ACT MODELLING OF THE PROPELLER WITH PALETTES FROM BUCKETS WHEAT HUMIDIFIERS

VOICU GHEORGHE, ORASANU NICOLAE, MARCU SILVIU

"Politehnica" University of Bucharest, Faculty of Biotechnical Systems Engineering

Abstract. In this work it approaches theoretical study of the motion of the propeller with palettes from buckets wheat humidifiers considers the interactions between the particles and the palettes. Also, it proposes some theoretical relation between the parameters of work necessary to obtain the rotation angular speed of stationary regime.

Keywords: wheat mills, humidifier, motion modelling, propeller, theoretical model

1. INTRODUCTION

Before milling, wheat seeds are wetting in two – three stages with the purpose to arrive at the milling moisture content of 16-16.5% and to obtain different milling properties of the main two parts: seed bran and endosperm. Deep wetting, which is performed in the first and second wetting stages, can be performed in humidifiers with buckets disc, act in rotation movement by weight force of seeds to be wetted [1,4].

The working process of these humidifiers can be followed on the schematic diagram presented in fig.1.

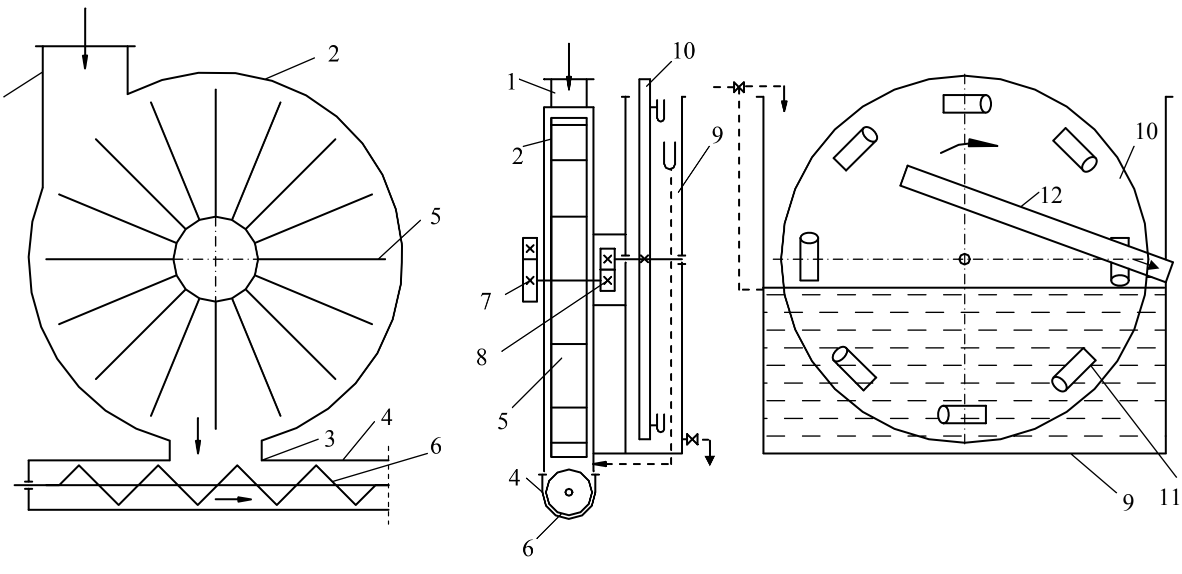

Fig.1. Schematic diagram of wheat humidifiers with buckets disc
1.seed feeding; 2.rotor shell; 3.screw conveyor feeding; 4.screw conveyor; 5.propeller with palettes; 6.blending screw; 7.electromagnetic brake; 8.cilindrical gear; 9.water chamber; 10.buckets disc; 11.buckets; 12.water collecting and evict eaves

The propeller with palettes is act in rotation movement by weight force of seeds which fall on palettes through feeding zone. The rotation movement is transmits by a cylindrical gear from the propeller with palettes to the buckets disc, which is placed inside a constant water level tank.

Buckets pass through the water tank and fill with water at a degree function of tank water level and buckets inclination angle. At the upper part buckets discharges in a collecting and evict eaves from which water is conduct to dry seed screw conveyors. In the screw conveyors take place a blending of water and seeds, and then wetted seeds are introduced in a resting bin.

2. THEORETICAL CONSIDERATIONS

On palettes of the propeller, falls from the height *H*, a known seed flow *Q*, each seed having a weight *m* presuppose known (fig.2).

It is also known the collision restitution coefficient k between wood palettes and wheat seeds. The propeller has 2*R* diameter and palettes wide is *b*.

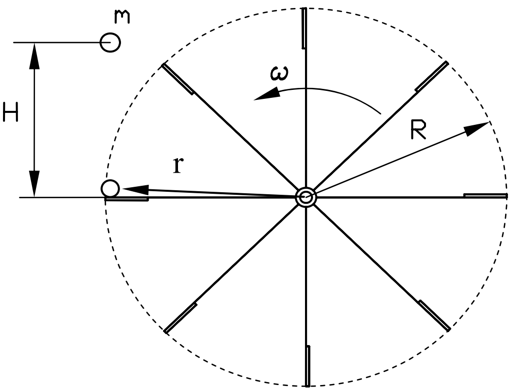

Fig. 2. Schematic presentation how a particle acts on the palettes

It is interesting propeller angular speed after collision with seeds, internal percussion in the collision point and percussion in propeller bearing.

I. ***Collisions theoretical study.*** It can be presuppose the following simplifying hypothesis:

- seed flow *Q* arrive on the palettes of the propeller when they are in the proximity horizontal position;
- seeds had in the falling zone a very concentrated distribution, that means their falling points will be situated at a constant distance *r* regarding the propeller axle;
- it will be taken into consideration only the main collision, for which particles have the maxim kinetic energy, later collisions will be neglected.

In conformity [2,3], the study will be made taking into consideration collision theorem and kinetic moment theorem.

a) *After collision speeds determination*. Applying collision theorem for the whole system and the restitution coefficient relation, two relations are written:

$$\begin{cases} J_O\,(\omega + \Delta\omega) - J_O\,\omega + r\,\Delta m\,v' - r\,\Delta m\,v = 0 \\ \dfrac{(\omega + \Delta\omega)\,r - v'}{v - \omega\,t} = k \end{cases} \tag{1}$$

where: J_O is inertia moment of the rotor regarding rotation axle; k – collision restitution coefficient (for wheat seeds k ≅0.689); r – rotation radius; v – particle speed before collision, v'- particle speed after collision.
Relations (1) are written for a time interval Δt in which material mass that is in collision with propeller palettes vary with Δm and propeller angular speed increase with$\Delta\omega$, as a result of collisions.

Eliminating seed speed after collision, it is obtained:

$$J_O\Delta\omega + (\omega + \Delta\omega)r^2\Delta m + \omega r^2 k\Delta m = vr\Delta m(1+k) \quad (2)$$

If equation (2) is divided by Δt, results:

$$J_O\frac{\Delta\omega}{\Delta t} + (\omega + \Delta\omega)r^2\frac{\Delta m}{\Delta t} + \omega r^2 k\frac{\Delta m}{\Delta t} = vr\frac{\Delta m}{\Delta t}(1+k) \quad (3)$$

At limit, for case $\Delta t \to 0$, results the differential equation:

$$J_O\frac{d\omega}{dt} + (1+k)\omega r^2\frac{dm}{dt} = vr(1+k)\frac{dm}{dt} \quad (4)$$

Knowing that seed weight variation regarding with time is seed flow Q, differential equation of rotor speed variation can be written:

$$J_O\frac{d\omega}{dt} + Q(1+k)r^2\omega = Q\,v\,r(1+k) \quad (5)$$

The first degree no homogenous differential equation of propeller angular speed will have the following general solution:

$$\omega = C\,e^{-\frac{Q\,r^2(1+k)}{J_O}t} + \frac{v}{r} \quad (6)$$

Integration constant C can be estimated if initial conditions of the problem are known. If we suppose that the propeller start from rest, so at: $t = 0$, $\omega = 0$, a particular solution can be calculated as form:

$$\omega = \frac{v}{r}\left(1 - e^{-\frac{Q\,r^2(1+k)}{J_O}t}\right) \quad (7)$$

What we are interested is propeller speed after a time t, by enough and results:

$$\omega = \frac{v}{r} \quad (8)$$

where speed, v, of particles before collision can be calculated with relation:

$$v = \sqrt{2gH} \quad (9)$$

presuppose that particles start from rest at the height *H* and all fall on the palettes when they are in the proximity of horizontal position.

b) *The determination of collision percussion and connection percussions*. In fig.3 it is schematic presented percussions acting on the two bodies in collision. Collision theorem projections on a classical Cartesian reference system for the two bodies can be written:

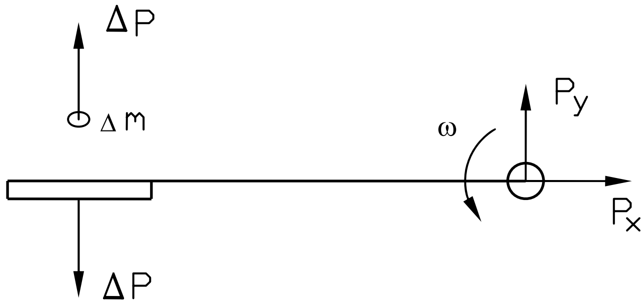

Fig.3. Schematic diagram of collision percussions

$$\begin{cases} \Delta m\left(v'-v\right)=-\Delta P \\ P_x=0 \\ P_y=\Delta P \end{cases} \tag{10}$$

Substitute relation (10a) in equation (1a) results:

$$J_O\Delta\omega=\Delta P \tag{11}$$

or, at limit, for Δt→0, after using the solution (7) it is obtained:

$$\frac{dP}{dt}=v\,r\,Q\,(1+k)\,e^{-\frac{Q\,r^2(1+k)}{J_O}t} \tag{12}$$

Knowing that the percussion definition relation at collision has a form:

$$\vec{P}=\int_{\Delta t}\vec{F}dt \tag{13}$$

It can be obtaining force equation which act during the time of these continuous collisions:

$$F=Q\,v\,r\,(1+k)\,e^{-\frac{Q\,r^2(1+k)}{J_O}t} \tag{14}$$

It can be find from the relation (14) that ones established the relation for stationary regime, force which act on propeller palettes tends to zero.

II. ***The movement study in the friction case at propeller bearing***. Due to fact that differential equation (5) is just like kinetic moment theorem projection for the case of a continuous collision, the friction movement differential equation, take the form:

$$J_O\frac{d\omega}{dt}+Q(1+k)r^2\omega=Qvr(1+k)-\mu_0r_0\left|\vec{R}\right| \tag{15}$$

where: μ_0 is friction coefficient from bearing; r_0 – bearing radius; $\left|\vec{R}\right|$ – reaction modulus from bearing.

In conformity with equation (14), during the stationary regime time, forces due to collision tend to zero, in the case without friction, or are sufficient small be neglected in the case with friction, it will be considered that reaction is equal with propeller weight G. Thus the equation (15) may be approximated as:

$$J_O \frac{d\omega}{dt} + Q(1+k)r^2\omega = Qvr(1+k) - \mu_0 r_0 G \tag{16}$$

The general solution of differential equation (16) well be:

$$\omega = Ce^{-\frac{Q r^2 (1+k)}{J_O}t} + \frac{v}{r} - \frac{\mu_0 r_0 G}{Q r^2 (1+k)} \tag{17}$$

In that case, rotations speed at stationary regime, well be:

$$\lim_{t \to 0} \omega = \omega_{reg} = \frac{v}{r} - \frac{\mu_0 r_0 G}{Q r^2 (1+k)} \tag{18}$$

III. ***The movement study in the case in which at propeller is mounted wetting device***. As component in the wetting installation of which propeller movement was studied above, is mounted another rotor tied with the first with wetting devices. This second rotor is provided with some tubular palettes (buckets) which, during the rotation movement, take the water from a water chamber placed under rotation axle and feed a device which ensure seed wetting.

In this situation at differential equation (15) will be added the terms which take into account the two aspects mentioned above:

$$J_O \frac{d\omega}{dt} + Q(1+k)r^2\omega = Qvr(1+k) - \mu_0 r_0 \left|\vec{R}\right| - M_{rez} - M_p \tag{19}$$

where: M_{rez} is a resistant couple which take into calculus only palettes passes through water chamber; M_p – utile couple which take into calculus pump function of this auxiliary rotor.

This two last force couples are not constant functions, they depend by a lot of parameters, so we consider that they can be express by two functions as:

$$M_{rez} = c \cdot f(n, \omega, t)\,\omega \tag{20}$$

$$M_{po} = h(z, \omega, V, t) \tag{21}$$

where: z is the number of tubular palettes (buckets) on rotor; V – liquid volume taken by a bucket; c damp coefficient, n- a coefficient which can include the influence of the form and number of the buckets.

In the rotor speed is low we can say that the resistant couple (20) depends of first power of angular speed. In functions f and h, the dependence of ω is not an explicit one, but depends of ω size as absolute value, to integrate the (19) equation it replaces the function with the medium value of function: $\bar{h}$, $\bar{f}$.

In these conditions, differential equation solution (19) may be approximated at general expression:

$$\omega = Ce^{-\eta t} + \frac{1}{\Phi}\left[Qvr(1+k) - \mu_0 r_0 \lambda G - \overline{h}\right] \tag{22}$$

where: $\eta > 0$ and:

$$\Phi = Qr^2(1+k) + c\bar{f} \tag{23}$$

For angular speed calculus of stationary regime, it is considered time big enough, so:

$$\omega_{reg} = \frac{1}{\Phi}\left[Qvr(1+k) - \mu_0 r_0 \lambda G - \overline{h}\right] = \frac{Qvr(1+k) - \mu_0 r_0 \lambda G - \overline{h}}{Q r^2(1+k) + c\bar{f}} \tag{24}$$

where λ is an over parameter which take into account growing effect of reaction modulus from bearing due to collision forces, necessary for resistant couple defect, but resistant forces at palettes movement through liquid aren't zero.
The relation (23) can give us quantitative information's about mode in which every factor mentioned above influences device angular speed. Due to fact that couple functions from expressions (20) and (21) aren't neither theoretical calculate, nor experimental determined, in expressions (22-24) it will be considered an average of a rotor complete rotation.

3. CONCLUSIONS

This theoretical study represents a first approach of the working process at buckets wheat humidifiers activate by weight force of seeds which will be wetted before milling.

It is only a theoretical study and for the future we want to obtain some experimental data for comparison.

Even now, it can be seen a clarification of some aspects leaving from ideal case solution (8), friction solution (18) to complex solution (24). The existence of these partial solutions gives us enough information's to previous the way in which every supplementary factor influences over stationary regime angular speed.

REFERENCES

[1]. Voicu Gh., Căsăndroiu T., *Utilaje pentru morărit şi panificaţie*, Litografia Universitatii Politehnica din Bucureşti, 1995;
[2]. Voinea R., Voiculescu. D., Ceauşu V. – *Mecanica*, Editura Didactică şi Pedagogică, Bucureşti, 1975;
[3]. Simion P. Fl., N. Oraşanu, ş.a. – *Aplicaţii în inginerie ale mecanicii*, Editura Bren, Bucuresti, 1998;
[4]. Yang P., Seib P.A., Wet Milling of Grain Sorghum Using a Short Steeping Period, Cereal Chemistry, 73(6), p.751-755.