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OPTIMIZATION AND AUTOMATION OF TANNERY PROCESSES – - DELIMING OF WHITE HIDE

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ABSTRACT
Within the optimization of the white hide deliming operation, both plain washing with pure water and chemical processing are concerned. The main goal is to give the answer to when it is suitable to interrupt the washing with pure water (non-chemical deliming) and replace it by washing with a deliming agent water solution (chemical deliming). Our paper, with the use of a mathematical-physical process model, gives the answer to the above mentioned question. Experimental determinations of sorption isotherm, as well as the effective diffusion coefficients are presented. The above mentioned parameters, economical and technological serve as input data for a computer program and the proposal of automatics control algorithm.
Keywords: Optimization, Mathematic modeling, Tannery process, Deliming, Automatic Control

1. INTRODUCTION
Unhaired hide reacts strongly alkali due to the content of sodium sulphide and lime as a result of employing these chemicals in the unhairing process. The alkalinity of raw hide has to be decreased because the following processes proceed in acid conditions. The changes from alkalinity to acidity proceed gradually to prevent the fine fibrous hide structure from being damaged. Sodium sulphide and partly calcium hydroxide are removed by washing with pure water. The rest of the lime is eliminated with the use of auxiliary deliming chemicals due to its strong bond with collagen protein. Deliming agents break bounds between lime and collagen protein, resulting in neutral salts.
There exist many acid reacting chemicals that are able to perform the chemical deliming process. Nowadays, environmentally friendly criteria should he applied to choose from those chemicals. Unfortunately, most of the environmentally friendly deliming agents are more expensive than those used till now (ammonium sulphate for example). For this reason the optimization of the deliming process becomes more topical.
The optimization of the white hide deliming operation concerns both plain washing with pure water and a chemical processing. The main goal is to give the answer to when it is suitable to interrupt the washing with pure water (non-chemical deliming) and replace it by washing with deliming agent water solution – chemical deliming. Our paper, with the use of a mathematical–physical process model, gives the answer to the above mentioned question.

2. THEORY

The exact mathematical model of the processes, especially of the chemical deliming, is too complicated; therefore from the practical point of view we introduce useful criteria and necessary simplifications. The degree of the deliming operation (y) is defined as a ratio of removed lime mass (m) to the total (initial) lime mass in white hide (ms):

$$y = \frac{m}{m_S} = \frac{C_O V_O}{C_S V} = \frac{C_O}{C_S} Na \qquad (1)$$

where we introduce an important technological parameter Na = Vo/V as a dimensionless consumption of water or water solution of deliming agents. Another very important parameter is Fourier's number (dimensionless time) (Fo) defined by the following equation where:

$$Fo = \frac{k\tau}{b^2} \qquad (2)$$

$$k = \frac{D}{1+K} \qquad (3)$$

When we accept that the practical equilibrious process is reached for *Fo~1*, the operation time thus can be easily estimated from . Parameter k in the equation of (3) is a modified adsorption coefficient which can be estimated from the adsorption isotherm t, e, and the dependence of adsorbed lime concentration (*CA*) on hide and on the free solution lime concentration (*C*) in the equilibrium conditions. Langmuir's isotherm is commonly used:

$$C_A = \frac{AC}{1+BC} \qquad (4)$$

And for *K*:

$$K = \frac{dC_A}{dC} = \frac{A}{\left(1+BC\right)^2} \qquad (5)$$

K equationuals zero in the case of chemical deliming, i.e. *k=D*, equation. (3).
Main operating costs (N_{iN}, N_{iCH}) are given by the sum of costs of electric power for rotation by electric motors and the cost of consumed washing water (non-chemical deliming) or water solution of a deliming agent (chemical deliming) for an *i* – step operation.

$$N_{iN} = P\tau_{iN} K_E + K_V V_{oi} \qquad (6)$$

$$N_{iCH} = P\tau_{iCH} K_E + K_{CH} V_{oi} \qquad (7)$$

$$N_N = \sum_{i=1}^{n} N_{iN} \qquad (8)$$

$$N_{CH} = \sum_{i=1}^{n} N_{iCH} \qquad (9)$$

By combination of the equationuations we received the operation times of deliming process:

$$\tau_{iN} = \frac{b^2\left[\left(1+Bc_i\right)^2 + A\right]}{D\left(1+Bc_i\right)^2} \quad (10)$$

$$\tau_{CH} = \frac{b^2}{D} \quad (11)$$

2.1 Deliming degree calculation

a) *Non-chemical de-liming*

Step 1; balance equationuation:

$$C_S V = C_{O1}V_{O1} + C_1V_1 + Vc_{A1} \quad (12)$$

By employing of the (4) we get:

$$c_S V = c_{o1}V_{o1} + V\varepsilon c_{o1} + \frac{A\varepsilon c_{o1}V}{1+B\varepsilon c_{o1}} \quad (13)$$

By solving of the (13) we receive

$$C_{01} = \frac{\varepsilon C_S B - Na_i - \varepsilon A - \varepsilon + \sqrt{\left(\varepsilon C_S B - Na_i - \varepsilon A - \varepsilon\right)^2 + 4C_S P}}{2P} \quad (14)$$

Total non-chemical deliming degree y_N is the sum of degrees in an i – step operation:

$$y_N = \sum_{i=1}^{n} y_i = \sum_{i=1}^{n} \frac{Co_i V_{oi}}{V \cdot C_S} = \sum_{i=1}^{n} \frac{Na_i Co_i}{C_S} = \frac{1}{C_S}\sum_{i=1}^{n} Co_i Na_i \quad (15)$$

$Na_i = 1$, for $i = 1,2 \ldots n$

b) *Chemical deliming*

Balance equationuations are the same, but A equationuals zero, resulting in that c_A is zero too.

$$c_s V = c_{o1}V_{o1} + \varepsilon c_{o1}V \quad (16)$$

And

$$\varepsilon Co_i V = Co_{i+1}V_{oi} + \varepsilon Co_{i+1}V \quad (17)$$

That means:

$$y_{CH} = \sum_{i=1}^{n} y_{CHi} = \sum_{i=1}^{\infty} \frac{Na_i Co_i}{c_p} = 1 - \left(\frac{\varepsilon}{\varepsilon + Na_i}\right)^n \quad (18)$$

because y_i are members of geometric sequationuence with quotient = $\frac{\varepsilon}{\varepsilon + Na_i}$

$Na_i = Na_1 = Na_2 = Na_3 \ldots\ldots Na_n$ are in the above equationuations and $c_i = \varepsilon Co_i$ are used. Using the equationuations (18) we receive the main operating costs of both non-chemical and chemical processes as a function of deliming degree and the sum of steps of the operations (*n*). The intersection of the above mentioned functions gives the interruption of the non-chemical deliming and its replacing by the chemical operation.

3. CONCLUSION

Costs curves, cost dependence on the deliming effectiveness are shown in the Figure 1 , for the non-chemical (blue curve) and chemical deliming processes (green curve). Points on the curves represent the unit decanted cycles.

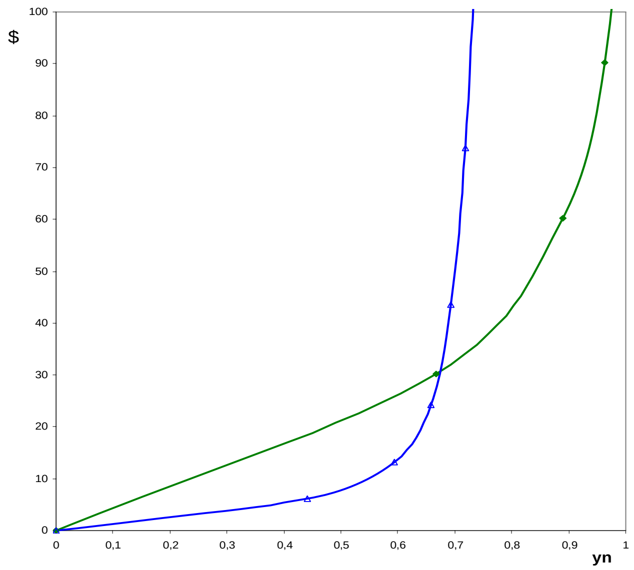

Figure. 1: Cost curves

They are:

- Sorption coefficient *A* (fixing power of lime on a collagen surface) = 100
- Sorption coefficient *B* = 57m3kg-1
- Initial concentration of lime in hide *Cp* = 5,1 kg.m-3 ~ 0,5%
- Hide thickness *2b* = 7mm
- Hide porosity ε = 0,5
- Soaking number *Na* = 1
- Effective diffusion coefficient of salt (calcium sulphate) D = 10-10m2s-1
- Unit price of technological water K_V = 1 USD m-3
- Unit price of chemical deliming solution K_E = 30 USD m-3
- Input power of drum electric motor P = 15 kW

The practically zero effectiveness of the non-chemical deliming results from the small initial concentration of lime in hide, which is approximately 0,5%; that means the process is found in an almost linear part of an adsorption isotherm, where the fixing power of lime on collagen surface is very strong.

It is necessary to note and remind that the validity of our mathematical simulations is a limited acceptance of presumptions on which the equationuations were derived. The most important is the assumption that the diffusion process is not controlled or during the programmed time equationuilibrium is reached. (Fourier’s diffusion number is about 1).

4. REFERENCES

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5. ACKNOWLEDGEMENT

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