УДК 676.18; 676,189

P. I. Pismenskiy, PhD student (BSTU);
Yu. G. Luka, production vice-director (RUE “Plant of Newsprint”, Shklov);
E. V. Dubodelova, senior lecturer (BSTU); **T. V. Solovyeva**, professor, D. Sc. (Engineering) (BSTU)

CHEMICAL ACTIVATION OF ASPENWOOD COMPONENTS IN THE PRODUCTION OF THERMOMECHANICAL PULP

The article represents the results of researches that allow to establish the appropriateness of usage of aspenwood modified by sodium monosulphite as a raw material for thermomechanical pulp (TMP) in newsprint production. Replacement of 30% of sprucewood by aspen using 1% consumption of sodium sulphite permits to achieve strength of samples of unbleached TMP 4510 m, which ensures the highest demands to newsprint. In this case the process of wood grinding accelerates and the reactivity of hemicelluloses and lignin increases.

Introduction. Fiber semiproducts in the form of various types of chip wood pulp are modern widely used raw materials for the production of mass types of paper and cardboard in the most developed countries of the world. Common to the production of various types of wood pulp is the grinding of wood in chips with preliminary thermohydrolytic treatment (presteaming). The most common type of chip wood pulp is thermomechanical pulp (TMP). Raw material base for its production is widely expanding due to the use of various types of waste softwood and soft deciduous wood. Aspenwood, that may be treated as the wood of low liquidity, is of a particular interest in this sense. Its reserves in the Republic of Belarus are quite large – about 150 million m^3, that is 30% of the whole hardwood [1]. It is known that manufacturing of fiber semiproducts from aspenwood and producing paper and cardboard of high quality index is rather problematic [2]. In our opinion the problem can be solved taking into account the particular anatomical structure, physical and chemical properties of aspenwood, and ultrastructure of its key elements. In this case the dimensional characteristics of wood anatomical elements are very important, just on them the parameters of thermohydrolytic treatment and wood grinding in the process of obtaining TMP depend [3, 4].

Main part. In the Republic of Belarus TMP is produced in the process of manufacturing of newsprint at RUE “Plant of Newsprint” in Shklov. At the given enterprise according to the process regulations newsprint is produced from fir-tree TMP with chip grinding on RTS method. This method is based on a combination of a short steaming period of chip (thermohydrolytic treatment) from 10 to 20 s in the temperature range of 160–170ºC, which is created by feeding saturated steam into the chips at a disk mill entrance. The characteristic of such grinding is a high speed of the refiner rotor – 2600 min^{-1}, that is in one and a half time higher than the speed accepted at traditional chip grinding [3].

At such thermohydrolytic processing heat supplied to the chip is distributed mainly in the intercellular space and the wood fibers cavities, therefore cell walls become elastic and there is no excessive breaking of fibers at high grinding speed. Due to this and short thermohydrolytic influence as well, the mechanical strength index of pulp increase while the whiteness of semiproduct does not reduce.

The researches on the establishment of the possibility to use aspenwood in TMP composition while manufacturing newsprint were done at the department of chemical processing of wood UO BSTU and RUE “Plant of Newsprint”.

In this case the pulp was obtained from the composition of chip that included 80–90% of spruce and 10–20% of aspen wood.

Table 1 shows the main features of TMP received after the first (primary) stage of grinding: before, during and after the pilot tests.

Table 1

Key Features of TMP after the first stage of grinding

Composition of chips: sprucewood / aspen,%	Grinding degree, °ShR	Breaking length of paper, m	Fractional composition of pulp, %			
			I (large)	II (aver.)	III (small)	IV (very small)
100/0 (Before pilot tests)	26	2300	61.9	10.8	5.9	21.4
90/10 (During pilot testing)	28	2200	58.3	11.9	6.2	23.6
80/20 (During pilot testing)	30	2200	56.1	12.4	6.4	25.1
100/0 (After pilot testing)	27	2400	59.0	10.2	6.0	24.8

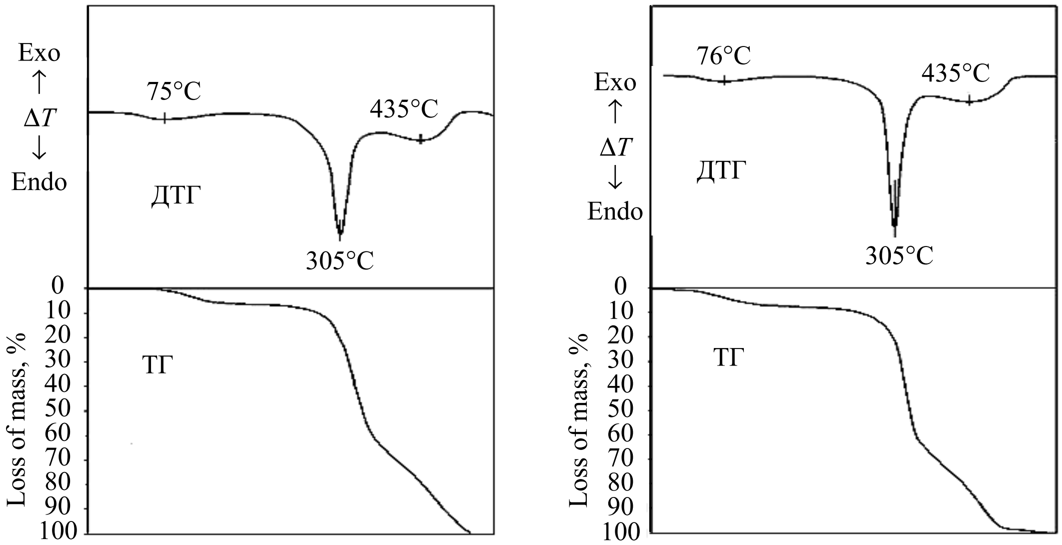
Table 2

Quality index of newsprint produced during the pilot testing

Parametres	Requirements for GOST 6445	Quality index of newsprint			
		Before pilot tests	During the pilot testing		After pilot testing
			Replacing of 10% of spruce	Replacing of 20% of spruce	
Weight 1m^2, g	45.0±1.5	45.6	45.6	45.9	45.8
Breaking length, km long. / later.	3100/	4150/ 1250	4300/ 1050	3850/ 1250	4100/1300
Tearing strength, mN	not less than 196	293	293	249	284
Yellowness, %		8.7	8.8	8.9	8.6
Whiteness, %	not less than 60	60.0	60.0	59.5	60.5
Opacity, %	not less than 95	94.0	93.5	95.0	94.0
Smoothness, s Top/grid	not less than 50/50	43/38	39/38	40/36	42/38

During the testing it was not required to change the operation mode of refiner of the first stage grinding. In the case with replacement of 10% of the spruce by aspen the grinding degree of TMP increased by 2°ShR, the fractional composition of TMP changed in the direction of reducing of the content of large fraction by 3% and the increasing of very small fractions by 3–8%. With the further increase of the aspenwood portion in the composition the changes characterizing the reducing of pulp quality took place. Table 2 shows the quality index of newsprint obtained during the pilot testing.From the data presented in Table 2 it is seen that replacing of 10% of the spruce by aspen when producing TMP did not influence the strength and optical properties of newsprint. At replacement of 20% of spruce by aspen, when producing TMP with subsequent manufacturing of newsprint, strength characteristics of newsprint decreased. However, their values fully met the requirements of GOST 6445 for all paper grades including grade O. Optical properties of paper virtually unchanged as compared with these that are achieved at manufacturing of paper only from sprucewood TMP.

However, looking for the ways to improve the strength of TMP received on the basis of chip composition including aspenwood was also of a great interest. The activation of components of aspenwood in the process of thermohydrolytic treatment of chips before grinding by the use of additional chemical injection gave positive results.



a *b*

Fig. Thermograms of TMP samples
a – from the original aspen; *b* – from aspenwood treated by chemical reagent

The results of complex thermal analysis of the pulp samples processed by chemicals with 3% consumption to a. d. timber indicate the changes of the structure of the wood fibers in the process of activation of aspenwood components while producing TMP. TMP obtained without the use of chemicals was taken as a comparative sample.

Samples were prepared under the same conditions of thermohydrolytic processing and grinding. Chips were steamed in the autoclave at 160°C (vapor pressure 500 kPa) for 15 min. Steamed chips were ground for 10 min at 1600 min^{-1} in a laboratory set LCR-1 including a hydropulper LH-3 and HDM-3 mill.

Thermograms are obtained on the derivatograph of MOM firm (Hungary) type OD-103. They are shown and analized in the figure.

(Thermal effects shown in the DTA curves turned to be lessinformative because of the high thermal activity of the organic components that make up the wood [5]). At DTH curves three exothermic peaks are easily observed, the first is in the range of 75–80ºC, the second – 300–305ºC, the third – 435–460ºC.

The first peak, very slight, is due to the evaporation of residual water in the samples. The second is characterized by the maximal rate of weight loss that is about 40%. In this area pyrolysis of the polysaccharide part of wood takes place. The third peak is due to thermal destruction of lignin [5]. From the presented illustration it is shown that for the TMP samples obtained with the using of chemical treatment the temperature, at which the maximal rate of destruction is observed, is by 20–30ºC lower than that of a comparative sample. This fact confirms the destructive changes in the polysaccharide part of the wood caused by exposure of chemicals on it.

The kinetic parameters of the process of the thermal decomposition of wood were determined by the calculation of the activation energy (U), performed by Broido method, modified by N. R. Prokopchuk concerning the thermal destruction of polysaccharides and lignin [6, 7]. The obtained values of U for the destruction of polysaccharides in the samples are presented in Table 3.

Table 3

The activation energy of thermal destruction of wood components

TMP sample	Units of polysaccharides, kJ/mol	Units of lignin, kJ/mol
original aspen	78.6 ± 1.9	48.4 ± 1.2
aspenwood treated by chemical reagent	74.8 ± 1.8	58.0 ± 1.4

Table 3 shows that the activation energy necessary to initiate the destrucion of polysaccharides for the sample of original aspen wood is about 80 kJ/mol. (This is comparable with the U for sulfite cellulose (90 kJ/mol), this fact once more confirms the rightfulness of the address band assignment.) For the pulp treated by chemicals U value decreases, this fact showed that the destruction took place. It is known that during grinding of the wood subjected to thermohydrolytic treatment there is a separation of fibers mainly on the median plate and the outer layer of the secondary membrane [8–10]. In these layers there is the greatest concentration of lignin. According to the data of thermal analysis lignin under the influence of chemicals changed, its thermal stability increased, that is, during the manufacturing of TMP it was not decomposed, it remained on the surface of the fibers and served as a binder in the process of paper sheet making. This is indicated by the data in Table 4 containing the results of the testing of the paper samples received from TMP based on aspenwood with chip processing during thermohydrolytic treatment before its grinding.

Table 4

The dependence of TMP quality on the chemicals consumption

Chemicals consumption, %	Grinding degree of pulp, °ShR	Physical and mechanical properties of paper samples	
		Breaking length, m	Porosity, cm^3/min
0	59	2650	500
1.0	61	4510	310
3.0	62	5370	155
5.0	62	5830	95
7.0	74	5640	60
10.0	79	9300	30

It is clear from Table 4 that at 3% chemicals consumption the strength of paper of 50 g/m^2 weight increased more than two times compared with the samples obtained without the use of chemicals. Simultaneously the porosity index decreased from 500 to 155 cm^3/min, e. i. the density and uniformity of paper sheet increased. With the further increasing of chemicals consumption up to 10% physical and mechanical properties of paper continued to improve.

Conclusion. The results of experiments allow us to make recommendations on the partial replacement of sprucewood by aspenwood in the manufacturing of thermomechanical pulp and the appropriateness of usage of the additional treatment of chip by chemicals before grinding for improving strength of paper received from it.

References

1. Пузырев, С. С. Современная технология механической массы: в 2 т. / С. С. Пузырев. – СПб.: ООО «ВЕСП», 1995–1996. – Т. 2: Механическая масса из щепы, 1996. – 236 с.

2. Соловьева, Т. В. Технология древесной массы из щепы / Т. В. Соловьева, В. Э. Шульга. – Минск: БГТУ, 2008. – 136 с.

3. Пузырев, С. С. Технология целлюлозно-бумажного производства. В 3 т. Т. 1. Сырье и производство полуфабрикатов. Ч. 3. Производство полуфабрикатов / С. С. Пузырев [и др.]. – СПб.: Политехника, 2004. – 316 с.

4. Производство волокнистых полуфабрикатов из лиственной древесины / А. И. Бобров [и др.]. − М.: Лесная пром-сть, 1984. − 248 с.

5. Куземкин, Д. В. Разработка технологии волокнистого полуфабриката на основе дефибраторной массы для использования в композиции бумаги и картона: дис. ... канд. техн. наук: 05.21.03 / Д. В. Куземкин. − Минск, 2004. − 152 л.

6. Broido, A. A Simple / A. Broido // J. Polym. Sci. Part A. − 1969. − Vol. 7, № 3. − P. 1761−1763.

8. Прокопчук, Н. Р. Определение энергии активации деструкции полимеров по данным термогравиметрии / Н. Р. Прокопчук // Пластические массы. − 1983. − № 10. − С. 24−25.

9. Азаров, В. И. Химия древесины и синтетических полимеров / В. И. Азаров, А. В. Буров, А. В. Оболенская. − СПб.: СПбЛТА, 1999. − 628 с.

10. Закис, Г. Ф. Методы определения функциональных групп лигнина / Г. Ф. Закис, Л. Н. Можейко, Г. М. Телышева. − Рига: Зинатне, 1975. −176 с.

11. Фенгел, Д. Древесина (химия, ультраструктура, реакции) / Д. Фенгел, Г. Вегенер. − М.: Лесная пром-сть, 1988. − 512 с.

Received 23.03.2012