20th International Conference
ENGINEERING MECHANICS 2014
Svratka, Czech Republic, 12 – 15 May 2014

MODELLING OF THE VIBRATING DRYER DRIVE SYSTEM

D. Żórawski*, W. Dzikowska**, K. Peszyński***

Abstract: *The paper presents an analysis of the drive system of the vibrating dryer. The source of the vibration exciting force is two electrovibrators fastened to the body of the dryer. It is possible to change the angle of their inclination and size of the unbalanced mass. The mathematical model of the vibrator was determined. Also components of excitation were analysed. The results were compared with values of force declared by the manufacturer of vibrators. The resulting mathematical model was implemented in the SCILAB environment. There were performed many simulations to determine the impact of parameters on the magnitude of the force.*

Keywords: Mathematical modelling, Vibrations, Dryer, Drive system, SCILAB.

1. Introduction

Drying is one of the basic technological operations applied before storage of seeds. The moist seeds tend to form lumps. As a result of this process a drying air flows through wide channels and does not flow precisely around drying seeds (Blechman, 1971; Luyben, 1996). To reduce this phenomenon the research on the use of vibrating dryers for drying seeds are carried out. It is hypothetically assumed that this type of dryer allows unifying the structure of drying deposit and thereby energy efficiency of the process will be improved.

Device used in the research is a vibrating dryer which is based on the previously made sifter (Korpal et al., 2005) with round sieves. The dryer is characterised by spatial motion caused by two identical electrovibrators fastened to the body of the dryer. Each vibrator consists of electric motor and unbalanced masses mounted on its shaft. Mathematical model of the process has to be designed to device the proper methodology of experimental research. In the initial phase the mechanical part of the device was designed.

2. Mathematical Model

The task of the vibrating dryer is to cause circumferential motion of seeds in the horizontal plane. Testing this trajectory is done by fluoridation of certain seeds and then their recording by motion-picture camera.

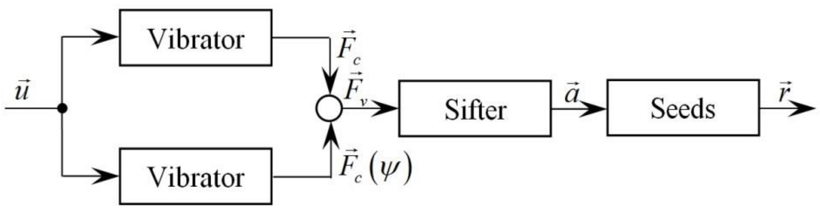

Fig. 1: Schematic diagram of mechanical system of vibrating dryer.

* Damian Żórawski, MSc: PhD. student: Faculty of Chemical Technology and Engineering, University of Technology and Life Sciences; ul. Seminaryjna 3; 85-326 Bydgoszcz; Poland, damzor000@utp.edu.pl

** Weronika Dzikowska, MSc: PhD. student: Faculty of Mechanical Engineering, University of Technology and Life Sciences; al. Prof. S. Kaliskiego 7; 85-789 Bydgoszcz; Poland, weronika.dzikowska@wp.pl

*** Assoc. Prof. Kazimierz Peszyński, CSc.: Mechanical Engineering Department, University of Technology and Life Sciences; al. Prof. S. Kaliskiego 7; 85-789 Bydgoszcz; Poland, peszyn@utp.edu.pl

Fig. 1 shows the schematic diagram of the process of forcing the seeds motion. The value of input is a vector of parameters $\vec{u} = u(n, \alpha, \beta, \psi)$, where n is a rotational speed set by the power inverter, α is an angle defining setting of the unbalanced masses in relation to a plane passing though the axis of the electric motor (Fig. 2), β is an angle of deviation of plane of centrifugal force rotation from vertical (Fig. 3) while ψ is a mutual phase shift of both vibrators.

The vibrations of vibrator are caused by 4 masses in the shape of semicircle (two masses on the one side of the motor) positioned relative to each other at an angle $\pi - 2\alpha$ (Fig. 2). Change in angle α allows to change the unbalance of the mass, i.e. a change of centrifugal force constituting the vibration extortion.

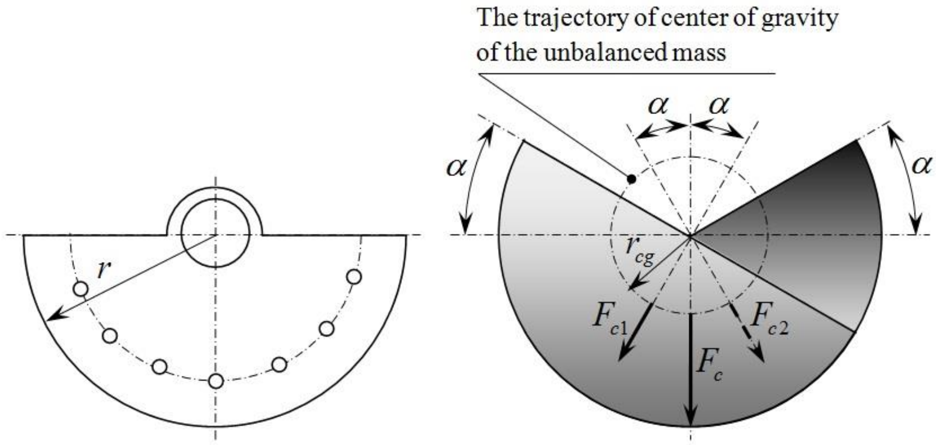

Fig. 2: Unbalanced masses: a) Real; b) Model system.

The real part for calculations, shown in Fig. 2a, was simplified to the form of full semicircle (Fig. 2b) hereinafter referred to as a disk. The ring of mounting was omitted as well as 7 boreholes used for positioning disks relative to each other. For the calculations, after precise weighting, the disk mass was $m_{\mathrm{d}} = 0{,}9\,\mathrm{kg}$. Radius of centre of gravity trajectory of unbalanced mass r_{cg} was determined from formula

$$r_{cg} = \frac{4 r_{\mathrm{d}}}{3\pi} \tag{1}$$

where r_d is a radius of the disk.

It is possible to define more precisely the radius of centre of gravity trajectory of unbalanced mass by taking into account the negative mass of 7 boreholes and the ring of mounting but it is not necessary. The difference was less than 1% in result.

The value of the centrifugal force acting on one disk, e.g. disk 1, was given by the formula

$$F_{c1} = m_{\mathrm{d}} a_{\mathrm{n}} = m_d r_{cg} \omega^2 \tag{2}$$

where: a_{n} - centrifugal acceleration, ω – angular speed of a disk. Angular speed is calculated from the rotational speed $\omega = 2\pi n$, where n is a value of rotational speed set by the power inverter.

Due to the symmetry the value of centrifugal force F_{c2} acting on the second disc is the same. The resultant centrifugal force that causes vibrations of the system is the vector sum of the centrifugal forces of both discs.

$$\vec{F}_c = \vec{F}_{c1} + \vec{F}_{c2} \Rightarrow F_c = 2 m_d r_{cg} \omega^2 \cos\alpha \tag{3}$$

where: F_{c} is a value of resultant force.

The direction of the resultant force depends on the angles β and $\varphi = \omega t$. Fig. 3 shows established coordinate system $0xyz$. Lined plane is perpendicular to the axis of the vibrator. In this plane the centrifugal force moves in a circular motion. In this arrangement, the values of centrifugal force components along the axis of the coordinate system were determined. They are necessary to determine the vibrations of vibrating dryer in the vertical and horizontal plane.

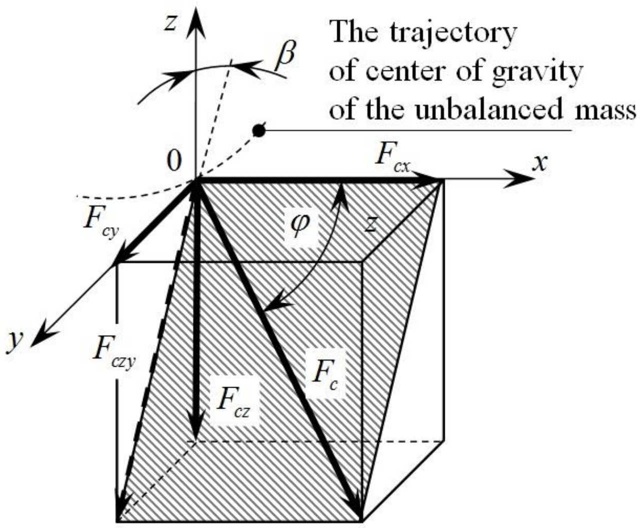

Fig. 3: Determination of the components of the centrifugal force.

$$F_{cx} = F_c \cos\varphi = 2m_d r_{cg}\omega^2 \cos\alpha \cos\varphi \tag{4}$$

$$F_{czy} = F_c \sin\varphi \tag{5}$$

$$F_{cz} = F_{czy}\cos\beta = F_c \sin\varphi \cos\beta = 2m_d r_{cg}\omega^2 \cos\alpha \sin\varphi \cos\beta \tag{6}$$

$$F_{cy} = F_{czy}\sin\beta = F_c \sin\varphi \sin\beta = 2m_d r_{cg}\omega^2 \cos\alpha \sin\varphi \sin\beta \tag{7}$$

Components calculated by equations (4), (6), and (7) determine vibrations which are motion excitation of vibrating dryer in specific planes for the system.

3. Numerical Model of the Vibrator

Numerical mathematical model of vibrator (equations (4), (6), and (7)) has been carried out in SCILAB environment, exactly in Xcos graphical editor.

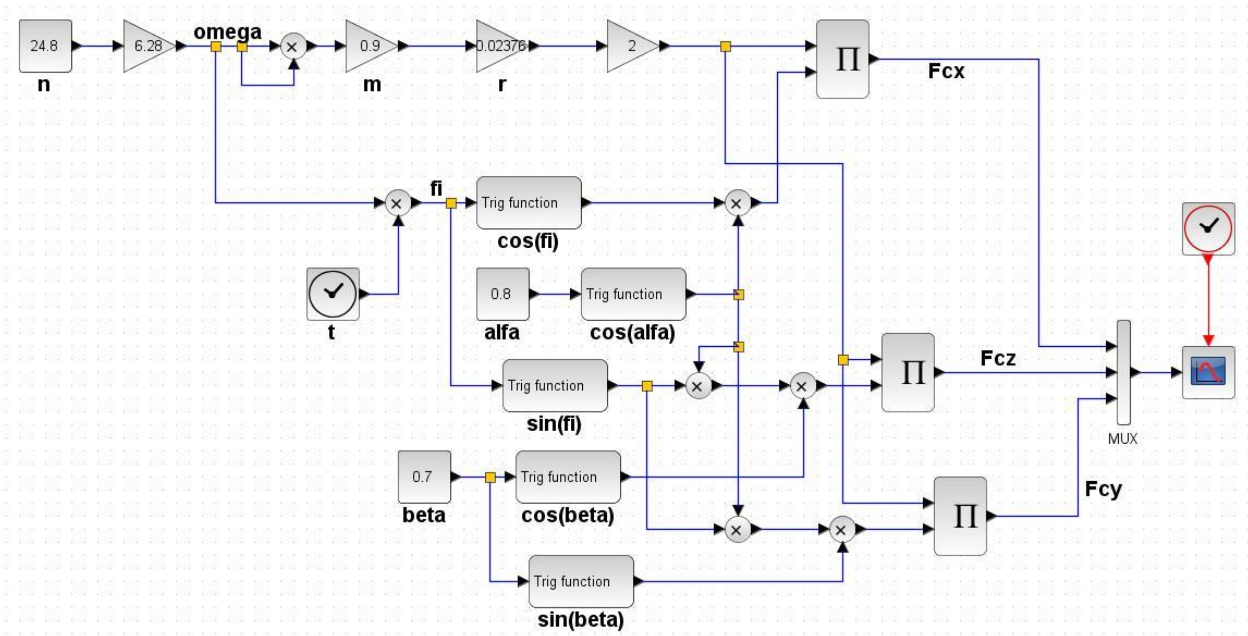

Fig. 4: Algorithm diagram for the mathematical model of the vibrator.

Variable parameters in the model are angles α and β. Several simulations were carried out for the vibrator with variable values of these parameters. Simulation results are presented in the form of diagrams for randomly chosen variables.

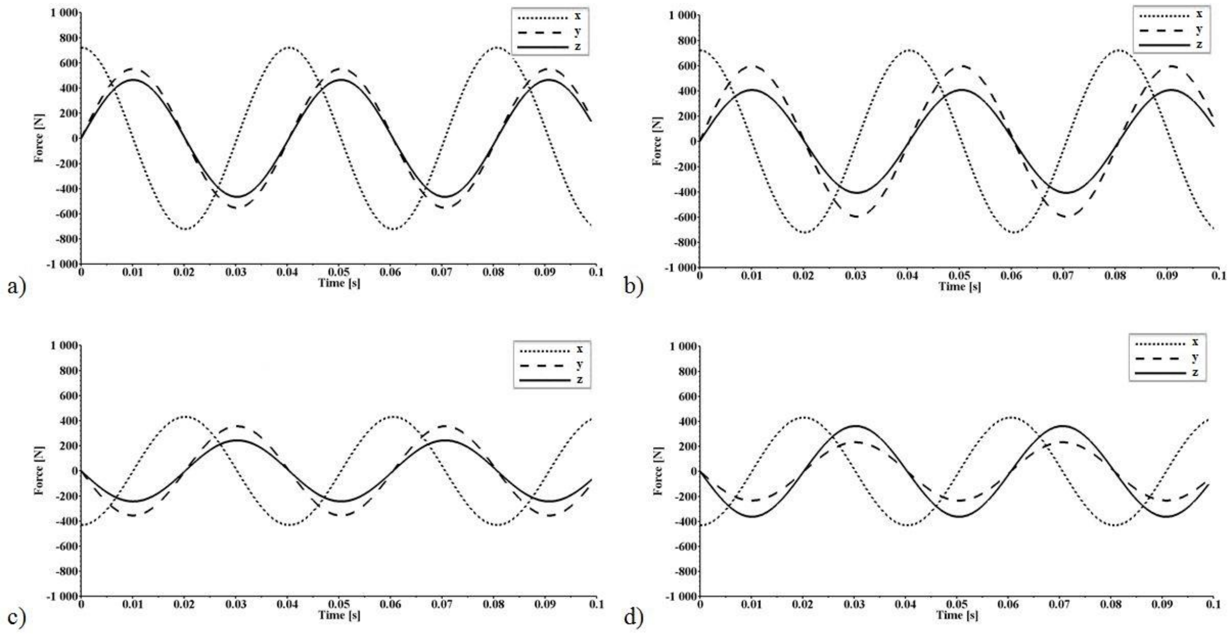

Fig. 5: Graphical simulation of excitation forces of drive system
a) $\alpha = 0.8\,\mathrm{rad}, \beta = 0.7\,\mathrm{rad}$ *b)* $\alpha = 0.8\,\mathrm{rad}, \beta = 0.6\,\mathrm{rad}$
c) $\alpha = 2.0\,\mathrm{rad}, \beta = 0.6\,\mathrm{rad}$ *d)* $\alpha = 2.0\,\mathrm{rad}, \beta = 1.0\,\mathrm{rad}$.

4. Conclusions

Values of forces determined from the mathematical model have been compared with the data obtained experimentally from the manufacturer. Despite the simplifying assumptions, there is a significant compatibility with data obtained from the manufacturer of electrically driven vibrators.

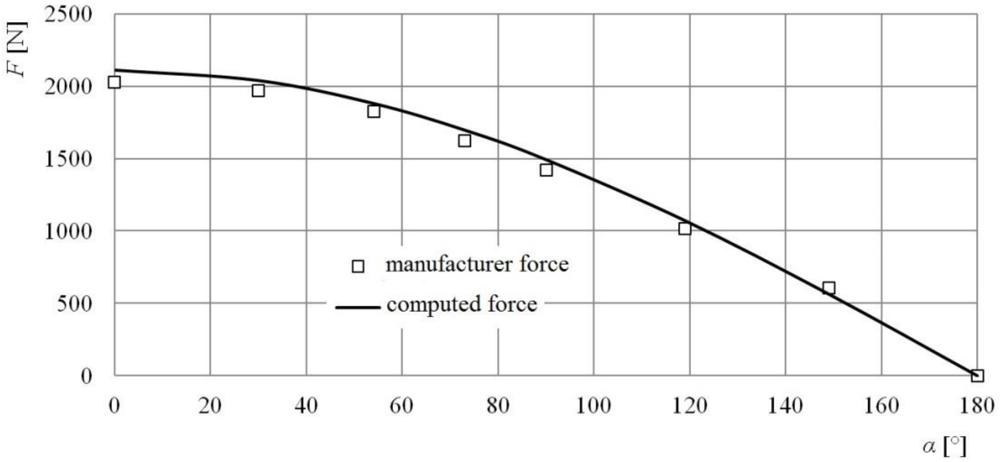

Fig. 6: Comparison of the calculated and the manufacturer data.

Obtained mathematical model will be very useful in subsequent steps of the mathematical modelling of the seeds motion during the drying process.

References

Blechman, I. (1971) Synchronization of Dynamic Systems). Moskwa Nauka, (in Polish).

Luyben, W. L. (1996) Process Modelling, Simulation, and Control for Chemical Engineers. WNT Warszawa (in Polish).

Korpal, W., Weiner, W. (2005) Multilevel Vibration Sifter. University of Technology and Agriculture, University Press, Bydgoszcz.