MATHEMATICAL MODEL OF THE ENERGY AND TEMPERATURE-HUMIDITY PROCESSES IN A STOCK-BREEDING FARM WITH DOSED DISTRUBUTED INFLOW OF AIR
PART 1. BASIC HYPOTHESES AND RELATIONS

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Abstract: The correct feeding of fresh air in a stock-breeding farm is a decisive factor for achieving high quality microclimate sustenance. Distributed dozed feeding of input air is a method, allowing for the achievement of best microclimate parameters in the animal zone, while at the same time making the most efficient use of the energy, emitted in the premises. The application of this method requires constant control of energy and temperature-humidity processes in the farm on the basis of a mathematical model.
This paper aims at developing a model, describing the processes in a stream, fed into stock breeding farm premises.

Keywords: mathematical model, inflow of air, distributing, basic hypotheses.

1. HYPOTHESES AND FUNDAMENTAL THERMODYNAMIC RELATIONS

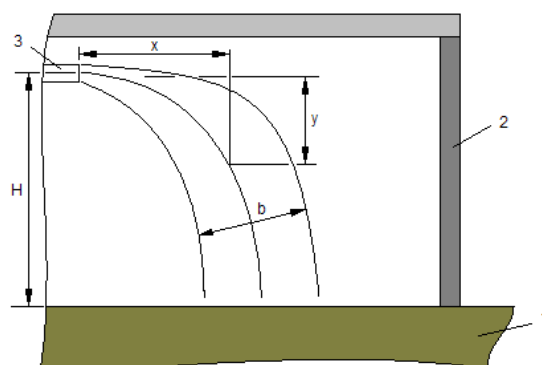The input air stream is assumed to be flat, horizontal and non-isothermal (Figure 1).

Fig. 1. Cross- section of air stream in farm premises.

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The deviation of the stream's axis under gravitational forces is determined by the following Equation [2]:

$$\frac{y}{b_0} = 0.7.\sigma^2.\chi.A_{r0}\left(\frac{x}{b_0}\right)^{3/2}$$

(1)

where:

y represent space coordinates, m ;

b_0 - width of the inflow section, m ;

σ - coefficient of velocity variation;

χ - coefficient of temperature change;

x - space coordinates, m ;

A_{r0} - the Archimedes criterion for the initial section, in the starting section is calculated according to [2]:

$$A_{r0} = \frac{g.b_0\left(t_A - t_F\right)}{v_0^2\left(t_F + 273.15\right)}$$

(2)

The angle of expansion of the stream according to [2] is $\alpha = 0.57, rad$. The inductance coefficient for the volume capacity is represented by [2]:

$$\frac{D_X}{D_0} = \sqrt{\frac{2.\sigma.x}{b_0}}$$

(3)

where:

D_0, D_X represents Volume capacities of stream at the section of outflow and at distance x from the section of outflow, $m^3.S^{-1}$;

σ - coefficient of velocity variation;

x - space coordinates, m ;

b_0 - width of the inflow section, m .

The temperature is assumed to be the same within the entire premises. As the air stream enters the premises, air from inside the premises enters the stream. The volumes of air mix and an exchange of energy takes place. The air temperature is assumed equal along the whole cross-section of the stream. It is also assumed, that the temperature in the premises is the same in the zone outside the stream for the short time interval under investigation.

The main energy index of humid air is the enthalpy. It is calculated as [1, 3]:

$$h = t + X\left(2500 + 1,84.t\right), kJ.kg^{-1}$$

(4)

were:

h represent enthalpy of humid air, $kJ.kg^{-1}$;

t - air temperature, ^0C ;

X - absolute humidity contents, $kg.kg^{-1}$.

Humidity contents is defined by [2]:

$$X = 0,622\frac{\varphi.P_N}{B - \varphi.P_N}, kg.kg^{-1}.$$

(5)

where:

φ is relative humidity;

P_N - partial pressure of water vapours for saturated air, Pa ;

B - atmospheric pressure, Pa .

Atmospheric pressure is measured or set as a constant for the given altitude (the most frequently used value being $B = 101325 Pa$).

The calculation of partial pressure of water vapours for saturated air is, according to [2]:

$$P_N = 271{,}98 \left[0{,}01.(t + 273{,}15) - 1{,}623 \right]^8 , \ Pa \tag{6}$$

where:

P_N is partial pressure of water vapours for saturated air, Pa ;

t - air temperature at start of air stream, ^0C .

The relations, describing the process of mixing of two air streams for known temperature, humidity and enthalpy [2] are as follows. For the enthalpy:

$$h_{SM} = \frac{m_{V1}.h_1 + m_{V2}.h_2}{m_{V1} + m_{V2}} , \ kJ.kg^{-1} \tag{7}$$

where:

h_1, h_2, h_{SM} represent enthalpy of humid air, of mixing volumes and after mixing, $kJ.kg^{-1}$;

m_{V1}, m_{V2} - masses the two volumes of air to be mixed, kg .

Humidity contents after mixing is defined by [2]:

$$X_{SM} = \frac{m_{V1}.X_1 + m_{V2}.X_2}{m_{V1} + m_{V2}} , \ kg.kg^{-1} \tag{8}$$

The air temperature after mixing is calculated by Equation (4). Solving it for t , the result is:

$$t_{SM} = \frac{h_{SM} - 2500.X_{SM}}{1 + 1.84.X_{SM}} , \ ^0C \tag{9}$$

The mass for a given volume of air is calculated based on density [2]:

$$\rho = \frac{28.96.B - 10.94.\phi.P_N}{8314.(273.16 + t)} , \ kg.m^{-3} \tag{10}$$

where:

ρ represent air density, $kg.m^{-3}$;

φ - relative humidity;

t - air temperature at start, ^0C ;

P_N - partial pressure of water vapours for saturated air, Pa .

In this case, the mass of the respective volume of air, taking (10) into consideration, is:

$$m = V.\boldsymbol{\rho}, \; kg \qquad\qquad (11)$$

where:

m is masses of the air volume, kg ;

V – air volume, m^3;

$\boldsymbol{\rho}$ - air density, $kg.m^{-3}$.

2. ALGORITHMIC MODEL

The description of energy and temperature-humidity processes in the stream in space and time is on the basis of the finite differences method. The various processes are described by several subroutines (Figure 2.), connected in a generic algorithm (Figure 2).
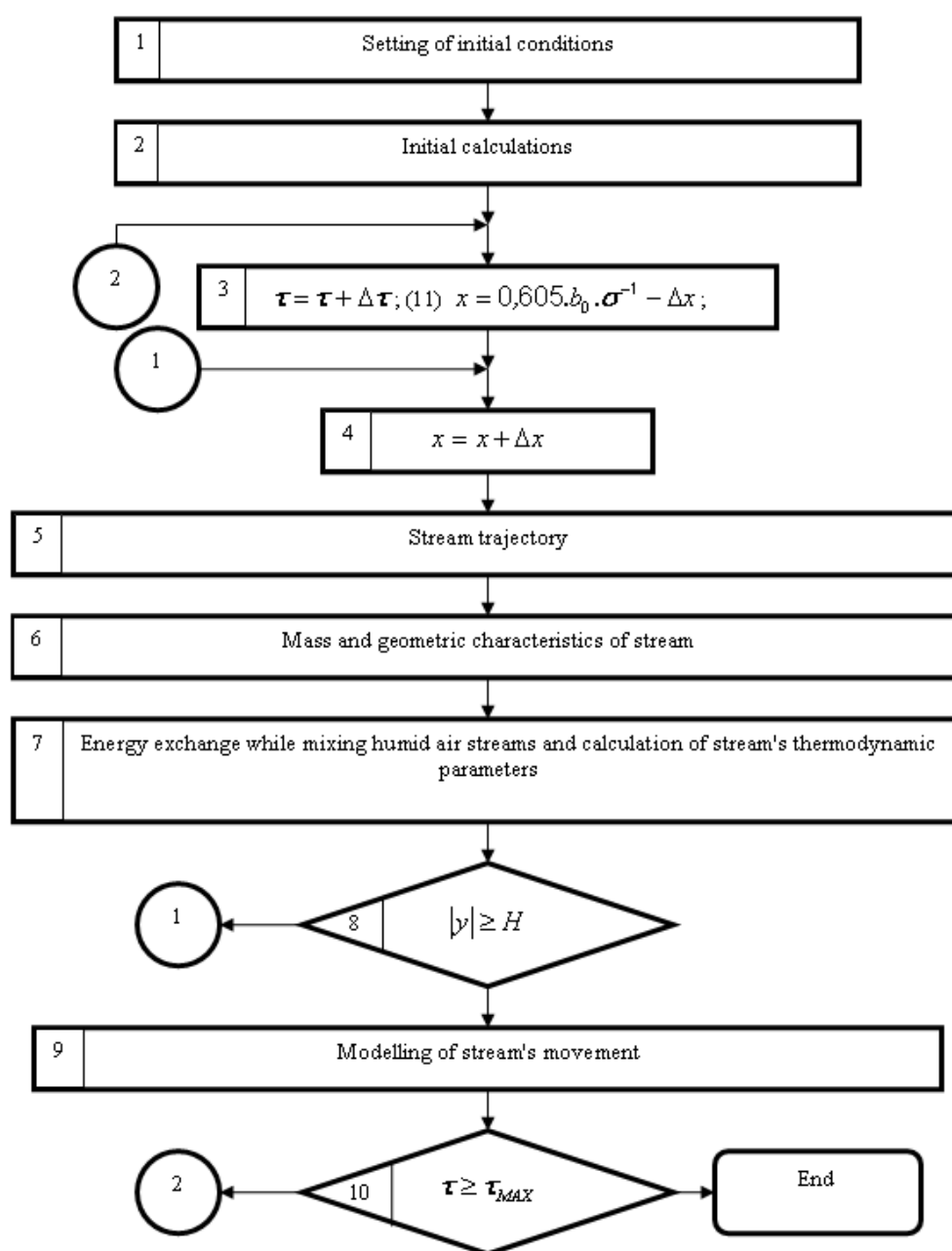

Fig. 2. Generic algorithm.

3. GENERIC ALGORITHM

Block 1 sets the initial conditions, block 2 does some initial calculations. Blocks 3 and 4 are responsible for incrementing time and space coordinates, represented respectively as τ, S and x, m. Time τ, S is changed by $\Delta\tau$ on each step; for every moment in time the variations of parameters along the full length of the air stream are calculated. It can be inferred from block 2, that the variation of length x starts at a value, calculated by means of (11). This is a prerequisite for the correct application of (3).

Blocks 4 and 5 represent the subroutines for calculating the stream trajectory and the mass and geometric characteristics, respectively. The energy exchange and the calculations of thermodynamic characteristics of the air in the room are accounted for in a subroutine in block 7. The conditions for leaving the loops are checked in blocks 8 and 10, and the movement of air within the stream is accounted for in block 9.

4. CONCLUSIONS

An analysis of the processes within an air stream has been carried out for dosed feeding in of fresh air in a stock-breeding farm premises.

Approximation hypotheses have been grounded as well as the fundamental thermodynamic relations, used for modelling.

A physical, mathematical-algorithmic model has been synthesized, describing the temperature-humidity processes in an air stream, applied to a stock-breeding farm.

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