EAN 2017
55th conference on experimental stress analysis

The Vibrating Bowl Feeder Dynamic Model

M. Sturm [1a], L. Pešík[2b]

[1]Faculty of Mechanical Engineering, University of Applied Sciences Zittau/Görlitz, Germany

[2]Faculty of Mechanical Engineering, Technical University of Liberec, Czech Republic

[a]m.sturm@hszg.de

[b]lubomir.pesik@tul.cz

Keywords: Vibrating conveyor, bowl feeder, resonance, dynamic model,echanical parameters.

Abstract: Vibrating conveyors also named bowl feeders are a common equipment for conveying goods into production systems. These systems are used for the supply of a certain number of goods to an individual designed inter-face and simultaneously arranging a correct orientation of the goods for the following manufacturing step conveyed by the same time. This type of conveyors are used in various industries, such as automotive industry, electronic industry and medical industry. The target of this article is to determine a dynamic model and mechanical parameters by means of testing, and a numerical simulation of a ready-to-operate conveyor under standard working conditions.

Introduction

The bowl feeder, which is used for determination of the dynamic model and mechanical parameters for future testing and numerical simulations, originally has been built to forward parts used in the automotive industry.

Fig. 1 Bowl feeder for testing

The technical specification of the bowl feeder was as follows in Tab. 1 and on Fig. 2:

Tab. 1 Parameters of the bowl feeder

Top Diameter	Bowl hight	Distance bottom to outlet	Foot diameter
700 mm	450 mm	400 mm	535 mm
Spring length	**Total mass**	**Capacity**	**Moving mass**
130 mm	123 kg	12 kg	33 kg

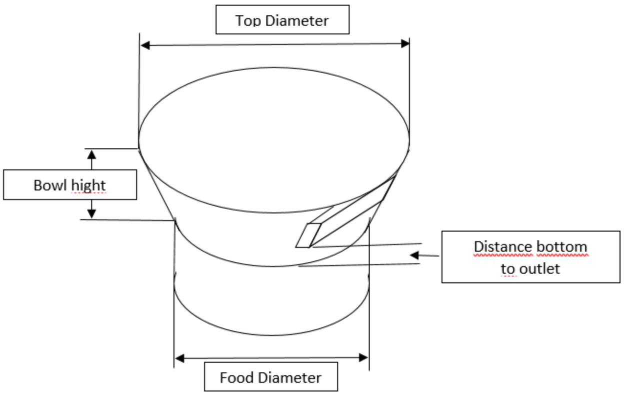

Fig. 2 Parameters of the bowl feeder

The spring material of the bowl feeder is a fiber-reinforced synthetic material. Each of the three springs (flat spring packages) is installed under 15° to a vertical boundary line. Each package consists of 8 flat spring elements, screwed together using 1mm thick distance discs. The excitation device consists of three electromagnetic vibration exciters. Each exciter is situated close to a spring package (Fig. 3).

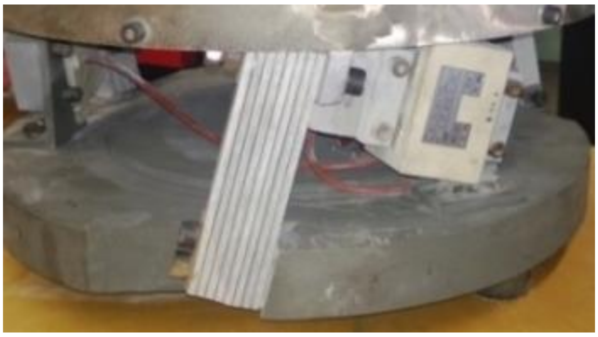

Fig. 3 Springs package with excitation device

1. Determination of the bowl feeder dynamic model

The assembly of a bowl feeder includes two principal parts, the conveying element with a conical form and a supporting cylindrical element. The conveying element is indexed by character N and the supporting element by character S. Both parts are connected by springs, which are uniformly distributed around their rotational axes y_N and y_S. In this case, three flat springs packages are assembled. Each package is declined by angle β_{NS} to the axis plane, it has its stiffness and the total values of all springs packages are defined as k_{NS}. The total damping coefficient is described by value b_{NS}.

The conveying element is defined by its mass m_N and by its moment of inertia J_{Ny} around rotational axe y. The supporting element has the mass m_S, the moment of inertia J_{Sy}, and it is placed on rubber springs with total stiffness k_{SRx} and k_{SRy}, and the total damping coefficients b_{SRx} and b_{SRy}. The whole system is fixed by a rigid connection to the frame.

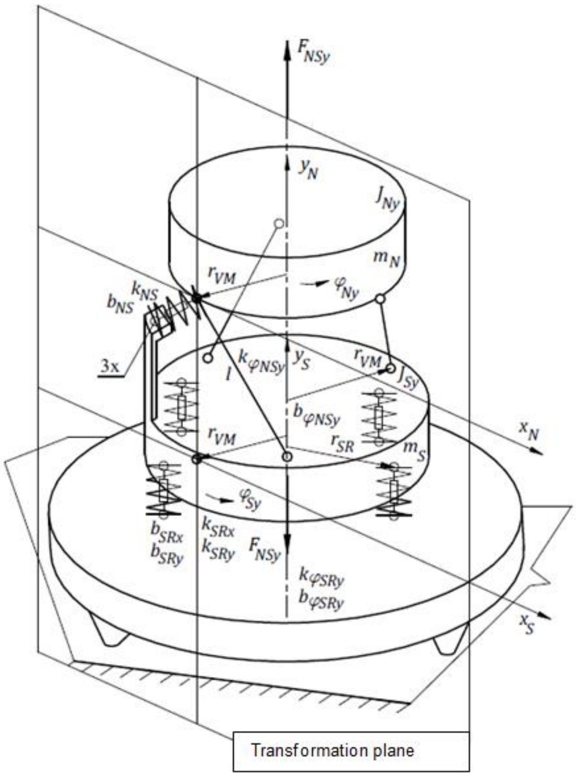

Fig. 5 Mechanical model of the bowl feeder with transformation plane

For the dynamic model of the system, each flat springs package is replaced by a rod and a spring with a perpendicular effect. All three rods creating a joint mechanism between two parts of the bowl feeder.

The motion of the bowl feeder system can be described by the help of four coordinates, two translating motions y_N, y_S and two rotating motions φ_{Ny}, φ_{Sy}. The relative motion of both parts is defined:

$$y_{NS} = y_N - y_S \tag{1}$$

and

$$\varphi_{NSy} = \varphi_{Ny} - \varphi_{Sy}\ . \tag{2}$$

Based on these intentions, four differential equations describing the movement of the bowl feeder system can be formed:

$$m_N \ddot{y}_N + F_{bNSy} + F_{kNSy} + F_{VM}\cos\beta_{NS} = F_{NSy}\ , \tag{3}$$

$$J_{Ny}\ddot{\varphi}_{Ny} + M_{bNSy} + M_{kNSy} - r_{VM}F_{VM}\sin\beta_{NS} = 0\ , \tag{4}$$

$$m_S\ddot{y}_S + b_{SRy}\dot{y}_S - F_{bNSy} + k_{SRy}y_S - F_{kNSy} - -F_{VM}\cos\beta_{NS} = -F_{NSy} \tag{5}$$

and

$$J_{Sy}\ddot{\varphi}_{Sy} + b_{\varphi SRy}\dot{\varphi}_{Sy} - M_{bNSy} + k_{\varphi SRy}\varphi_{Sy} - M_{kNSy} + +r_{VM}F_{VM}\sin\beta_{NS} = 0\ , \tag{6}$$

The force F_{VM} is a connection force between the conveying part and the supporting part which is transferred by the joint mechanism of both parts. The force F_{NSy} is the exciting force between the conveying part and supporting part.

The other dynamic forces can be calculated as follows:

$$F_{bNSy} = b_{NS}\dot{y}_{NS} , \tag{7}$$

$$F_{kNSy} = k_{NS}y_{NS} , \tag{8}$$

$$M_{bNSy} = F_{bNSx}r_{VM} = b_{NS}r_{VM}^2\dot{\varphi}_{NSy} , \tag{9}$$

and

$$M_{kNSy} = F_{kNSx}r_{VM} = k_{NS}r_{VM}^2\varphi_{NSy} , \tag{10}$$

where

$$F_{bNSx} = b_{NS}\dot{x}_{NS} , \tag{11}$$

and

$$F_{kNSx} = k_{NS}x_{NS} . \tag{12}$$

Torsional damping coefficient $b_{\varphi SRy}$ and torsional stiffness $k_{\varphi SRy}$ are:

$$b_{\varphi SRy} = b_{SRx}r_{SR}^2 \tag{13}$$

and

$$k_{\varphi SRy} = k_{SRx}r_{SR}^2 . \tag{14}$$

The relation between relative coordinates y_{NS} and φ_{NSy} is done by the joint mechanism:

$$y_{NS} = \varphi_{NSy}r_{VM}\tan\beta_{NS} . \tag{15}$$

In order to make a simplification of the calculation of equations (3) to (6), it is possible to write the balance of forces in the transformation plane (Fig. 6) as follows:

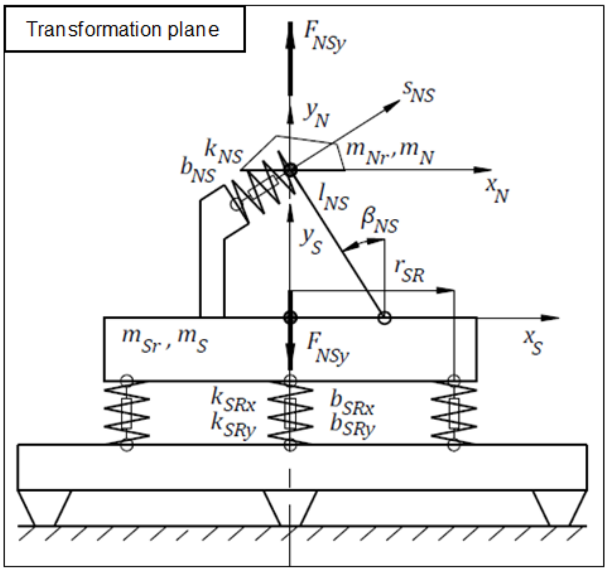

Fig. 6 Dynamic model in the transformation plane

$$x_{Nr} = r_{VM}\varphi_{Ny} \, , \tag{16}$$

$$x_{Sr} = r_{VM}\varphi_{Sy}, \tag{17}$$

$$x_{NSr} = r_{VM}\varphi_{NSy} \tag{18}$$

$$y_{Nr} = y_N, \tag{19}$$

$$y_{Sr} = y_S \, , \tag{20}$$

$$y_{NSr} = y_{NS} \tag{21}$$

$$J_{Ny} = m_{Nr} r_{VM}^2 \, . \tag{22}$$

$$J_{Sy} = m_{Sr} r_{VM}^2 \, . \tag{23}$$

By introducing the coordinate s_{NSr} , the number of unknown functions decreases to three:

$$x_{NSr} = s_{NSr} \cos \beta_{NS} \tag{24}$$

and

$$y_{NSr} = s_{NSr} \sin \beta_{NS} \tag{25}$$

After the adjustment of the equations (3) to (6), it is possible to write in the matrix form:

$$\bar{M}\ddot{\bar{q}} + \bar{B}\dot{\bar{q}} + \bar{K}\bar{q} = \bar{Q} \, . \tag{26}$$

where are the mass matrix is:

$$\bar{M} = \begin{vmatrix} m_N \sin^2\beta_{NS} + m_{Nr}\cos^2\beta_{NS} & m_{Nr}\cos\beta_{NS} & m_N \sin\beta_{NS} \\ m_{Nr}\cos\beta_{NS} & m_{Sr} + m_{Nr} & 0 \\ m_N \sin\beta_{NS} & 0 & m_S + m_N \end{vmatrix} , \tag{27}$$

the damping matrix is:

$$\bar{B} = \begin{vmatrix} b_{NS} & 0 & 0 \\ 0 & b_{SRr}\frac{r_{SR}^2}{r_{VM}^2} & 0 \\ 0 & 0 & b_{SRy} \end{vmatrix} , \tag{28}$$

and the stiffness matrix is:

$$\bar{K} = \begin{vmatrix} k_{NS} & 0 & 0 \\ 0 & k_{SRr}\frac{r_{SR}^2}{r_{VM}^2} & 0 \\ 0 & 0 & k_{SRy} \end{vmatrix} , \tag{29}$$

the coordinates vector is:

$$\bar{q} = \begin{vmatrix} s_{NSr} \\ x_{SR} \\ y_{SR} \end{vmatrix} \tag{30}$$

and the exciting vector is:

$$\bar{Q} = \begin{vmatrix} F_{NSy} sin\beta_{NS} \\ 0 \\ 0 \end{vmatrix} . \tag{31}$$

From the matrix equation (26) it is possible to calculate the time vector function $\bar{q}$. The parameters of the bowl feeder system are either known or can be measured. The mass parameters of the conveying and supporting parts are defined in the production documentation. The stiffness and damping parameters are difficult to measure and some differences can be expected between the parameters measured in a static or a dynamic way.

2. Experimental determination of dynamic parameters

Various dynamic parameters can be taken from the technical documentation of the bowl feeder (Tab. 1), others have to be calculated or measured during the correct excited oscillation.

The primary task of the bowl feeder is the generation of micro throws, and by doing this, the conveyance of goods. Therefore the excitation of bowl feeder free oscillating is generated by a rubber coated hammer in the tangential direction and the oscillation iss observed in the vertical direction. For this test, a sensor is mounted vertically under the spiral path of the bowl.

The base for the experimental determination of the dynamic parameters is the measurement of free oscillation kinematic values. The results of this step are time and frequency functions of acceleration (Fig. 7 and Fig. 8).

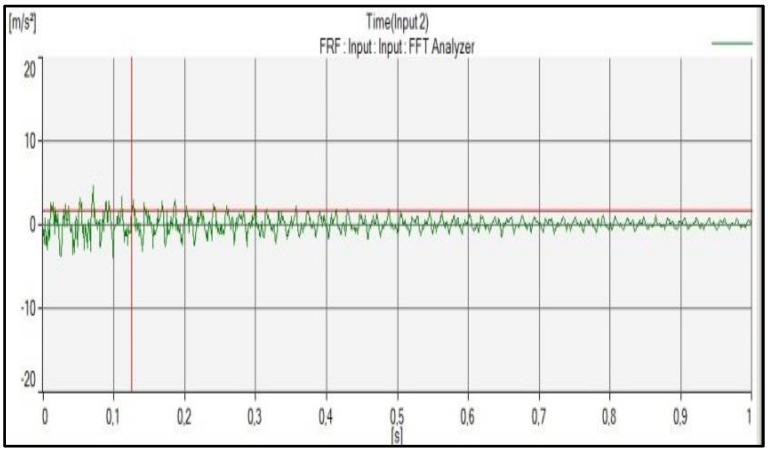

Fig. 7 Time function of acceleration in vertical direction by free oscillation

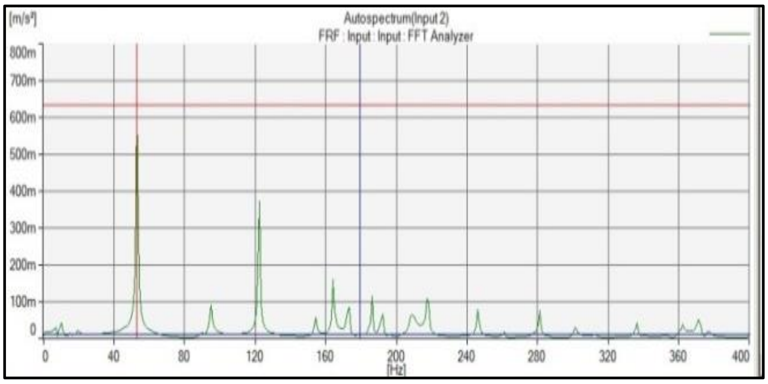

Fig. 8 Frequency function of acceleration in vertical direction by free oscillation

The data supplying the necessary information on amplitudes decrease and frequencies. Based on the time function of acceleration, it is possible to find the damping parameters of the bowl feeder system. The frequency function supplies the information on the natural frequencies of the system.

In the analysed case of the particular bowl feeder, relative weak damping and three principal natural frequencies have been determined, which corresponding to three coordinates of vector function $\bar{q}$.

The identification of the dynamic parameters is simplified by a reduction of the system. An example for this is a system with only one degree of freedom. It is considered that the stiffness of the rubber springs having an infinitive value. In reality, the supporting part is fixed to the frame and then the equation (26) in case of the free oscillation is reduced to the form:

$$\left(m_N \sin^2 \beta_{NS} + \frac{J_{Ny}}{r_{VM}^2} \cdot \cos^2 \beta_{NS}\right) \ddot{s}_{NS} + b_{NS}\dot{s}_{NS} + +k_{NS}s_{NS} = 0\,. \qquad (32)$$

Based on this equation (32), the values of damping coefficient b_{NS} and stiffness k_{NS} are determined by the help of comparing measured and calculated time function $\ddot{s}_{NS}$.

The simplified system is excited and brought in free oscillating. Measured acceleration $\ddot{s}_{NS}$ of coordinate s_{NS} is shown on Fig. 9 as the time function.

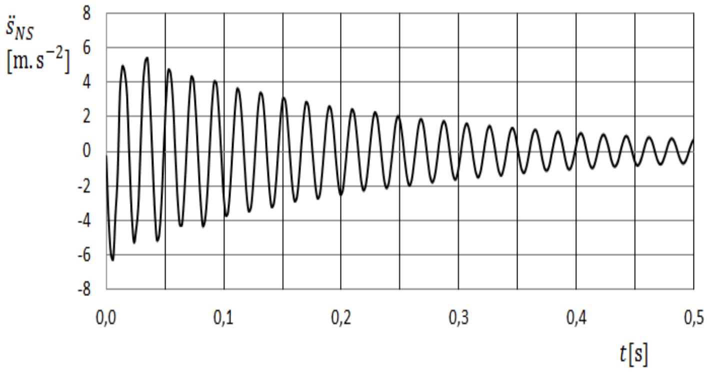

Fig. 9 Time function of acceleration measured on the simplified system

The values of parameters b_{NS} and k_{NS} are chosen in the way that the measured and calculated time function will show the same or similar curve (Fig. 10).

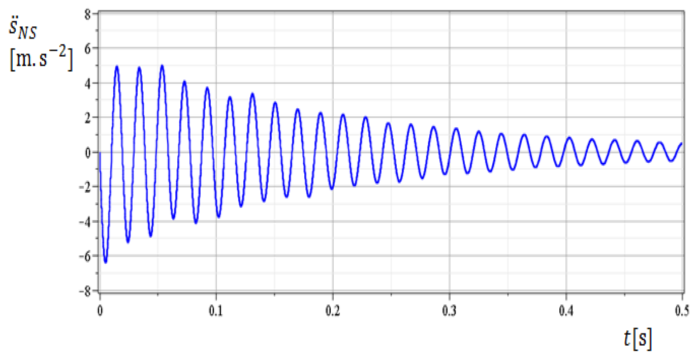

Fig. 10 Time function of acceleration calculated for the simplified system

After obtaining of the parameters b_{NS} and k_{NS}, the bowl feeder system can be returned into a more general configuration as illustrated in Fig. 6. The method then will be repeated for the parameters b_{SRx}, b_{SRy}, k_{SRx} and k_{SRy}.

Conclusions

This paper deals with the determination of dynamic parameters of a bowl feeder conducted with a comparison method of simulation and testing results.

The behavior of the dynamic bowl feeder system is simulated by free oscillation. The results of this simulation are kinematic functions of the bowl feeder oscillation, above all the acceleration time function with data about natural frequencies and the damping of the system. It is advantageous to simplify the dynamic system and thus the kinematic functions. In addition, its parameters have to be determined and advanced systematically as far as the full system of the bowl feeder. The same time functions are measured by tests done on the bowl feeder in a corresponding configuration of the system. By identical behavior of simulated and measured functions, the dynamic parameters are defined in equations of motion.

References

1. **Dresig H., Holzweißig F.** (2008), *Maschinendynamik 8, Auflage, Springer Verlag*, Berlin.
2. **Harris C.M. (**2005)**,** *Shock and Vibration Handbook, Fifth edition, McGraw-Hill***,** New York.
3. Rhein-Nadel Automation GmbH**:** *Zufuhrtechnik. [online].[Cit. 5. 2. 2013]. Available on WWW: http://rna.de/Zufuehrsysteme_Basis-geraete.mfpx?ActiveID=*
4. **Nendel, K.** (2008), *Zweidimensionale Bewegungsformen bei Vibrationsförderern [online].. Available on WWW: http://www.vibrationsfoerdertechnik.de/ Download/ 2D-Bewegungsformen_WGTL_Tagungsband08.pdf.*
5. **Risch, T. (**2008), *2D-Vibrationsformen bei Vibrationsförderern. [online].. Available on WWW: http://www.vibrationsfoerder-technik.de/Download/2D-Bewegungsformen_WGTL_Poster08.pdf*
6. **Buja, H.O. (**2007): *Praxishandbuch Ramm- und Vibrationstechnik. Bauwerk Verlag Berlin.*
7. **Pešík, M. (**2012), *Kinematics of Objects in Vibratory Conveors. In ACC JOURNAL. 1st edition. Liberec: Technical University of Liberec. Available on WWW: http://acc-ern.tul.cz/cs/journal/item/root/acc-journal-xviii-12012.*