculture and for packaging. The increase of manufacturing biopolymers coming from renewable resources will be possible thanks to improving production processes and, due to this, lowering biopolymers prices [1, 2].

Biopolymers are completely biodegradable polymers, which means completely converted by micro-organisms to water, humus and CO\textsubscript{2}. 
There are two main groups of biopolymers [3]:
- The natural biopolymers – existing in living organisms and being produced by them. In that group there are hydrocarbons and proteins (such as polysaccharides, lignin, natural rubber). Polyhydroxycids as PHB, PHV, PLA, PGA also belong to the group of materials being produced by micro-organisms.
- 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].

The technologies of obtaining biopolymers are divided into two main groups [3]:
- The fractional fragmentary technology – based on decomposition of agricultural and wood products to primary components by using analytical methods.
- The enzyme technology – using enzymes (hydrolases) that decompose e.g. starch to glucose. [3].

Thanks to using physical and chemical processes and biotechnology a primary raw material can be transformed to large number of complicated products [3].

The biggest expectations for getting advance in using renewable resources to produce macromolecular materials is connected to spreading biochemical methods in monomers synthesis and some polymers classes [5]. Nowadays such methods are used mainly to produce lactic acid, triethylene glycol, poly(hydroxyalkanoates) and to fragmentary fermentation of wastes with high starch content coming from food industry [5].

Increasing concern 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-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].

2. Own researches

2.1. The examinations of moulding sands’ strength properties

As a result of looking for polymer binders, the following materials were used as binders: PHB, CA, PCL, PLA, PLGA, PLA1 and PLA2.

Moulding sands with the following composition were taken into elaboration:

<table>
<thead>
<tr>
<th>Material</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartz sand</td>
<td>100 parts by weight</td>
</tr>
<tr>
<td>PHB, CA, PCL, PLA, PLGA</td>
<td>1,67 parts by weight</td>
</tr>
<tr>
<td>PLA1, PLA2</td>
<td>2 – 4 parts by weight</td>
</tr>
</tbody>
</table>

The strength properties of the moulding sands were tested after their complete hardening (after the solvents vaporization).

The researches results of the tested moulding sands’ bending strength are shown in the figures 1 – 2 [6-7].

The figure 1 shows the comparison of bending strength of moulding sands with biodegradable materials: synthetic biopolymers CA and PCL, and natural biopolymers PHB, PLA, PLGA as binders. The figure shows that the moulding sands with the natural biopolymers PLA and PLGA have better bending strength than the moulding sands with synthetic biopolymers CA and PCL. The strength properties of new binders are good enough for high quality moulding sands.

![Fig.1. The comparison of bending strength of moulding sands with PHB, CA, PCL, PLA, PLGA](6-7)

The figure 2 shows the comparison of bending strength of moulding sands with modified materials based on PLA, called PLA1 and PLA2. The researches proved that the moulding sand with PLA2 has much better strength properties than the moulding sand with PLA1.

![Fig.2. The comparison of bending strength of moulding sands with PLA1 and PLA2](6-7)

The researches proved that the moulding sand with PLA2 as binder strength properties are good enough for foundry practice [6-7].
2.2. The examination of moulding sands’ ability to reclamation

Researches aimed at estimating the ability to reclamation of moulding sands with biopolymer binders. There were tested moulding sands with biopolymer binders PHB, CA, PCL, PLA, PLGA, PL A1 and PL A2 in quantity of 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 parts by weight
- Hardener (aqueous solution of PTS acid) - 0,55 parts by weight

The examination schedule of the ability to reclamation of moulding sands contents:
- crushing the material before secondary reclamation. The material obtained by crushing is called used moulding sand,
- the secondary reclamation treatment in 10 and 20min time of reclamation,
- the final classification (pneumatic) of the obtained in reclamation process material. The obtained material is called reclaim.

Used moulding sands and reclaims were analyzed to define the degree of liberating sand grains from binders left-overs of moulding sands.

The following analyses were done:
- ignition loss,
- defining of the degree of liberating sand grains from binders left-overs of moulding sands $W_{SR}$,
- defining of dusts content,
- value of pH,
- analyzing of surface morphology,
- sieve analysis.

The device working as a rotor reclaimer were applied for the researches [8]. The device realizes grinding-reclamation treatment in the range of rotor rotational speed of 300rpm. The rotations of properly shaped rotor realize elementary operations of crushing, grinding and rubbing. The device works in periodical system and the one time reclamation treatment of 150g of the polydispersity material is possible [8].

The device examine grinding ability to reclamation of moulding sands with water glass, cement and with resin binders. Used moulding sands were secondary reclamation treated in experimental testing reclaimer. The investigations of the reclaims content: sieve analysis after the final classification, dusts content defining in reclaim before the final classification, loss ignition defining, pH value defining, surface morphology analyzing, defining of the degree of liberating sand grains from binders left-overs of moulding sands $W_{SR}$.

The loss of ignition value was defined on the basis of the loss of mass value of the 20g samples of moulding sands burning in a furnace for 2h at a constant temperature of 900°C. The obtained results of ignition loss are presented in the figure 3.

$$W_{SR} = \left(1 - \frac{U_C}{S}\right) \times 100\%$$  \hspace{1cm} (1),

where:
- $U_C$ – mass loss of the 100g sample of the reclaim due to burning in a furnace for 1h at a constant temperature, [%],
- $S$ – total content of the binder and all removable, at the determined temperature, combustible substances determined by total burning of 100g moulding sand sample before the reclamation, [%].

The figure 4 shows the obtained values of the degree of liberating sand grains from binders left-overs of tested used moulding sands.

Fig.3. Ignition loss vs reclamation time for used sands and reclaimed sands after 10 and 20 min of reclamation
The obtained results initially prove that the best ability to reclamation have the moulding sands with PHB, PLA1 and PLA. The worst ability to reclamation has the moulding sand with typical furfuryl resin.

The dusts content in tested reclaims were defined on the basis of blowing through of 100g samples of moulding sands in fluidized column with air blowing speed of 1m/s and in time of 4min. The obtained results of examinations are presented in the figure 5.

The presented in the figure 5 results of the dusts content in used moulding sands and in reclaims complete well the calculated value of the degree of liberating sand grains from binders left-overs of used moulding sands. The biggest dusts contents were in the reclaims having the highest value of $W_{SR}$ index. The smallest dusts content was defined in the used moulding sand with typical furfuryl resin, which has the lowest $W_{SR}$ index.

The dust content in reclaims before the final dust collection process can give many information about the intensity of reclamation elementary operations (crushing, grinding and rubbing). The more intensive the processes are, the bigger dusts content is.

In the conducted researches all the moulding sands were tested in the same device work parameters and the same reclaimed moulding sands masses were used. Stable conditions of the process let initially say that in that case bigger dusts content in the reclaim before the final dust collection is caused by better ability to reclamation of the tested moulding sand (no sand grains crushing was noticed during the treatment).
The pH value was defined for used moulding sands and for reclaims after 20 min of reclamation treatment. The results of the examinations are presented in the figure 6.

![Figure 6: pH value of tested used moulding sands and reclaims](image)

Fig. 6. The pH value of tested used moulding sands and reclaims.

The obtained results show that pH value of reclaims changes with increasing the intensity of reclamation. The values correlate with the ignition loss values. The most interesting result was obtained for the used moulding sand with PHB and for the reclaim of moulding sand with PHB. The value of pH is about 7, but it equals 6.78 (acidic character) for used moulding sand and 7.14 (alkaline character) for reclaim.

3. Conclusions

The applied initially researches of the ability to reclamation of moulding sands with biopolymer binders let arrange the moulding sands in the following order:

1. moulding sand with PHB – having the best ability to reclamation,
2. moulding sand with PLA 1,
3. moulding sand with PLA,
4. moulding sand with PGLA,
5. moulding sand with CA,
6. moulding sand with PLA 2,
7. moulding sand with PCL,
8. moulding sand with furfuryl resin – having the worst ability to reclamation.

The applied researches prove that the moulding sands with biopolymer binders have high ability to reclamation, much exceeding the typical moulding sand’s with furfuryl resin analogical parameters.

The ability to reclamation examinations of the moulding sand with PCL prove that the moulding sand may generate problems while reclamation treatment in industrial devices. It’s caused by the fibrous “character” of the tested moulding sand. The problem is connected to the part of the moulding sand that is not burnt-out. The fibrous phenomenon can cause improprieties on knock-out grate and on reclaimer’s sieves clogging them. The phenomenon disappears after burning the moulding sand out.

The conducted researches were the initially examinations with using primary parameters of reclaim quality estimation. For complete reclaim quality estimation it’s necessary to examine the moulding sands with reclaims properties and make casts in moulds made of moulding sands with reclaims.

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