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METHODS FOR DETERMINATION OF PULP CHIPS PREHEATING RATE IN FIBERBOARD MANUFACTURING

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ABSTRACT:
Quality of pulping process is essential for the final quality of fiberboards, for the total energy input, and for the percentage yield of wood raw material. More then 70% of the mills all over the world are using “Asplund” thermo-mechanical pulping method. In that method, in order to reduce pulping energy, pulp chips are preheated. During the preheating are accomplished important physical, physic-chemical and chemical alterations of wood structure. The properties of the pulp, independently from the wood species, are in correlation whit preheating rate. In the present report are scrutinized heating processes of pulp chips and it is substantiate indispensability of experimental determination of pulp chips preheating rate in fiberboard manufacturing.
KEYWORDS:
fiberboards; pulp chips; defibration; preheating; pulp.

1. INTRODUCTION

The data source for fiberboards manufacturing in EU [5] indicated that the production rate didn’t meet the requirements of the market. So the production should be increase. This can be achieved in two ways: by building new manufacturing installations and/or by correct determination of technological parameters.

In fiberboards manufacturing the general determinative technological components are pulping and hot pressing processes [7,8]. And until the hot pressing processes were object of many researches, the pulping processes are less studied. The fiber flow is incoming for the fiberboard manufacturing. It forms so called down flow. The pulping process determinate the main part of energy input in the mill, raw material yield and it is very important for the final fiberboards quality.

In world wide the 70% of pulp is produced by defibration /Asplund method/ [2,4]. In this method the refining takes advantage of the beneficial effects of thermal treatments of the pulp chips on pulp properties. The treatment is achieving whit steam at elevated pressure and temperature.

The preheating of pulp chips of various wood spices must be accomplished at optimum rate. This imposes the indispensability of thoroughness study and optimization of pulp chip preheating rate in fiberboards manufacturing.

2. GENERAL PRINCIPLES

Fig.1 presents the general model of wet process fiberboard production, as a subject of technological control. In the model the aggregates are presented as transformable blocs, accomplishing mechanical, thermal, hydraulic and compounded processing of the materials. This model, in conjunction whit description of processes, data for the stability of quality indicators of the production and technological variables, affirmative in production mill, specifically “Lesoplast” Trojan, and the matrix of the flows /tabl.1/, presenting cumulative information which analyze is allowing to be elaborated strategy for control of technological processes.

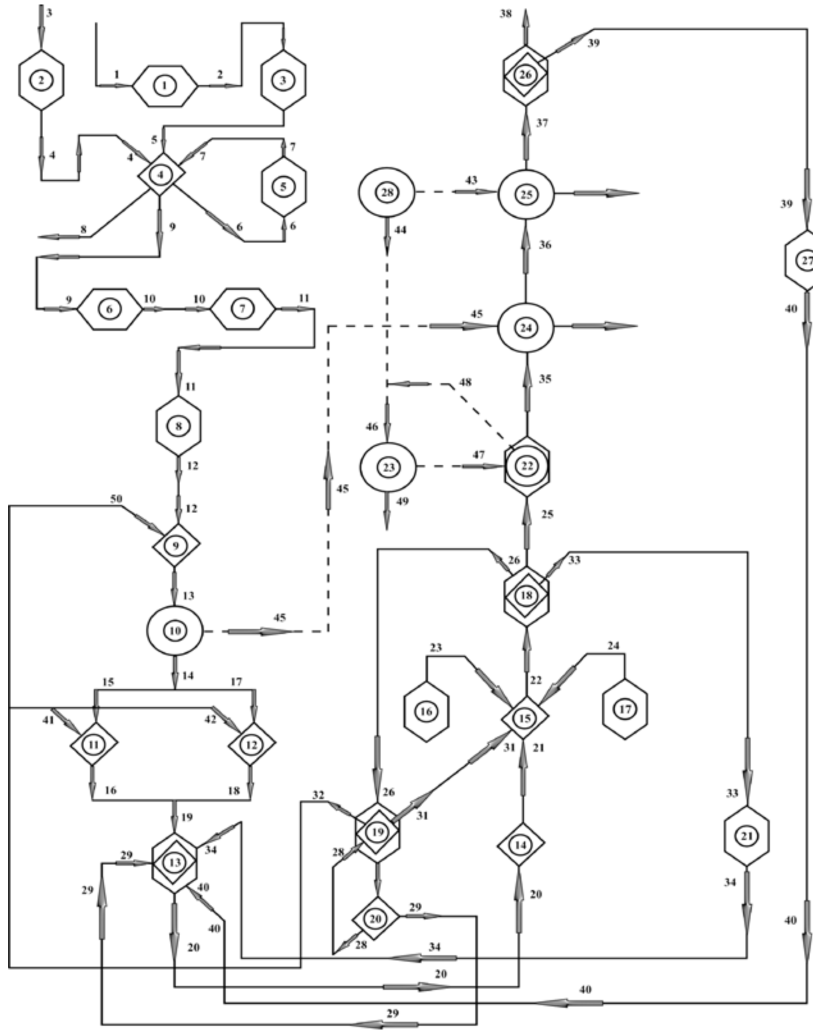


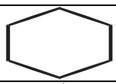
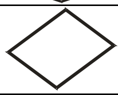
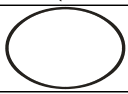
Figure1. General model of wet process fiberboards manufacturing

From the presented model is clear that the fiber flow is incoming for the fiberboards manufacturing line. And affirmatively the capacity of the mill and quality of the fiberboards are in strong correlation whit the quantity and quality of the pulp.

The properties of the pulp, independently from the wood species, are in correlation whit preheating rate [4,9].

Table1. Matrix of wet process fiberboards manufacturing

Abbreviations	
(1) (2) ... (28)	Number of bloc
1, 2, ..., 50	Number of flow;
“+”	Incoming flow;
“–“	Out coming flow.

Number of bloc	Name of the bloc	Number of flow
1	**2**	**3**
1	Pulpwood	+1 22
2	Pulp chips	+3 24
3	Chop machine	+2 25
4	Grading	+4 +5 +7 26 28 29
5	Disintegrator	+6 27
6	Cyclone	+9 210
7	Hopper	+10 211
8	Metal separator	+11 212
9	Chip washer	+12 +50 213
10	Defibrator	+13 214 245
11	Cyclone 1	+15 +41 216
12	Cyclone 2	+17 + 47 218
13	Unregulated slurry vat	+19 +29 +34 +40 220
14	Regulated slurry vat	+20 +30 221
15	Stock tank	+21 +24 +23 +31 222
16	Wax tank	223
17	Resin tank	224
18	Forming machine	+22 225 226 233
19	White water	+26 +29 227 230 231 232
20	Pulp strainer	+27 228 230
21	Pulp shuffle	+33 234
22	Hot press	+25 +47 249 235
23	Pressure accumulator	+46 247 249
24	Board Harden	+39 +35 236
25	Board Temper	+36 +43 237
26	Formatting processes	+37 238 239
27	Hydraulic splitter	+39 240
28	Power-station	+44 243
	Bloc whit two connections /in – out/	
	Bloc whit limited 3 – 4 connections	
	Bloc whit unlimited connections	

As it was said earlier in the paper the 70% of fiberboard mills are using Asplund method. Fig.2. presents "Metso Defibrator" pulping plant for thermo-mechanical pulping [6]. The process sequence follows:

1) From the chip chute the green chips are fed into the screw feeder, which features a conical horizontal feed screw rotating in a conical feed pipe and enforcing considerable compaction of the pulp chips. Compression ratios are variable, but they are high enough so that the moving densified chip plug blocks the escape of steam from the preheater. Splines in the plug pipe prevent the plug from rotating and pressed-out water is removed trough drainage holes. 2) As the compressed chip plug enters the preheater it falls apart in the steam atmosphere. At a given rate of chip removal from the bottom, the preheating time is controlled by the level of the chips in the preheater. This is accomplished by means of a gamma ray level controller, mounted outside the preheater, which senses the fill level and maintains it by regulating the speed of the feeder screw. A higher fill level increase the preheating time. 3) A conveyor screw at the bottom of the preheater feeds the

softened chips into the center of the defibrator mill. This consists of two grinding disks, a stationary one mounted to the housing and a rotating one mounted on the main shaft rotor. The gap between the disks is controlled by adjusting the pressure differential on both sides of an oil-hydraulic piston. 4) The pulp is discharged to the atmospheric pressure through a reciprocating valve discharge chamber.

The defibrator pulping plant is hermetic isolated from the conical feed pipe to reciprocating valve. In that space is ensured from one side continuously chip flow and from the other high pressure (1,1 ÷ 1,4 N/mm²) and temperature (140 ÷ 180° C).

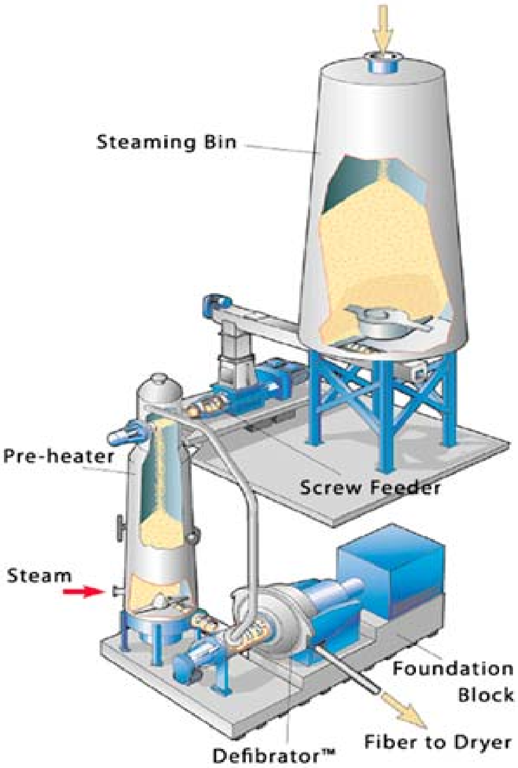


Figure 2. Metso Defibrator

The effect of preheating is discovered from the Swedish engineer Arné Asplund in the middle 1930's. Asplund found that there is a significant drop in the power required to fiberize wood chips when the refiner temperature exceeds 150° C. Theoretical explanation of this phenomena is in structure of wood cell. The thermal softening of lignin allows relative easy mechanical separation of fibers along the middle lamella [1,2].

Trough preheating of pulp chips is aspiring to be achieved:

1) increasing the temperature of whole volume of chips up to 175 – 180°C;
2) softening of the lignin;
3) increasing the water content of the chips.

From theoretical point of view the preheating can be scrutinize as a three dimensional convection of anisotropic capillary-pore body. Trough the preheating in wood are accomplished compound physical, physic-chemical and chemical alterations [3,7].

The preheating is fulfill in an environment of constant temperature and pressure and it is continues in time. The preheating time is determinate by the time heating time of the chips and from the time needed of lignin in the middle lamella to exceed his glass pint. To work out this problem we must to adopt a idealize model: first, the pulp chips is a lamella whit dimensions replied to the conditions – $l > b$; $l > 3\delta$; $b > 3\delta$ /l, b and δ, respectively length, width and thickness of pulp chips; second, all chips are encirclement of steam whit continues pressure and temperature; third, in the symmetrical plane of the chips must be accomplished temperature of given rat; and four, there isn't any heating by diffusion. In that case can be use the equation:

$$\frac{\partial t}{\partial \tau_1} = \frac{\lambda}{c.\rho} . \frac{\partial^2 t}{\partial x^2} = \alpha . \frac{\partial^2 t}{\partial x^2} \tag{1}$$

where:

λ – coefficient of heat conductivity of wood, W/m.K;
c – conductance of wood, kJ/kg.K;
ρ – wood density, kg/m³;
τ_1 – preheating time, s;
x – distance on axes X, m;
α – coefficient of temperature conductivity of wood, m²/s.

Equation (1) is solved by using the criterions of Bio / $B_i = \frac{\alpha}{\lambda}.R$ R = 0,5δ/ and Fourier / $F_o = \frac{a\,\tau_1}{R^2}$ /. The determination, for the taken limits, is:

$$\tau_1 = \frac{F_o.\delta^2.c.\rho}{4\lambda}\text{, s} \tag{2}$$

The real process of heating of pulp chips is more complicated from the scrutinized model. Many of the chips are whit dimension that didn't correspond to the limits and during the process soma heat is imported through diffusion from the wood vessels. Heaping of chips in the preheater and impeding of steam can be account through experimental coefficient k_1, which has value above 1.

The diffusion accelerates heating process. Acceleration value depends from wood spices, conditions of chip's frontal surface, free moister and many etc.

As a result of lower pressure in the wood vessels, steam is penetrating into and started the process of fast diffusion. According to the Poaisle principle, equation of mass interchange is:

$$\frac{d\,M}{d\,\tau_2} = F\frac{d\,x}{d\tau_2}\text{, but } \frac{d\,M}{d\,\tau_2} = \frac{\pi.r^4}{8\mu.l}\Delta p \text{ and } F = \pi.r^2 \tag{3}$$

where:

- F – area of the vessel, m²;
- r – radius of the vessel, m;
- μ – viscose of the fluid, m²/s;
- l – length of the vessel, m;
- Δp – pressure differential, N/m²;
- M – mass of the fluid, kg;
- τ_2 – time of the diffusion, s;

The influence of the diffusion can be accounted in the equation (2) by the experimental coefficient k_2:

$$\tau = \frac{F_o.\delta^2.c.\rho}{4\lambda}.k_1.k_2\text{, s} \tag{4}$$

The determination, for the taken limits, of equation (3), is:

$$\tau_2 = \frac{4\mu.x^2}{\Delta p.r^2}\text{, s} \tag{5}$$

Softening time of the lignin is determinate through the equation:

$$dV = Fdx;\ dQ = q_r Fdx;\ \frac{dQ}{dr} = q_r F\frac{dx}{dr} \tag{6}$$

where:

- V – volume of the lignin, m³;
- Q – heat quantity, J;
- q_r – hidden heat for softening of volume unit, J/m³;
- F – area of the chip, m².

The determination of equation (4) is :

$$\tau_3 = \frac{q_r\,\delta^2}{4\lambda(t_2 - t_1)}\text{, s} \tag{7}$$

where: $t_{1,2}$ are the start and softening temperature, °C.

As it was said before the heating of pulp chips is accomplished simultaneously by convection and diffusion, that's why the duration of the process, is shortened. It must be added and the softening time of the lignin. That's why the duration of the process is impossible to be determinate only by theoretical methods. Equations (2), (4), (5) and (7) are only tentative. But from the other side, because of the reasons scrutinized earlier in the paper, the preheating rates, for the different wood spices and engineered quality of boards, must be determinate correctly. Such pulp chips preheating rates can be determinate only by experimental methods by conducting optimization experiments and solve an optimization problem.

3. CONCLUSIONS

- Under conditions of market shortage of fiberboards production profound analysis, aiming to optimize the technological rates, are indispensable;
- Quality of pulping process is essential for the final quality of fiberboards, for the total energy input, and for the percentage yield of wood raw material;
- Preheating of pulp chips is very important process in engineered pulp production;
- Heat treatment of pup chips, from given wood spices, should be accomplished at optimum rates;
- During the preheating of pulp chips compound process of heat interchanges accrued and because of that the preheating rates can not be determinate only by theoretical methods.

These conclusions are imposing need of experimental analysis, in order to determinate pulp chips preheating rate, to be accomplished.

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