ARCHIVES
of
FOUNDRY ENGINEERING

ISSN (1897-3310)
Volume 8
Issue 1/2008

51 – 54

10/1

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

Biopolimers – structure, properties and applicability in the foundry industry

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Received 22.06.2007; accepted in revised form 17.07.2007

Abstract

A review of literature data concerning physicochemical properties and possibilities of practical utilisation of the most important natural biopolymers (proteins, celluloses, starch, chitozan) are presented in the paper. Biopolymers being renewable natural polymers characterised by several required physicochemical properties (adhesivity, activity, no toxicity, biodegradability) constitute more and more interesting processing raw material for various industrial utilisations including environment friendly binding agents for moulding sands. Protein and starch compositions are used as binding agents for moulding and core sands in the foundry industry. Preliminary tests – performed within own research - of modification and utilisation of biopolymers as binding agents for moulding sands are promising from many aspects: technological (adequate properties of moulding sands), ecological (no toxicity, biodegradability) and economic (low price). Starch from the polysaccharide group seems to be especially interesting since it is abundant, easily obtainable, biodegradable and the cheapest polymer. At its actual low price and the possibility of using agricultural wastes in the production, problem of utilising starch in many industry branches can become significant, especially in Poland.

Keywords: Biopolymers, Starch, Binding material, Moulding sands, Foundry engineering

1. Introduction

Gradual substitution of polymers obtained from petrochemical raw materials by biopolymers from renewable sources will become a real scientific challenge for the polymer technology in the XXI century. When natural biopolymers, adequately prepared or modified, have proper mechanical properties they can be utilised in several industries and after certain „life-time" undergo biodegradation [1, 2].

Processing methods and constructional solutions allow already utilization of natural raw materials for production of various elements mainly in the automotive industry, building engineering and in medicine [3, 4, 5, 6, 7]. Light, durable composites with natural fibres instead of glass fibres of mineral fillers, used previously, are now-a-days applied in several car accessories. Composites reinforced by biomaterials were widely used, in the last decade, by European car producers for making doors, seats etc. Forecasting indicate that application of natural fibres in the automotive industry will increase to 100 000 tons to 2010. It is estimated presently that approximately 50 kg of natural fibres are used for production of a single vehicle. Biopolymers as biocompatible and biofunctional materials predicted for long-term contacts with life tissues and for either temporary or permanent reinforcement or substitution of tissues or body organs are widely used in medicine, e.g. in ophthalmology (lenses), orthopedics (prosthesis of bones and joints, cements), stomatology (dental materials) or as dressing materials.

Growing environmental awareness of producers and consumers as well as governmental policy favouring protection of natural resources contribute to increasing sale of biodegradable natural polymers. Growing popularity of environment friendly ‘green’ products provides opportunity for innovations and an increased market share. It is expected that the production of materials of natural origin will increase from 5% to approximately 12% in 2010, to approximately 18% in 2020 and to approximately 25% in 2030 [1]. The European Union forecast of 300% increase of the chemical industry production by the year 2040, without increasing consumption of useful fossils, indicates starch as a main raw material for this production [5].

2. Biopolymers

Proteins and polysaccharides are included in the group of biopolymers [2, 6, 7, 8]. Proteins are built mainly from amino acids constituting approximately 90% of building materials in living organisms.

Polysaccharides constitute approximately 80% of dry matter of plants. Polysaccharides - the most often appearing in nature - are: cellulose, starch and chitosane.

The most abundant natural polymer is cellulose. Billions tons of this polymer are formed annually by photosynthesis. Cellulose is a linear polymer of glycopyranosis (Fig. 1).

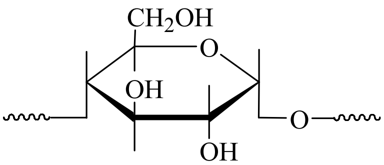
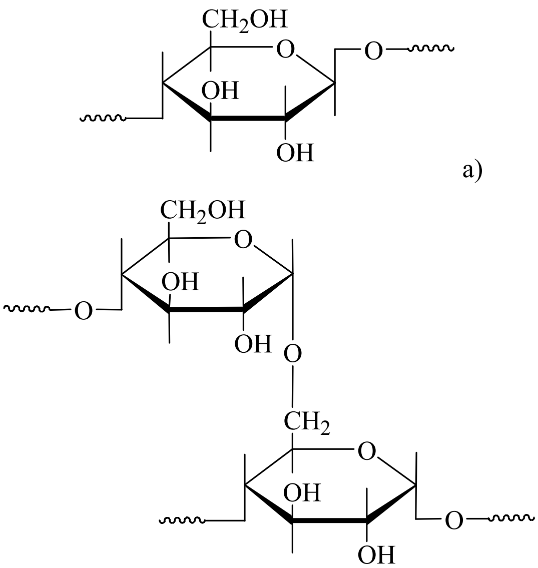


Fig. 1. Structure of cellulose



a)

b)

Fig. 2. Starch structure: a) amylose, b) amylopectine

Cellulose produced mainly from wood and fibrous cotton is technologically utilised for obtaining: fuels, building materials, paper, silk and cellulose foils, while by various modifications of cellulose derivatives explosive materials and lacquers can be produced.

Starch, apart from cellulose, is the most widely present polysaccharide in the plants’ world. It is produced - on the commercial scale - from seeds, bulbs and roots of plants. Cellulose consists of linear polymer chains of two components: amylose (Fig. 2a) and amylopectine (Fig. 2b).

Properties and the range of industrial utilisation of starch depend on its botanic origin, on the ratio of amylose to amylopectine and on the size of starch grains. Specific properties of starch are related to its structure, insolubility in cold water, strong swelling in hot water and solubility in water at approximately 140^{o}C as well as good solubility in alkaline solutions.

Broad possibilities of technical applications of starch result from its physicochemical properties and easiness of its modifications. Due to strong adhesive and membrane forming properties starch finds the main application in paper-making and textile industries (as dressing). Modification processes related to hydrolysis, oxidation, estrification, etheryfication or cross-linking allow to obtain new polymers broadening the application range. The progress in starch modification and modifiers prompted the development of new group of chemical components and fibres undergoing biodegradation or fragmentation, environment friendly.

Chitosan due to its bioactivity, biodegradativity, high adhesive attraction, membrane and fibre forming properties, no toxicity, ability of bonding heavy metal ions as well as good solubility in organic acids solutions has found various applications in food and cosmetic industries, medicine, agriculture, in water treatment and paper impregnation. Chitozan is a copolimer containing mers of N-acetylglucose and aminoglucose (Fig. 3).

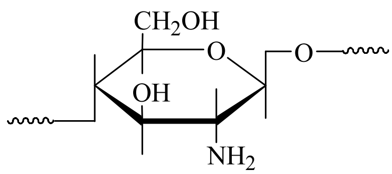


Fig. 3. Structure of chitosan

3. Biodegradable polymers

Biodegradable polymers are plastics formed during the polymerisation process and characterized by the biodegradation ability (biological decomposition) [1, 8, 9]. Fully biodegradable polymers are totally converted by microorganisms into carbon dioxide, water and humus. Polymer is considered to be biodegradable if it undergoes a total decomposition by bacteria - in soil or in water - within 6 months. In many cases the decomposition products are carbon dioxide and water (Fig. 4).

Biodegradable plastics are produced from renewable raw materials such as saccharides from corn or from petrochemical raw materials. Biodegradable polymers can be converted by means of the majority of standard processing technologies applicable for plastics including: thermoforming, extrusion moulding, injection and blow moulding.

The most common biodegradable polymers are polyhydroxyalkanolans (PHA), polylactic acid (PLA), synthetic aliphatic polyester, modified PET as well as modified starch. Majority of biodegradable plastics belongs to the polyester class, however some of them are obtainable from other materials, such as modified starch.

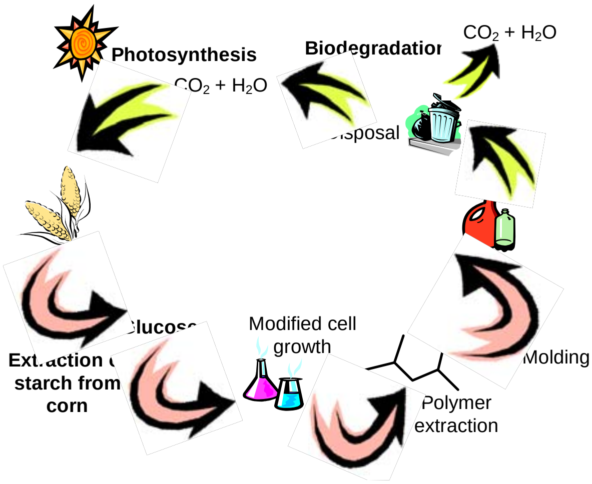


Fig. 4. Life cycle of biodegradable polymers can maintain CO_2 balance in the environment [1, 9]

Polylactic acid, PLA, is the most popular biodegradable polymer obtained from corn. This plastic undergoes biodegradation in the natural environment and is assimilated by living organisms (bacteria), thus it is an ecological polymer. Bottles produced from polylactide are presently decomposed within 75-80 days. PLA is formed from lactide in the polymerisation process. PLA belongs formally to linear aliphatic polyesters (Fig. 5).

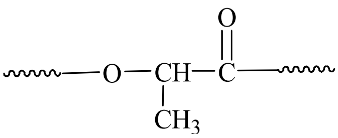


Fig. 5. Structure of polylactide (PLA)

PLA can be composted after using. Bioabsorbable materials applied in surgery (e.g. surgical threads) as well as all kinds of foils are produced from polyactide.

4. Biopolymers in the foundry industry

One of the basic problems of the foundry industry is selection of the proper binding agent for moulding and core sands. Properly selected binding agent should correspond to technical standards, be harmless for the environment and simultaneously eligible for recycling of used moulding sands.

Organic binders, based on synthetic resins, have found a broad application in recent years. Those binders are characterized by good technological properties, however - in many cases - they are hazardous for the environment and for the health of employees. Therefore research on the organic binder selection, which will meet the requirements of the foundry industry and will endanger neither the natural environment nor the work environment, is currently underway.

Biopolymers, being reproducible natural polymers characterised by several useful physicochemical properties including biodegradability, constitute very interesting raw material for various industrial utilisation, among them environment friendly binding materials for moulding sands.

General Motors Corporation developed in the 90th a new system of binding, based on protein composition, GMBOND [10]. Raw materials, mixture of polypeptide chains, which are components of this binder originate from renewable natural sources and do not constitute any hazard for the environment. Solubility of a binding agent in water is significant, since the binding process occurs during the dehydration of wet moulding sand as well as that the inverse process – of hydration – can lead to the binder partial recovery. It was found, after the preliminary technological tests of the protein binder, that the obtained castings meet the requirements: dimension accuracy, no thermoplastic deformations, high quality of castings - regardless of lowered by 45% contents of binders in comparison with hot-box cores with furane binders. A kind, temperature and humidity of a matrix have no influence on physicochemical and technological properties of moulding sands. This binding agent was introduced into the foundry engineering in 1996 [11].

Starch is a binding agent of the II or III class bonding during the dehydration process (drying temperature 160-180^{o}C) [12]. The so-called boiled starch, introduced into core moulding sands in order to increase its resistance prior to hardening or drying, finds recently application. Dextrin, a product of a partial starch hydrolysis, which is more soluble in water and form colloidal solutions with water, is a product of a partial starch hydrolysis. It bonds by dehydration (160-180^{o}C). Dextrin is sometimes added to classic moulding sands (mainly to decrease pouring ability), to moulding sands with other binding agents - in order to increase their resistance prior to hardening or drying - and to protective coatings as a binding and stabilising agent.

Possibilities of starch modifying lead to obtaining new resins applicable as binding agents in several branches of industry including the foundry [13]. Developed modified starch binder is characterised by the proper viscosity and high bonding ability in comparison with the binder based on pure starch only. In addition, the moulding sand bonded by the modified starch resin exhibits good technological properties. Thus, in future, this resin - as an alternative binding agent for moulding sands - can substitute currently applied synthetic organic resins.

5. Conclusions

Direction of production development and at the same time the possibility of utilising synthetic resins depends on various aspects: technological, economic as well as ecologic. Synthetic resins used in the foundry industry as binding agents of moulding sands have to meet the requirements of casting companies and in consequence clients, the buyers of the final castings.

Biopolymers, characterised by several required physicochemical and technological properties, can constitute an alternative in the range of binding agents of moulding and core sands. Preliminary tests – performed within own research - of modification and utilisation of biopolymers as binding agents for moulding sands are promising from many aspects: technological (adequate properties of moulding sands), ecological (no toxicity, biodegradability) and economic (low price). Starch from the polysaccharide group seems to be especially interesting since it is abundant, easily obtainable, biodegradable and the cheapest polymer. At its actual low price and the possibility of using agricultural wastes in the production, problem of utilising starch in many industry branches can become significant, especially in Poland.

Thus, taking into account the world tendency of utilising biopolymers in industries, the idea of developing new ecological binding agents - based on natural polymers - for foundry industry, seems to be justified and sensible.

Acknowledgements

Paper financed by the scientific grant in years 2007-2009 as a Research and Development Project No R07 012 02

References

[1] Mohanty A. K., Misra M., Drzal L. T.: Natural fibres, biopolymers and biocomposites, Taylor & Francis Group, USA, (2005).
[2] Wilpiszewska K., Sychaj T.: Heat plasticization of starch by extrusion in the presence of plasticizers, Polimery No 5 (2006) 327 (in Polish).
[3] Sobczak M., Olędzka E., Kołodziejski W. L., Kuźmicz R.: Polymers for pharmaceutical applications, Polimery No 6 (2007) 411.
[4] Middleton J., Tipton A.: Biomaterials, No 21 (2000) 2335.
[5] Tomasik P.: Materiały polimerowe, Materiały konferencyjne, Pomerania Plast, Szczecin-Kołobrzeg (2007) 37 (in Polish).
[6] Kricheldorf H. R.: Handbook of polymer synthesis, part B, USA (1992).
[7] Floriańczyk Z., Penczek St.: Chemia polimerów, tom III, Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa (1995) (in Polish).
[8] Mucha M.: Polimery a ekologia, Wydawnictwo Politechniki Łódzkiej, Łódź, 2002 (in Polish).
[9] Ogletree A.: The Sustainability of the Biobased Production of Polylactic Acid, Global Change, 2004.
[10] Eastman J.: Protein-Based Update: Performance Put to the Test, Modern Casting, October (2000) 32.
[11] Siak J., Whited W., Schreck R. i in.: GM Develops a Breakthrough "Green" Binder for Core Sand, Modern Casting, October (1996) 24.
[12] Lewandowski J. L.: Tworzywa na formy odlewnicze, Warszawa (1997) (in Polish).
[13] Zhou X., Yang J., Qu G.: Study on synthesis and properties of modified starch binder for foundry, Journal of Materials Processing Technology, 183, Issues 2-3 (2007) 407.