VOL. 17, NO. 21, NOVEMBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

NATURAL POLYMER MATERIALS FOR THE SYNTHESIS OF ENVIRONMENTALLY CLEANED CASTING TECHNOLOGIES

Falah Mustafa Al- Saraireh
Department of Mechanical Engineering, Faculty of Engineering, Mutah University, Jordan
E-Mail: f_saraireh@yahoo.co.uk

ABSTRACT

This paper is given an analysis of the use of technical lignins for creating new binding materials that meet the current level of foundry requirements. The reasons that restrain their use are discussed. Their objective (based on the physical nature of the material) and subjective (based on commercial benefits) origins are shown. Prospects for the use of technical lignins are considered, for example, the use of technical lignosulfonates (the main representative of the family of technical lignins on the markets of binders). The place and role of lignin-containing materials in the general view of the thematic focus of research on the synthesis of new binders, namely the creation of binders on a biopolymer basis, are investigated. The reasons for the relevance of this direction, based on ensuring a full cycle of environmental safety of production, from sanitary and hygienic working conditions in production to ensure the free biodegradation of production wastes are revealed. Examples of successful implementation of technological processes for producing castings based on technical lignosulfonates through the use of methods of high-energy mechanical action are given.

Keywords: technical lignin, biopolymer binding materials, binding capacity, strength, technical lignosulfonates, casting technologies.

INTRODUCTION

Technical lignin is a product of the delignification of plant raw materials, which can be any plant tissue, from wood to seaweed. In a plant cell, this material is invariably present in different states, performing the function of a bond that ensures the overall strength of the structure [6]. For this reason, during processing, it is generated as a by-product, usually in the form of waste. The scale of the problem is such that in 1992. The International Lignin Institute was established in Lausanne (Switzerland).

According to the data [1] is generated annually in the world from 40 to 50 Mill. Tons of technical lignin, which disposal is substantial difficulties and has not to date management solutions.

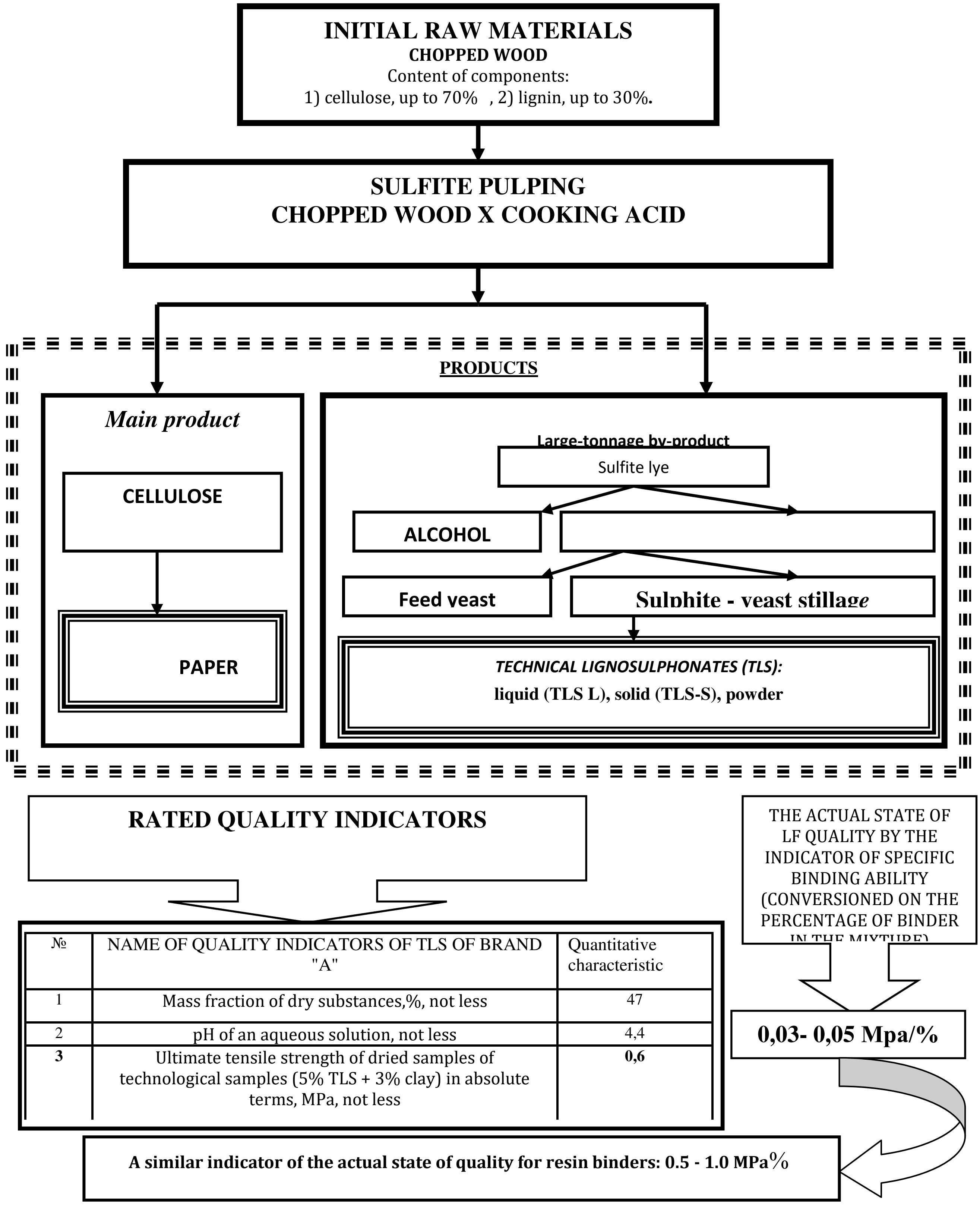
The countries with the largest forest resources, are the main producers of technical lignin. The leader in this process is the pulp and paper industry. According to estimates in [2, 3], the controlled volumes of the annual composition of this product, in various forms of its presentation (liquid sulfite, technical lignosulfonate, hydrolyzed embryo, etc.) range from 4-5 million tons. According to experts, it will increase The volume of processing plant raw materials, it is expected that by 2050. This indicator will increase by 50-60% [1, 4], in this regard, the question of reasonable disposal of lignin waste will be acute in the near and the future.One of the promising areas for the rational use of lignin is the use of its modifications as binders in the casting foundry.

Purpose of the Research

To evaluate the possibility of establishing on the basis of technical lignosulfonate binders that meet the modern requirements of the foundry industry.

Solutions Perspective

Technical lignosulfonates (TLS) are a modification of technical lignin widely and traditionally presented in the markets of binders. They are a large-tonnage waste when processing wood into sulfite cellulose. This material has traditionally been used in various industries, including in the production of castings, as a binder. General scheme for the formation of lignin products and (TLS) production, in the process of processing wood is shown in Figure-1.



№	NAME OF QUALITY INDICATORS OF TLS OF BRAND "A"	Quantitative characteristic
1	Mass fraction of dry substances,%, not less	47
2	pH of an aqueous solution, not less	4,4
3	Ultimate tensile strength of dried samples of technological samples (5% TLS + 3% clay) in absolute terms, MPa, not less	**0,6**

Figure-1. Schematic diagram of the production of technical lignosulfonates and their quality indicators.

VOL. 17, NO. 21, NOVEMBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Objectively, TLS-based binders do not meet the current level of requirements, which consists in meeting the following requirements:

a) do not have sufficiently high strength properties inherent in a resin binder (Figure-1).

b) have unstable properties, which manifests itself in sharp (up to 30% of the nominal values) fluctuations in the properties of the material of different batches from one manufacturer, and the inconsistency of properties in the case of switching to the purchase of material from another manufacturer, as well as the dependence of properties on seasonal temperature fluctuations;

c) has insufficient thermal stability, limited to the temperature range of 300-3500C^0;

d) foundry cores/molds based on them are characterized by high hygroscopicity;

e) technologies for their application require thermal curing, which increases energy consumption and lengthens the production cycle.

The importance of bonding materials in casting should be noted. The use of binders in various technological production processes is associated with the need to solve many different issues that lie not only at the level of technology but also in the field of economics, ecology, labor safety, etc. type of material. The technical component of this problem is determined by the complexity and variety of processes in which the bond participates at the stages of its life cycle since it is exposed to various influences and undergoes multiphase transformations from a bulk liquid (usually) the state of gasification during thermal destruction at the casting stage. molds in the foundry.

In the foundry, bonding materials are a defining component of the technological process, since the quality of the casting depends on the state of their quality, and therefore the final performance of the foundry.

The disadvantages of lignin-containing binders were mentioned, but they have a set of positive properties that are not mentioned. According to these indicators, they significantly exceed the existing imported resin binders:

a) the sources of raw materials for their production are domestic enterprises [3,7,8];

b) the cost of lignosulfonate binders is incommensurably less than liquid TLS for resin materials [2,9];

c) technologies based on them are environmentally friendly: during transportation, use, and disposal [7,10,11];

d) simplicity during storage: they do not require special regimes; they have a long shelf life [7,10];

e) domestic foundries have many years of positive experience in their use [7].

To understand, the significance and prospects of using lignin products, it is advisable to analyze the main trends in the development of foundry binders.

Binders, based on technical lignin, can be attributed to the biopolymer group of binders, which are traditionally and especially actively developed by the countries of the European Union [12, 13]. The reason for the activity is associated with the tightening of requirements for sanitary and hygienic working conditions in foundries and the overall environmental safety of foundries. This is reflected in the materials regulating this aspect of their functioning [14], and strengthened in the directive of 2010. [15], which strictly regulates the use of phenolic resin materials, which account for 90-95% of modern foundry binders. This is due to numerous studies that have revealed the negative impact of these materials on the health of production personnel [16], and the population living in areas where enterprises are using these materials [17, 18].

The specified directive [15] assumes the complete elimination of such resin binders from the technological production cycle. This led to research aimed at finding alternatives. In particular, compositions are proposed based on protein materials [19], based on starch [20], waste of various industries [21, 22]. Their common disadvantage is the limited raw material base in combination with the high initial cost of individual starting components (starch), in this regard, binders based on technical lignin, in particular on TLS, could compensate for these disadvantages.

Let's Consider Lignin-Containing Materials as a Basis for Creating New Foundry Binders

By its genesis, lignin performs the function of bonding individual elements of plant tissue and ensures the tightness of cell walls, and due to the pigments in it, it determines the shade of lignified tissue. It is located in the nodes of the intercellular space and in the cell walls, providing a strong adhesion of cellulose fibers. This positioning leads to the provision of strength - "wooding" of plant tissue.

The lignin polymer is formed at the stage of growth - lignification of the plant, after the formation of the plant cell in the intercellular space and directly in the cell wall itself.

The genesis of lignin explains the specifics of its structure and multifactorial influence on the formation of the structure and chemical composition. This entails difficulties in the process of technological processing of plant raw materials, explains the impossibility of extracting natural lignin from plant tissue in its natural, natural state. For this reason, there is a distinction between "protolignin" - a substance found directly in the plant and material - a product formed as a result of a combination of technological influences on the delignification of plant raw materials.

It should be emphasized that lignin is not produced purposefully according to rigidly established standards, but lignin-containing substances are obtained, which, as a rule, are a large-tonnage waste of various industries. This, in turn, predetermines the uncertainty of the chemical composition, polymolecular structure, and molecular weight distribution of the resulting lignin products. In the process of physicochemical action on plant tissue, regulated by the specific processing technology and the type of initial plant material, the molecular weight of lignin is transformed, due to a decrease several times, its chemical activity, consistency, and consistency change. properties change.

Chemically, lignin is not an individual chemical substance but is a composition of aromatic polymers of a related structure. The true, empirical, or gross formula of lignin can be represented as $C_{288H318}O_{102}$ [24]. The general view of the lignin material can be presented in the form of a diagram - a structural formula (see Figure-2). Its structural elements are phenyl-propane units, i.e. structural units that are derivatives of phenyl propane.

There are technical forms of lignin materials found on the market and therefore potential targets for further development: sulfate lignin, sulfite lignin, and hydrolytic lignin. It is these materials that can act as raw materials for the development of new competitive products for various needs. In this regard, lignin-containing materials are a typical representative of functional materials, a promising raw material for the development of new binders for foundry [25].

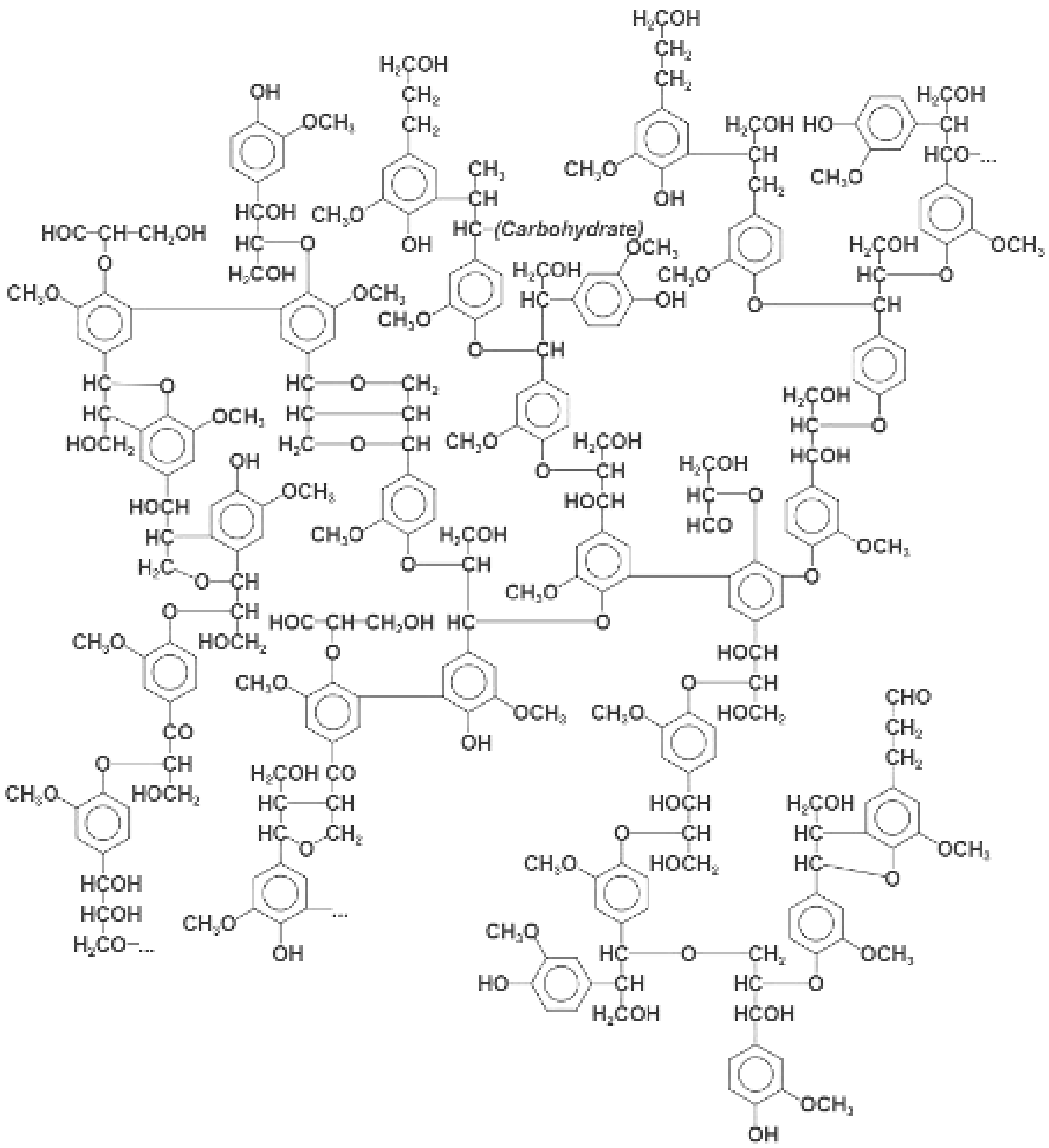


Figure-2. The structural formula of lignin [24].

VOL. 17, NO. 21, NOVEMBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

An Example of Implementation

Let us consider high-energy mechanical action as a tool for improving the quality of technical lignosulfonates. High-energy mechanical treatment of liquid media at disintegrator units can be an effective tool for controlling their properties. It consists of high-energy mechanical action on liquid systems in a certain range of energies. It is used to change the quality indicators of these systems: increasing the reactivity, changing acidity, modifying the structure, etc. Sometimes this treatment is called mechanical activation. The most effective treatment of liquid media is colloidal systems with a wide range of molecular weights.

Many types of organic binders are just such colloidal systems. In particular, these include technical lignosulfonates (TLS). The spread of molecular weights is in the range of 500 mass units to 5,00,000. Probably, by acting on TLS, it is possible to solve the problems of stabilizing their properties, increasing their reactivity, and hence improving the binding capacity, and, consequently, increasing the strength of molds and rods based on them.

The results of a comprehensive study on the effect of high-energy mechanical treatment on disintegrator installations are shown in Figure-3. The effect of mechanical activation on:

- the bonding ability of TLS and its compositions
- change in the pH of the medium;
- change in the molecular weight of the binder compositions.

The final results of the study are shown in(Figure-3c).

Established a general increase in binding capacity lignosulfonate binder compositions (Figure-3a).

Mechanical activation likely facilitates the reaction of structure formation of the binder, due to the formation in the structure of the binder composition of chemically active, radical centers formed as a result of ruptures of molecular structures during mechanical treatment, as evidenced by an increase in the acidity of the solution (Figure-3b), which, apparently acts as initiators of polymerization processes.

The technical characteristics of the experimental industrial disintegrator unit, on which the studies were carried out, are given in Table-1. The laboratory disintegrator unit is designed for processing fine-grained materials or liquids with gas purging. The installation allows for the activation and homogenization of the processed material during impact processing in the range of impact velocities of 30-400 m/s; investigates the processes of changing the consistency of suspensions; to process non-aggressive liquids.

Table-1. Technical data of the laboratory disintegrator unit DU.

1. Initial sizes of particles of materials, mm no more:	
- when using bladed rotors	2.5
- when using finger rotors	0.63
2. Performance on dry quartz sand, g / min, not less than	200
3. Continuously adjustable rotor speed r / s	50x400
4. Number of dispensing units, pcs.	2
5. Number of loading bins, pcs.	2
6. The capacity of the hopper for bulk materials, Dm^3	1.6
7. Capacity of the receiver of bulk materials, dm3	1.6
8. Cooling of electrical spindles to and from the tap working camera network	
9. Cooling water pressure, kPa	50-100
10. Consumption of cooling water, dm3 /	250
11. Power supply - from a three-phase network	
- with voltage, V	380
- with frequency, Hz	50
12. power consumption, kW, no more than	14
13. Lubrication of electric spindles - circulating drip, oil I5A GOST20799-75	
- dripping speed, drops / min	5 - 10
- Oiler volume, dm^3	0.25
14. Overall dimensions, mm, no more	
- disintegrator	880 x 550 x 455
- cabinet complete	1210 x 745 x 100
- converter	1550 x 360 x 570
- remote control	100 x 450 x 1660
15. Weight, kg, no more	
- disintegrator	300
- cabinet assembly	120
- converter	290
- remote control	150

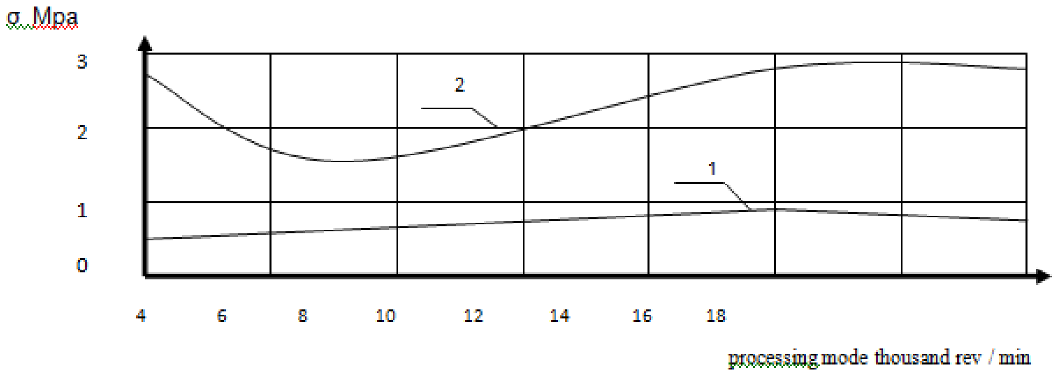
VOL. 17, NO. 21, NOVEMBER 2022 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

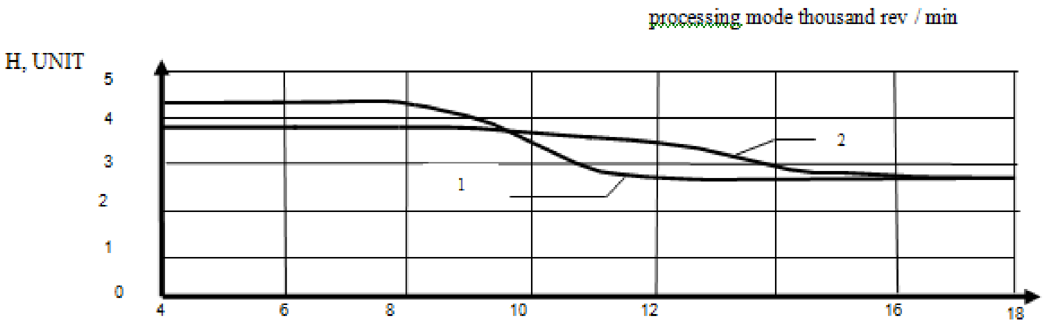
Mechanical processing provides the alignment of the molecular weight, as a result of the destruction of the largest molecular clusters, which leads to the homogenization of the poly-molecular composition of the binder composition (Figure-3c).

In the general case, the effect of high-energy mechanical treatment on highly dispersed colloidal systems leads to an increase in their strength characteristics by a factor of 2.2 (Figure-3a).

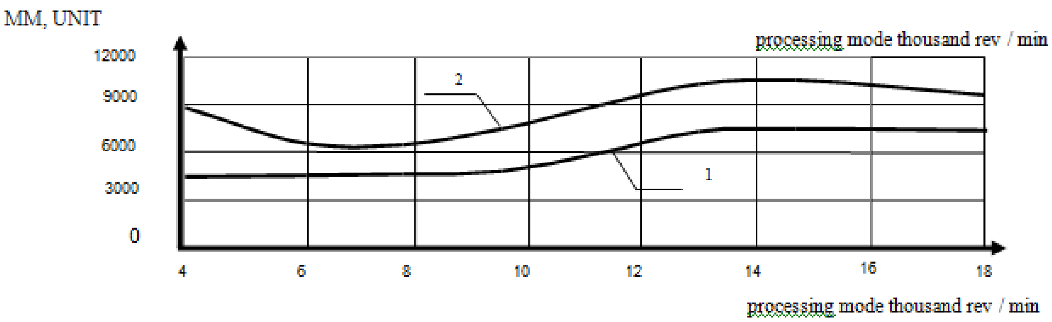
Thus, the use of UD technologies can be effective for increasing the bonding capacity of TLS.



(a)



(b)



(c)

Figure-3. Study of changes in the properties of binding compositions based on TLS as a result of mechanical activation, where, compositions based on:
1 - TLS; 2 - TLS SA: a) change in binding ability; b) change in the acidity of the pH-solution; c) change in molecular weight.

As a result of the research, it was found that exposure to TLS leads to the following results:

Activation of the structural components of the binder - its acidity changes due to the breaks of oligomeric TLS chains, active centers, free radicals appear, which can act as centers of initiation of reactions in the binder; dispersion of its phases, their modification - a change in the molecular weight distribution occurs, the binder passes into a metastable state, which increases the ability to control its properties; an increase in the reactivity of the material being processed, which is explained by the high functionality of the TLS oligo-molecule and opens up opportunities for the formation of spatial network polymers during structure formation, which, integrally, will significantly increase the viscosity index of the binder.

Studies have shown that the use of high-energy processing of TLS (over 4g), calls for an increase in the stability of properties, apparently, this is achieved due to the structural rearrangement of molecular aggregates at the nanoscale. The consequence of this is the improvement of some technological indicators: binding capacity, viscosity, and wettability, which significantly improves the quality of casting processes.

Such processing allows us to identify certain stable and repetitive patterns and draw the following conclusions:

a) There is a general tendency to increase the binding capacity of organic foundry binders during their disintegrator processing. This is typical for binders such as TLS, Universal core binders, and resid oil production. The bonding capacity of TLS increases by 20-25%.

b) An increase in the binding capacity of mechanically activated TLS is explained by their transfer to a met stable state, with increased reactivity, due to the appearance in the structure of the material of radical active centers initiating polymerization processes.

c) The low energy intensity of mechanochemical activation in UD devices predetermines the prospects for the use of high-energy mechanical treatment of LSTs to improve their technological properties, but most importantly, to increase the strength characteristics of the binder.

d) The considered TLS processing method is environmentally friendly.

CONCLUSIONS

Thus, the use of high-energy mechanical processing of TLSs makes it possible to improve their quality (stability, strength, manufacturability), and thereby reduce the content of expensive and environmentally hazardous components of the binder complex of the mixture, for example, phenolic resins or oil binders. The environmental friendliness, simplicity, and efficiency of the proposed technique predetermine the prospects for its application in the foundry.

There is a general tendency to an increase in the binding capacity of organic foundry binders during their disintegrator processing. This is typical for binders such as TLS, Universal core binders, and resid oil production. The bonding capacity of TLS increases by 20-25%.

An increase in the binding capacity of mechanically activated TLS is explained by their transfer to a meta-stable state, with increased reactivity, due to the appearance in the material structure of radical active centers initiating polymerization processes.

The low energy intensity of mechanochemical activation in UD devices predetermines the prospects for the use of high-energy mechanical treatment of TLSs to improve their technological properties, but most importantly, to increase the strength characteristics of the binder.

The considered TLS processing method is environmentally friendly.

The presented results of the development of a foundry binder based on technical lignin (TLS) allow us to talk about the technological possibility of creating binder materials based on lignin materials that can successfully compete with the now widely used synthetic resins on a phenolic basis. Lignosulfonate materials can be considered as a typical example of resource-saving technology and rational use of secondary raw materials produced from a renewable natural resource.

REFERENCES

[1] Electronic resource, information base International Lignin Institute: http://www.ili-lignin.com/aboutlignin.php

[2] 2015. Information resource - Review of the market for lignosulfonates: http://www.infomine.ru/research/36/500

[3] LIM, Huei Yeong, *et al*. 2020. Review on Conversion of Lignin Waste into Value-Added Resources in Tropical Countries. Waste and Biomass Valorization. 1-18.

[4] FUJINO Junichi, *et al*. 2008. Back-casting analysis for 70% emission reduction in Japan by 2050. Climate Policy, 8.sup1: S108-S124.

[5] Al-Saraireh, Falah Mustafa; Svinoroev Y. U. R. I. 2020. Assessment of Casting Binding Materials Based on Modified Technical Lignosulfonates. International Journal of Mechanical and Production Engineering Research and Development (IJMPERD). 10.2: 335-346.

[6] Al-Saraireh, Falah Mustafa; Svinoroev Yuri. Production of High Quality Casting Binders from Materials Containing Lignin. 2015. Bajpai, Pratima. Pulp and paper industry: chemicals. Elsevier.Information resource, the leading manufacturer of foundry binders. Hüttenes-Albertus. Germany, access address: http://www.huettenes-albertus.ru/

[7] Al-Saraireh, Falah Mustafa; Svinoroev, Yuri. 2001. Production of High Quality Casting Binders from Materials Containing Lignin. Beeley, Peter. Foundry technology. Elsevier.

[8] Zaretskiy, Leonid. 2016. Modified silicate binders new developments and applications. International Journal of Metalcasting. 10.1: 88-99.

[9] Serghini, A. 2011. The future of organic foundry binders in Europe. Przegląd Odlewnictwa. Nr 11-12, pp. 548-553 (in Polish). Integrated Pollution Prevention and Control Reference Document on Best Available Techniques in the Smitheries and Foundries Industry. European Commission, 2005, 363r.

[10] 2010. The Directive of the European Parliament and Council of the 24-th November 2010 concerning industrial emissions.

[11] Löfstedt H., Westberg H., Seldén A. I., Lundholm C. & Svartengren M. 2009. Respiratory symptoms and lung function in foundry workers exposed to low molecular weight isocyanates. American Journal of Industrial Medicine, 52, 455-463.

[12] Löfstedt H., Westberg H., Seldén A. I., Rudblad S., Bryngelsson I. L., Ngo Y. & Svartengren M. 2011. Nasal and ocular effects in foundry workers using the Hot Box method. Journal of Occupational and Environmental Medicine. 53, 43-48.

[13] Löfstedt H., Westberg H., Seldén A. I., Bryngelsson I. L. & Svartengren M. 2011. Respiratory symptoms and lung function in foundry workers using the Hot Box method - a 4-year follow-up. Journal of Occupational and Environmental Medicine. 53, 1425-1429.

[14] Eastman J. 2000. Protein-based binder update: Performance put to the Test. Modern Casting. No. 10.32-34

[15] Zhou X., Yang J. & Guohiu Q. 2007. Study on synthesis and properties of the modified starch binder for foundry. Journal of Materials Processing Technology. 18.407-411. DOI: 0.1016 / j.jmatprotec.2006.11.001.

[16] GUO, Xiaoying, *et al*. 2012. Sorption of four hydrophobic organic compounds by three chemically distinct polymers: role of chemical and physical composition. Environmental science & technology. 46.13: 7252-7259.

[17] Patterson, M. & Thiel, J. 2010. Developing Bio-Urethanes for No-Bake. Foundry Management & Technology.

[18] Antonio Pizzi, Milena Properzi, Jean-Michel Leban, Michela Zanetti. 2003. Frederic Pichelin Mechanically-induced wood welding / Maderas. Ciencia y tecnología. 5(2): 101-106.

[19] Kuleznev V. N. Chemistry and Physics of Polymers. Textbook. Manual for chem. - technol. universities. / V. N. Kuleznev, V. A. Shershnev - M. Doe. 2014. p. 312.

[20] LI Tao, Takkellapati Sudhakar. 2018. The current and emerging sources of technical lignins and their applications. Biofuels, Bioproducts and Biorefining. 12.5: 756-787.