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OPTIMISATION ALGORITHM DESIGN OF RAW HIDE DESALTING PROCESS

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ABSTRACT
Raw hide arrives in tanneries in a preserved state. In most cases, sodium chloride is used as preservation medium. In a whole number of operations through which raw hide is transformed into leather, raw hide desalting is a very important operation in view of final quality. The procedure incorrectly executed may cause considerable damage to edge parts of raw hide, effecting considerable economic losses in final area yield of leather substance. Another important factor playing a great role is environmental protection. The tanning industry consumes considerable amounts of power, chemicals and technological water, thus producing a great quantity of waste liquids. From this viewpoint, a specific optimum of processing procedures should also be sought. Hence, the presented paper deals with desalting of raw hides, meaning soaking operations when viewed from the position of tanner.
Keywords: Raw hide, optimisation, desalting process, algorithm design, waste treatment.

1. INTRODUCTION
The aim of presented paper is analysis, mathematical models and optimisation procedure for desalting of raw hides. During the first stage of the desalting process takes place meaning soaking operations. Raw hide is transformed into leather in a number of operations Among them, raw hide desalting is a very important one in view of final quality. The incorrectly performed procedure may cause extensive damage to border parts of raw hide and consequently considerable economic losses in final production of leather substance. Optimization of industrial systems covers a wide range of engineering applications. Moreover, many of these problem formulations lead to complex tasks that may exhibit severe nonlinearities and degeneracy. As a result, algorithms are needed that exploit structure, handle constraints efficiently, and also have desirable global and local convergence properties.

2. DESCRIPTION OF KINETIC MECHANISM
There are thus two desalting process mechanisms – kinetic, related to dissolving solid surface salt, and diffusion, related to transport mechanisms, i.e. to internal diffusion [4]. This contribution mainly deals with the kinetic mechanism taking place in the first stage of desalting process, i.e. through dissolving of solid salt [1] and the optimization of the process from the operational point of view.
Desalting is performed in rotating cylindrical reactor - tanning drum in which salted hides and water are loaded. Drum rotation is produced by means of electric motor.
The total general operating costs N of are given by the sum of costs of power NE for rotation by electric motor and of consumed technological water NW (desalting solution).

$$N = N_E + N_W = PK_E\tau + VK_V \qquad (1)$$

The complete list of symbols is described at the end of the article. Time τ in equation (1) naturally depends on the volume of technological water. In order to derive this dependency, it is assumed that rate of surface salt dissolution is proportionate to difference between concentration of saturated solution and immediate concentration of salt in technological water. The relation can be expressed by a differential equation:

$$\frac{da}{d\tau} = k(a_n - a) \qquad (2)$$

The desalting degree x is defined as

$$x = \frac{am_v}{a_p m_s} = \frac{a\rho_v V}{a_p \rho_s V_s} \approx \frac{a}{a_p} \cdot N_a \qquad (3)$$

where $N_a = \frac{V}{V_s}$ (soaking number).

The function a(τ) in (2) can be derive from (3) by:

$$a = \frac{xa_p}{N_a} \qquad (4)$$

and after some substitution and derivation a similar equation is obtained in the form:

$$\frac{dx}{d\tau} = k(K - x) \qquad (5)$$

where the parameter K is given by

$$K = \frac{a_n N_a}{a_p} \qquad (5a)$$

Integration of (5) gives

$$\tau = -\frac{1}{k}\ln\left(1 - \frac{x}{k}\right) \qquad (6)$$

and after the substitution for τ from equation (6) into (1) the final relation for operating costs is given by:

$$N = K_v V - \frac{1}{k}\ln\left(1 - \frac{x}{k}\right) \qquad (7)$$

This function is the proper cost function for an optimizing process which results in optimal industrial operating conditions.

3. EXPERIMENTAL RESULTS

The rate constant *k* can be easily determined from equation (2) which integration gives:

$$\ln\left(\frac{a_n}{a_n - a}\right) = k\tau \qquad (8)$$

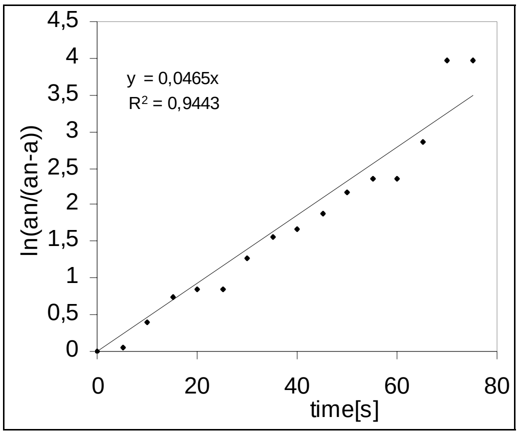

Figure 1. Determination of rate constant of dissolving (Dependence ln(an/(an – a)) on time).

Table 1. Kinetics of surface salt dissolving.

time [s]	conductivity [mS]	conc.a [mass%]	ln(an/(an-a))
0	0,0023	0	0
5	3	0,1883	0,0583
10	17	1,0673	0,3868
15	28	1,7579	0,7514
20	30	1,8835	0,8348
25	30	1,8835	0,8348
30	38	2,3857	1,2622
35	42	2,6369	1,5724
40	43	2,6996	1,6675
45	45	2,8252	1,8908
50	47	2,9508	2,1785
55	48	3,0136	2,3609
60	48	3,0136	2,3609
65	50	3,1391	2,8714
70	52	3,2647	3,97

The calculated value of rate constant of dissolving is k=0,0465 s^{-1} (k=167,4 h^{-1}).

3.1. Optimisation algorithm

In practical desalting processes of raw hides three cases may occur. The first one is very similar to dissolving of pure salt. This situation seldom appears because salt is considerably polluted with low-molecular ingredients such as soluble amino acids, fats, dirty particles and the like [2], [3]. It is shown in Figure 3 for dissolving rate constant equaling 160 h^{-1} . The second case involves weakly polluted salt particles with a dissolving rate constant of 16 h^{-1} and finally the third case involves strongly polluted salt particles, where the dissolving rate constant has a value of 1,6 h^{-1}. The majority of real situations in desalting of raw hides occur between cases 2 and 3 (dirty soakings) [5].

Common starting parameters applied in all cases were as follows:

Economic parameters: K_E = 0,12 EUR kW h^{-1}
K_v = 1,3 EUR m^{-3}

Technological parameters: x = 0,999
Vs = 10 m^3
a_n /a_p = 1
P = 20 kW

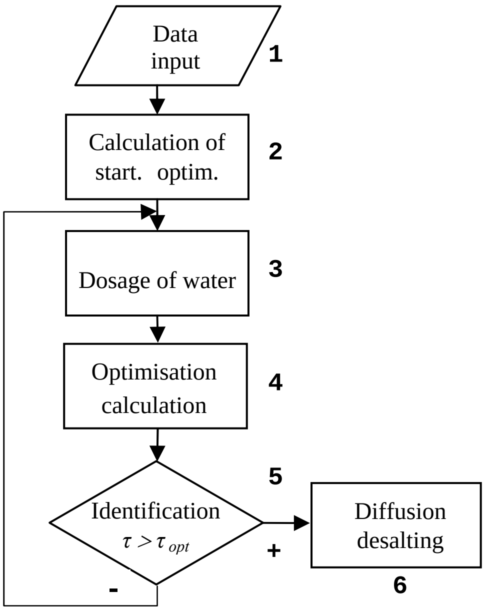

Figure 2. Flow chart of a desalting operation

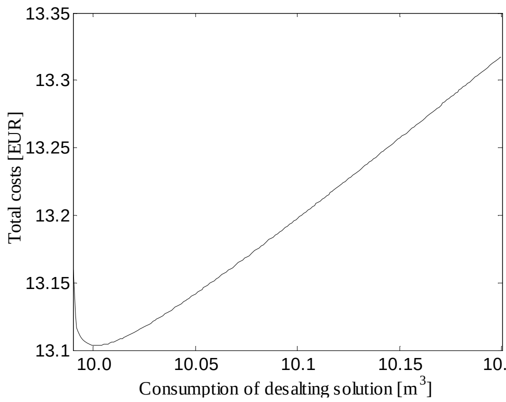

Figure 3. Dependence of total costs on consumption of desalting solution for k=160 h^{-1}

The final procedure of the desalting operation process consists of six steps. The flow chart of this procedure is depicted in Figure 2. Optimal consumption of desalting solution for rate constant k=160 h-1 is Vopt=10,001 m3 , optimal desalting time τopt = 0.04 h = 2,54 min, optimal total costs Nopt = 13,10 EUR (see Figure 3); for rate constant k=16 h^{-1} is V_{opt} = 10,10 m^3 , optimal desalting time τ_{opt} = 0.28 h = 16,81 min, optimal total costs N = 13,81 EUR; for rate constant k=1,6 h-1 is V_{opt} = 11,03 m3, optimal desalting time τ_{opt} = 1,47 h = 88,40 min, optimal total costs N = 17,88 EUR.

4. CONCLUSION

In a whole number of operations through which raw hide is transformed into leather, raw hide desalting is a very important operation in view of final quality. The incorrectly performed procedure may cause extensive damage to border parts of raw hide and consequently considerable economic losses in final production of leather substance. The developed derivations and results demonstrate that the specific optimum volume of technological water (desalting solution) and the total costs for desalting process can be found and optimized.

5. ACKNOWLEDGEMENTS

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6. LIST OF SYMBOLS

P - electric motor input [kW]
K_E - unit price of power [EUR/kWh]
V - volume of technological water [m^{-3}]
K_v - unit price of technological water [EUR/m3]
τ - time
a - mass fraction of salt in technological water
a_n - mass fraction of salt in technological water corresponding to concentration of saturated solution at given temperature [l]
a_p - surface mass fraction of salt related to mass of raw hide at start of desalting process (τ = 0) [l]
N_a - soaking number [1]
N_E - costs of motor energy power [1]
N_v - costs of consumed technological water [1]
k - dissolving rate constant of salt [h^{-1}]
m_v - mass of technological water [kg]
m_s - mass of raw hide [kg]
ρ_v - density of technological solution [kg m-3]
ρ_s - density of raw hide [kg m-3]
V_s - volume of raw hide [m3]
x - required leather desalting degree [l]

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