Process Study on the Work of a Dough Kneader with a Planetary Motion of the Kneading Arm

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Abstract: *For choosing the best working arrangements for the movement of machinery and processing the kneading of the dough, technological flux on the bread, it is necessary to gain greater knowledge of physical characteristics of the raw materials used, as well as rheological behavior and knowledge of the mixtures obtained. The mathematical formula shown in work and the results obtained may be of assistance to specialists working in connection with the design, construction and use of planetary mixers.*

Keywords*: kneading machine, planetary mixers, hypocycloid*

1. Introduction

Planetary kneading machines belong to the category of operating kneading machines with discontinuous, with the kneading tanks cylindrical flat-bottomed or ball-and-bottomed, being provided with the kneading arms spiral type, cage or an anchor, single or dual.
The kneading arms have planetary movement because all dough from the tank to be driven on-the-move, and all the particles of flour hydrated forms to participate in the process of mixing. The kneading area snapshots is restricted with a diameter approximately equal to the outer diameter non sheathed spiral arm or the kneading.
In the process of working flour particles hydrated form agglomerations which join in the end between them forming dough.
Each point of the kneading arm describes hypocycloid trajectories so that the batter beside the wall basin is driven by the center of it and vice versa so that all the components of the tank are well mixed and thoroughly kneaded.

2. Materials and methods

In the case of the bread dough, the process will continue until it is formed the network of gluten which gives consistency and which constitutes the matrix which holds dough linked to and incorporates the fermentation gases (1,2).
Planetary mixers have, in general, the variable speed operation, in such a way that kneading and mixtures oxygenation should be carried out at an optimum level.
The kneading arm speed can be changed even during operation without feeling shocks when switching from a speed to another.
The mixer Dito Sama BE5 (Fig.1), used to experimental determinations is a three speed ranges in ten steps, the first two steps are used to knead crusts with normal consistency (baked goods) with the arm spiral kneading; another six steps used for mixing creams with the arm type anchor and two more steps very quickly foams used to tapping the egg or in the preparation of the cream, with transition from one gear to another during operation.
The mixer has been used for kneading the dough of wheat flour for the manufacture of fine bakery using the kneading arm spiral.
Tank capacity is 5 liters, but the capacity of work of the mixer is 1.5 kg flour at the ability of solvation (water absorption) and 1 kg stiff dough.

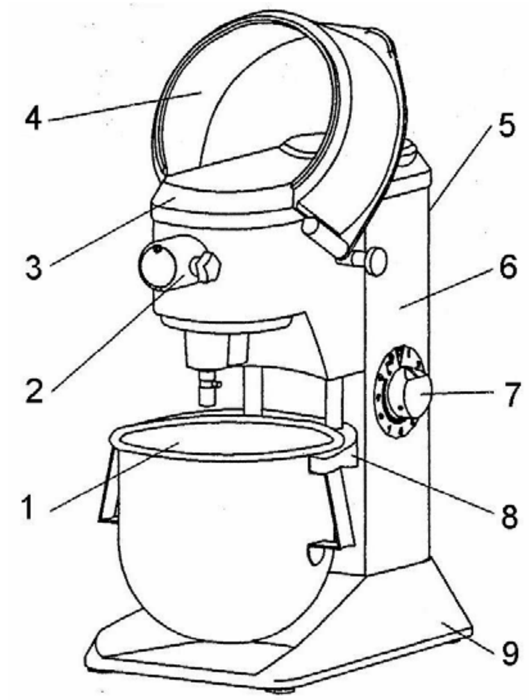

Fig.1. Planetary mixers with three bodies of work [155] 1.vat; 2.capable fixing optional accessories; 3.cover; 4. removable screen; 5. housing; 6.column; 7. on / off switch and speed control; 8.support tank; 9. frame

The kneading arm drive is done with an electric single phase motor via a transmission belt with serrated and a hypocycloidal mechanism through which the mixing arm forms a planetary movement.
In figure 2 is illustrated the hypocycloidal mechanism drive and the kneading arm mixer planetary drive will be analyzed.

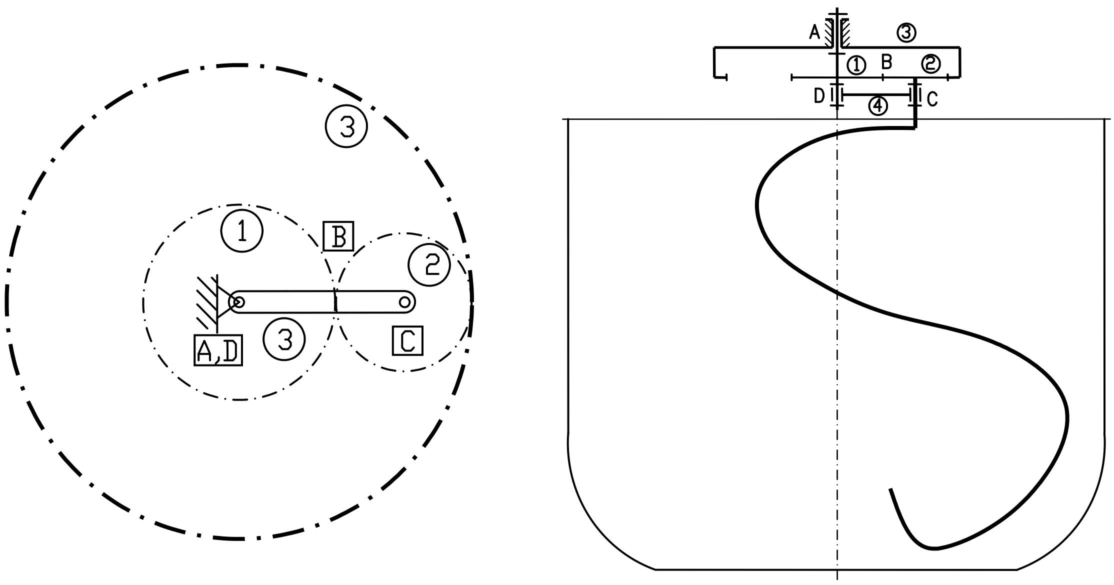

Fig.2. The hypocycloidal mechanism of planetary mixers and computing notations, (2): 1.main drive pinion; 2.driving gear arm with planetary motion; 3.the ring gear fixed; 4.leverage and the kneading arm pick-up; A,B,C,D characteristic points

Determining the equations of the hypocycloid, in Cartesian coordinates is shown in Fig.3. For the purpose of determining the equations of the hypocycloid in Cartesian coordinates is used vector equation

$$\overline{O_1T} = \overline{O_1O} + \overline{OT} \,. \tag{1}$$

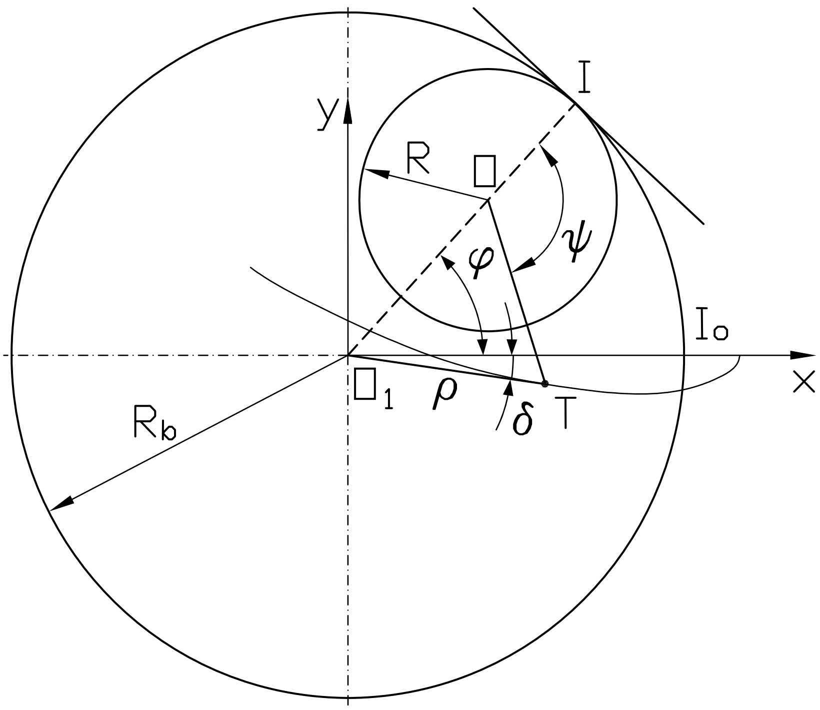

Fig.3. Layout for the calculation of the trajectory points on the kneading arm (1)

Projection vector of equation (4.5), to the axis coordinate system xOy there are obtained two equations scale, as follows (3, 4, 5):

$$\begin{aligned} x_T &= (R_b - R)\cos(\varphi) + OT \cdot \cos(\varphi - \psi) \\ y_T &= (R_b - R)\sin(\varphi) + OT \cdot \sin(\varphi - \psi) \end{aligned} \tag{2}$$

where: Rb is radius ring gear; R - radius of drive sprocket of the kneading arm; φ - the rotation angle at the center of the crown planetary gears in motion.

In view of the fact that tape measure radius R rolls out smoothly on the circle, the radius, it can be written the relationship

$$R \cdot \psi = R_b \cdot \varphi \,, \tag{3}$$

It results:

$$\psi = \frac{R_b}{R} \cdot \varphi \,. \tag{4}$$

Using the relation (4), the equations (2) becomes:

$$\begin{aligned} x_T &= (R_b - R)\cos(\varphi) + OT \cdot \cos\left[(1 - \frac{R_b}{R})\varphi\right]; \\ y_T &= (R_b - R)\sin(\varphi) + OT \cdot \sin\left[(1 - \frac{R_b}{R})\varphi\right]. \end{aligned} \tag{5}$$

which means the equations of the hypocycloid, in Cartesian coordinates.

Depending on the position of the front point T circumference circle, following conditions occur:

a) OT = R, hypocycloidal normal;
b) OT > R, hypocycloidal lengthened;
c) OT < R, hypocycloidal shortened.

Kinematic analysis of the planetary drive. The planetary drive gear, for the operation of the kneading arm mixer, consists of:
Sun gear (center) 1, with external teeth, which receives the rotating movement of the electric motor, by means of a belt transmission with serrated; sun gear 3, with internal teeth which is fixed at the frame; satellite wheel 2, with external teeth; carrier 4, which forms a link between sun gear 1 and satellite 2.
Between the components of the rotation speed planetary drive, it is possible to write the following relations, taking into account the configuration mechanism (Fig.2).
So, using his relationship Willis (7, 8), between rotation speeds of items 1, 2 and 4 shall be written the relationship:

$$i_{12}^{4} = \frac{\omega_1 - \omega_4}{\omega_2 - \omega_4} = -\frac{z_2}{z_1}. \tag{6}$$

From the relation (1) results:

$$\omega_2 = -\omega_1 \frac{z_1}{z_2} + \omega_4\left(1 + \frac{z_1}{z_2}\right). \tag{7}$$

Between rotation speeds of items 1, 3 and 4 there is no relationship:

$$i_{13}^{4} = i_{12}^{4} \cdot i_{23}^{4} = \frac{\omega_1 - \omega_4}{\omega_3 - \omega_4} = \left(-\frac{z_2}{z_1}\right)\left(\frac{z_3}{z_2}\right) = -\frac{z_3}{z_1} \tag{8}$$

In view of that fact, from the relation (8) results:

$$\omega_4 = \frac{\omega_1}{1 + \frac{z_3}{z_1}} \tag{9}$$

In cinematic diagram of the planetary drive, it is to be noted that:

$$z_3 = z_1 + 2 z_2, \tag{10}$$

So that:

$$\omega_4 = \frac{\omega_1}{2\left(1 + \frac{z_2}{z_1}\right)}. \tag{11}$$

The gears of the planetary drive have the following numbers of teeth: z_1 = 25; z_2 = 19; z_3 = 63 teeth. The module gears being m=1.5 mm, it follows that they have the diameters of division: d_1=37,5 mm, d_2 = 28.5 mm and d_3 = 94.5 mm. Using relations (7) and (11), results from: ω_4=0.28409·ω_1 (rad/s), and ω_2 = –0.65789·ω_1 (rad/s).
Using the model of calculation presented there have been drawn graph trajectories of the kneading arm to the lowest point of the arm, that is for the point that is the furthest away from the center (r=60 mm). The graphs are shown in Figures 4, 5 and 6.

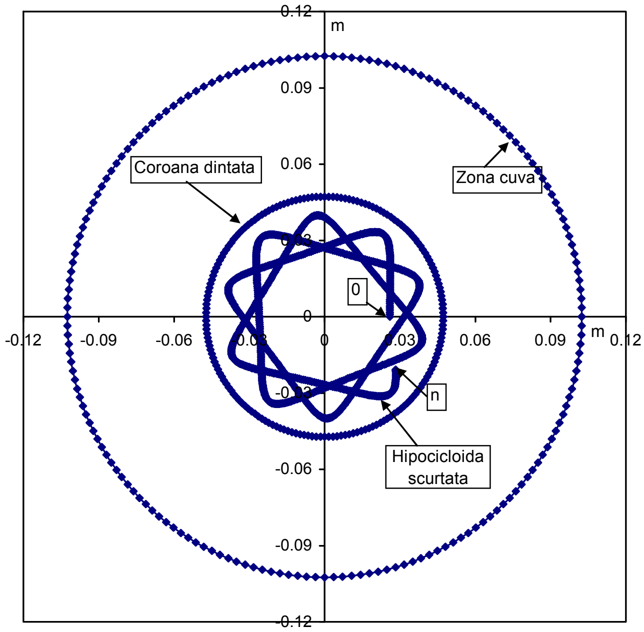

Fig.4. Hypocycloidal lower point of the kneading arm, (1)

Having regard that the number of teeth for the two sprockets located in mesh, 1, 2 respectively, is different, after a cycle of operation (i.e., a complete rotation of the item 4) the trajectory any point on the kneading arm spiral will move from the first electronic stability program, which is beneficial for the flow of the process of work because all areas in cross-section of the tank will also be covered.
The actuators of planetary mixers are, in general, hypocycloidal mechanisms with two main gear trains connected to each other by means of a lever, the drive pinion of the kneading arm while remaining in constant contact and with a ring gear which ensures fixed planetary movement in cross-section of the tank.
The kneading zone instant the area is small compared to the tank of the kneading, but by planetary movement of the kneading arm it is ensured that they will cover the entire surface area of the tank.
The kneading arm has also a rotating movement that provides a main process of mixing properly.

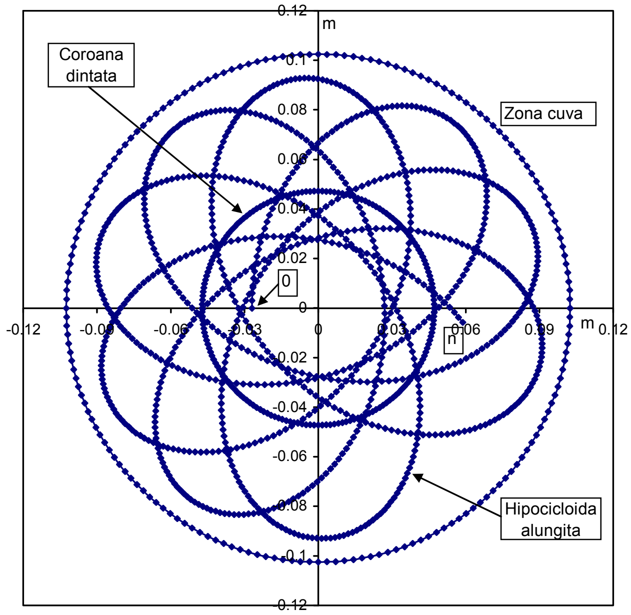

Fig.5. The trajectory of the point hypocycloid exterior to spiral kneading arm for a complete cycle, (1)

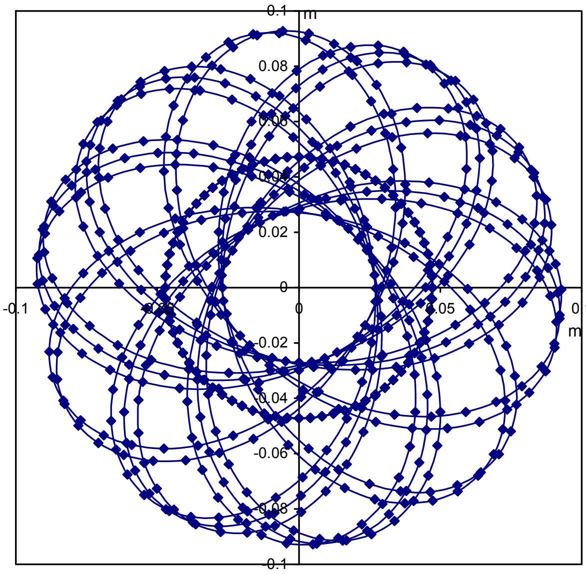

Fig.6. The trajectory of the point hypocycloid exterior to the kneading arm spiral for three cycles, (1)

The mathematical formula shown in this paper work, as well as the results obtained may be of assistance to specialists working in connection with the design, construction and use of planetary mixers.

CONCLUSIONS

1. The process of mixing operation is extremely significant in baking industry; by this wheat flour, water and additional ingredients are modified by the flow of mechanical energy for kneading inconsistent. Dough properties are strongly influenced by the way of their mixing;
2. Knowing the physical and rheological parameters of bread and mixtures is useful to specialists and workers in the field for the evaluation of process parameters of functional machinery which processes pie crusts, as well as for the establishment of process quality parameters of bread-making;
3. Use of models in complex rheological behavior modeling dough at molding and machining is also cumbersome relations because of the complexity involved in mathematical models, but also because of the high degree of difficulty for the verification of models in experimental determinations.

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