UDC 676.056:621.3
DOI: 10.17238/issn0536-1036.2019.5.188

REDUCTION OF ENERGY CONSUMPTION OF PAPER AND CARDBOARD MACHINES IN PRODUCTION OF GLUED PAPER AND CARDBOARD

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The objective of this research was to conduct studies of the influence of the sizing complexes dimensions and rosin sizing methods proceeding in the modes of homocoagulation and heteroadagulation on the temperature regime of paper and cardboard drying. The drying regime ensures the sintering and melting processes of coarse (existing technology) and fine (developed technology) sizing complexes with the formation of a hydrophobic film on the surface, responsible for such values indicators for glued types of paper and cardboard, as the degree of sizing by the bar method and absorbency with one-sided wetting. Coarse electroneutral sizing complexes gauged 4200–6000 nm are formed in the second phase of electrolyte coagulation of hydrodispersions of modified rosin (HMR). The ratio of HMR : electrolyte is 1: 3. The rosin sizing process takes place in the mode of homocoagulation, since such complexes are not able to distribute evenly and adhere firmly to the surface of the fibers and the hydrophobic film formed of them is heterogeneous in thickness and area. Fine sizing complexes have a size of 180–220 nm and an electrokinetic potential from +30 to +50 mV. They are peptized particles formed from coagulates (2000 nm), first formed in the first area of electrolyte coagulation of HMR, when the ratio of HMR : electrolyte (first batch) is 1 : 1, and then subjected to further disaggregation (peptization) into the presence of peptide ions Al^{3+}, introduced into the pulp with the second portion of the electrolyte in a ratio of 1 : 0.8. It has been established that reducing the size of sizing complexes from 4200–6000 to 180–220 nm due to the shift of the rosin sizing process from the homocoagulation mode to the heteroadagulation mode helps to reduce energy consumption in the drying part of paper-making and cardboard-making machines by 2–3 % or more. This process is facilitated by lowering the temperature of not only the last 4–6 drying cylinders located at the end of the second group – from 130 to 115–120 °C, but also the first 2–4 drying cylinders of the third group – from 115 to 100–105 °C.
For citation: Chernaya N.V., Fleisher V.L., Bogdanovich N.I. Reduction of Energy Consumption of Paper and Cardboard Machines in Production of Glued Paper and Cardboard. *Lesnoy Zhurnal* [Forestry Journal], 2019, no. 5, pp. 188–193. DOI: 10.17238/issn0536-1036.2019.5.188

Keywords: glued paper, cardboard, paper machine, homocoagulation, peptization, power usage, drying paper and cardboard.

Introduction

At present, the global cellulose and paper industry produces a varied range of glued paper and cardboard, characterized by consumer properties such as hydrophobicity, strength, etc. [4]. They are widely used for documents and archival materials production in chemical, electrical and radio-industries, as well as in printing, furniture-, food-, construction-, automotive-, tractor- and other sectors of industry. In this case, the current trend of cellulose and paper industry is characterized by a need to increase production output and reduce its costs [9, 11, 13].

A distinctive feature of glued paper and cardboard production is a need to use sizing agents (e.g. neutral and highly resinous hydrodispersions of modified rosin (HMR)) and electrolytes, mainly aluminum hydroxocompounds [7, 10]. Traditional technology of their application is based on the sequential introduction of HMR required quantities and electrolyte solution (aluminum sulfate) with the formation of sizing systems in 3–6 %-ing fiber suspension [3, 5]. From the obtained paper pulp (dispersed system) after diluting it with water to 0.1–0.8 % concentration, paper and cardboard are produced by water removal on the frame of paper (PM) and cardboard (CM) machines, followed by implementation to the ordinary stages of pressing and drying till a moisture content of 5–7 %. A special role is played by temperature drying of paper and cardboard, providing melting and sintering of sizing complexes with a formation of hydrophobic film on the fiber surface. Its thickness and homogeneity depend significantly on the dispersion of present sizing systems, the degree of their retention in the structure of paper and cardboard, and the homogeneity of their distribution on the surface of the fibers [6, 12].

It should be noted that drying temperature mode of paper and cardboard is making a significant impact on the intensity of the melting processes and sintering sizing systems [2, 3] and, therefore, on the hydrophobicity of production output. Technology of glued types of paper and cardboard production is energy intensive due to the need to remove from the wet paper web of 50–55 % water by evaporation in the dryer section of PM and CM and provision with the completeness of the processes of sintering and melting of sizing complexes with the formation of hydrophobic film on the surface. While passing of paper and cardboard web through a dryer section of PM and CM its dryness should be increased from 40–42 to 93–95 %.

Our studies [1, 2] have shown that the degree of retention of sizing complexes in the structure of paper and cardboard essentially depends not only on the particle size and ξ-potential, but also on the nature of the distribution and strength of their fixation on the fiber surface. A common use of technology HMR sizing fiber suspension is based on the formation of electro-neutral coagulums, aggregating, as established by us [2], in the second region of rapid coagulation of HMR in different-sized coarse coagulates with the size of 4200–6000 nm and more [8]. The latter are not able to be uniformly distributed and firmly fixed on the fiber surface. Therefore, the sizing process in homocoagulation mode is accompanied, on the one hand, by a low degree of retention of sizing complexes in the structure of paper and cardboard, not to exceed 58 % [2] and, on the other hand, by the need to raise the temperature in the second group of drying cylinders to 130 °C [3].

Usually dryers for PM and CM are divided into three groups. In the first group there is a gradual increase in temperature from 60 to 105 °C, allowing the removal of the “free” water from paper and cardboard structure. The second group of drying cylinders consists of two parts: in the first part of dryers the removal of “free” water completes, while in the second part sintering and melting of sizing complexes occur, thereby giving the finished product the required degree of hydrophobicity, and for this, the temperature is gradually increased from 115 to 130 °C. In the third group of drying cylinders processes of drying and hydrophobization of paper and cardboard are terminated, and the temperature decreases from 130 to 60 °C.

Known ways to reduce energy consumption of paper and cardboard machines are based on the improvement of its drying section by changing the supply of steam to the drying cylinder, by correction of steam distribution scheme and condensate removal, by the use of specially designed ventilation systems to improve moist air removal, by additional drying of siccative cloth with warm air, by the use of infrared rays to speed the paper web heating, by the installation of additional hot suction press in the drying part of paper and cardboard machines, etc.

The main outstanding issues in the operation of paper and cardboard machines is high energy consumption spending to dry paper and cardboard, resulting in a significant increase in the cost price of production output. Therefore the problem of reducing energy consumption of paper and cardboard machines in the production of glued paper and cardboard is of current importance from scientific and practical points of view.

One of the most promising ways to reduce energy consumption in the drying part of paper and cardboard machines is, in our opinion, the method based on in-intensification of melting and sintering of sizing complexes by reducing their size and to ensure a uniform distribution on the surface of the fibers.

The purpose of research is scientific rationale and development of the method to reduce energy consumption at paper and cardboard drying step with no additional cost for the improvement in the dryer section of paper and cardboard machines by reducing the dimensions of sizing complexes and ensure even distribution of the monolayer on the surface of the fibers.

Results of research and discussion

To achieve the objectives the work was carried out in two stages: in the first stage of the process it has been studied the effect of electrolytic coagulation flowing in the first and second regions of coagulation, the dispersion and ξ-potential sizing complexes (coagulates); in the second phase it has been examined the effect of temperature mode of paper and cardboard drying on the hydrophobicity and durability of paper and cardboard.

We have established that while colloid-chemical interaction of negatively-charged particles of the dispersed phase of HMR and positively charged ions of the electrolyte can be formed not only the traditional electro-neutral coagulums (according to existing technology – in the field of critical values of ξ-potential in the second area of rapid coagulation HMR), from which were formed coarse sized coagulates 4200–6000 nm and greater, and the positively charged particles pregelatinized (the developed technology – in the peptization) the size of 180–220 nm. To get the last they must first be in the first area of rapid coagulation of HMR get coagulates with dimensions not exceeding 2000 nm (they can pregelatinized), and then ensure their peptization (disaggregation) by adding to the dispersion system of electrolyte solution (aluminum sulfate) containing the necessary amount of aluminum hydroxyl compounds in the form of hexa-aqua-aluminium ions $Al(H_2O)_6^{3+}$.

Below there are the results of our comprehensive research on the effect of dispersion of sizing complexes for sizing of paper and cardboard in homo-coagulation modes (option 1 – the existing technology) and heteroadagulation (option 2 – developed technology) [11, 12].

The developed technology (option 2) compared with the existing one (option 1), as can be seen from the table, provides for the improvement of the hydrophobic and mechanical properties of paper (120 g/m^2) and cardboard (340 g/m^2).

It should be noted that the role of sizing complexes can perform coarse electroneutral coagulates (option 1) or fine-dyspersated pregelatinized positively charged particles (option 2).

Effect of the sizing and drying temperature on the properties of paper and cardboard

Parameter	Option 1	Option 2
Terms sizing of paper and cardboard		
View HMR	Neutral hydrodispersion TM	High resin dispersion TMVS-2H
Consumption HMR, kg/t	15	15
View sizing complexes	Coagulate	Particles pregelatinized
Dimensions of sizing systems, nm	3250–4370	180–200
Sizing mode fiber suspension	Homoadagulation	Heteroadagulation
pH of the mass in the headbox paper and board machines	4.8–5.2	6.5–7.2
Temperature conditions of drying of paper and cardboard		
The temperature in the first group of drying cylinders, °C	Rises from 60 to 105	Rises from 60 to 105
Temperature of the second group of drying cylinders, °C	Rises from 105 to 130	Rises from 105 to 115–120
The temperature in the third group of drying cylinder, °C	Is reduced from 130 to 40	Is reduced from 115 to 40
The processes occurring during drying of paper and cardboard		
Temperature 60–80 °C	Evaporation of water	Evaporation of water
Температура 80–90 °C	Evaporation of water	Evaporation of water, sintering peptizi-plated particles
Temperature 90–115 °C	Evaporation of water, fusion peptideized particles	Evaporation of water, melting coagulates
Temperature 115–130 °C	Evaporation of water,melting coagulates	–
The quality of paper and cardboard		
Degree of sizing bar-method, mm	1.6–1.8	2.4
Absorbency at unilateral wetting process, g/m^2	22–30	10–12
Breaking length, m	5700–5850	7600–7800
Tensile index, H·m/g	60–62	78–79
Energy absorption at break, J/m^2	47–48	75–80
Young's modulus (modulus of elasticity), GPa	5.3–5.5	7.8–8.0
Stiffness at break, kN/m	500–510	680–710
Stiffness index at break, kN·m/g	6.5–6.7	9.9–10.1

It is seen that in contrast to the implementation of option 1, option 2 can decrease the drying temperature from 130 to 110–115 °C from the middle of second group and in the beginning of the third group of drying cylinders.

Comparative analysis of the data presented in the table allows to give preference to option 2 and to reject option 1. This is explained by energy consumption reduction in the drying step of glued paper and cardboard in the dryer section of paper and cardboard machines [3]. The achieved effect is due to reduced dimensions of sizing systems and to increase their ability to process the melting and sintering. All this confirms the expediency of changing the sizing process of paper and cardboard from homocoagulation mode to the mode of heteroadagulation of pregelatinized particles [1]. This is evidenced by a decrease in temperature on the last 4–6 drying cylinders located in the second group from 130 to 115–120 °C and on the first 2–4 drying cylinders of the third group from 115 to 100–105 °C.

Conclusion

Therefore replacing the process of sizing paper and cardboard in the mode of homocoagulation with the mode of heteroadagulation of peptized particles makes it possible to reduce the temperature of the drying cylinders by 10–15 °C at the end of the second (4–6 cylinders) and the beginning of the third (2–4 cylinders) groups. This demonstrates the practical possibility of solving a current problem, aimed at reducing (by 2–3 % or more) the energy consumption of paper-making and cardboard-making machines in the production of glued types of paper and cardboard.

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СНИЖЕНИЕ ЭНЕРГОПОТРЕБЛЕНИЯ БУМАГОДЕЛАТЕЛЬНЫХ И КАРТОНОДЕЛАТЕЛЬНЫХ МАШИН ПРИ ПРОИЗВОДСТВЕ КЛЕЕНЫХ ВИДОВ БУМАГИ И КАРТОНА

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Изучено влияние размеров проклеивающих комплексов и способов канифольной проклейки в режимах гомокоагуляции и гетероадагуляции на температурный режим сушки бумаги и картона, обеспечивающий спекание и плавление крупнодисперсных (традиционная технология) и мелкодисперсных (разработанная технология) проклеивающих комплексов с образованием на поверхности волокон гидрофобной пленки, отвечающей за степень проклейки по штриховому методу и впитываемость при одностороннем смачивании клееных видов бумаги и картона. Крупнодисперсные электронейтральные проклеивающие комплексы, имеющие размер 4200…6000 нм, образуются во второй области электролитной коагуляции гидродисперсий модифицированной канифоли (ГМК). Соотношение ГМК : электролит – 1 : 3. Процесс канифольной проклейки протекает в режиме гомокоагуляции, поскольку такие комплексы не способны равномерно распределяться и прочно фиксироваться на поверхности волокон, а образовавшаяся из них гидрофобная пленка является неоднородной по толщине и площади. Мелкодисперсные проклеивающие комплексы имеют размер 180…220 нм, их электрокинетический потенциал 30…50 мВ. Они представляют собой пептизированные частицы, образовавшиеся из коагулятов (2000 нм), сформированных сначала в первой области электролитной коагуляции ГМК, когда соотношение ГМК : электролит (первая порция) 1 : 1, а затем подвергшихся дезагрегированию (пептизации) в присутствии ионов-пептизаторов Al^{3+}, введенных в бумажную массу со второй порцией электролита в соотношении 1 : 0,8. Установлено, что уменьшение размеров проклеивающих комплексов от 4200…6000 до 180…220 нм за счет смещения процесса канифольной проклейки из режима гомокоагуляции в режим гетероадагуляции способствует сокращению энергопотребления в сушильной части бумагоделательных и картоноделательных машин на 2…3 % и более. Это вызвано снижением температуры не только последних 4–6 сушильных цилиндров, расположенных в конце второй группы, от 130 до 115…120 ^{o}C, но и первых 2–4 сушильных цилиндров третьей группы – от 115 до 100…105 ^{o}C.
Для цитирования: Chernaya N.V., Fleisher V.L., Bogdanovich N.I. Reduction of Energy Consumption of Paper and Cardboard Machines in Production of Glued Paper and Cardboard // Лесн. журн. 2019. № 5. С. 188–193. (Изв. высш. учеб. заведений). DOI: 10.17238/issn0536-1036.2019.5.188

Ключевые слова: клееная бумага, клееный картон, бумагоделательная машина, гомокоагуляция, пептизация, энергопотребление, сушка бумаги и картона.

Поступила 22.02.19 / Received on February 22, 2019