Determination of spring-tensions of a vibrating bowl feeder

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Abstract: Vibrating conveyors designed as bowl feeders are common equipment for conveying goods into production systems. These systems are designed for the supply of a certain number of goods to an individual designed interface and simultaneously and arranging the correct orientation of the goods conveyed by the same time. This type of conveyer is used various industries such as for example the automotive industry, electronical industry and medical industry. The target of this work is to find the resonance frequencies of the ready-to-operate conveyer, the resonance frequencies of the spring packages and to identify the stresses and the displacement of the spring packages under standard working conditions. In addition a comparison of the results from the test and the simulation including the interpretation of these results will be done.

Keywords: Vibrating conveyor, bowl feeder, resonance frequencies, stresses of the spring package.

1 Introduction

The bowl feeder that is used for the tests and the simulation was originally built to forward parts for the electrical industry.

Fig. 1: Sortimat bowl feeder type SMB 6 (own source).

The technical specification of the bowl feeder is as follows:

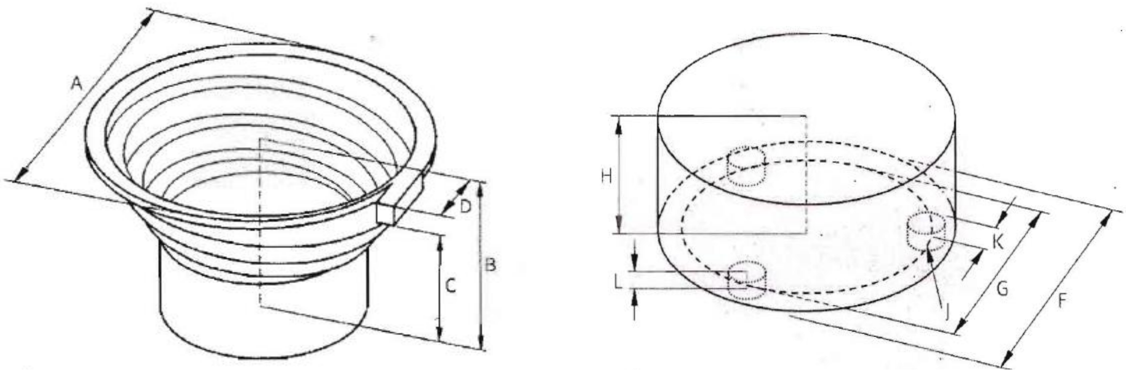

Fig. 2: Parameters Sortimat bowl feeder type SMB 6 (own source).

Tab. 1: Parameters of the bowl feeder.

A	B	C	D
700 mm	450 mm	400 mm	300 mm
F	**G**	**H**	**K**
535 mm	485 mm	190 mm	48 mm
L	**Total mass**	**Capacity**	**Moving mass**
130 mm	123 kg	12 kg	33 kg

Spring material: "Durostone", similar to the present available quality UPM S16 fiber-reinforced plastic (brand of Röchling SE & Co. KG, Germany), installed under 15° to vertical boundary line.

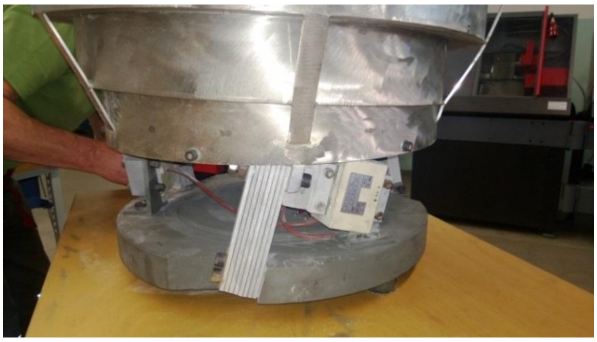

Fig. 3: Spring package with excitation device 220/230 V, 25Hz.

2 Experimental determinations of characteristic values

The first part of this elaboration deals with the experimental determination of characteristic data of the bowl feeder. The data will supply the necessary information on frequencies and amplitudes on typical operating conditions of the conveyer as well as information of the resonance frequencies of the whole system and the spring packages. Based on this information, the calculation of effective forces to the spring package can be done and using the technical values of the spring material, the tensions in the springs will be worked out.

-Excitation and measurement in radial direction

-Excitation and measurement in tangential direction

-Excitation in tangential direction and measurement in vertical direction

The primary task of a bowl feeder is the generation of micro throws and by doing this, the conveyance of goods. Therefore the last of the three mentioned excitation cases is the most significant one and will be tested. For this test the sensor is mounted vertically under the spiral path of the bowl as shown in figure 5. The excitation once is done by a rubber coated, so called Tang hammer. The excitation point is the end of the guiding channel as it has been before. The reason for this is that the major conveying direction generated by the excitation device as well is oriented tangentially. The sensor records the frequency and the acceleration of the oscillation. The analyzer and the software convert the data into acceleration over time diagram and an acceleration over frequency diagram.

2.1 Resonance frequencies of the bowl feeder

To get the necessary information on the resonance frequencies of the operational conveyer it has to be mentioned that there are different possibilities to generate and measure resonances of the conveyer system, using different fix points for the sensor as well as different exciting points and directions to bring the system into oscillation. Three exciting and measuring conditions are of interest to be analyzed, i.e. The result of the test is visualized in the following diagram.

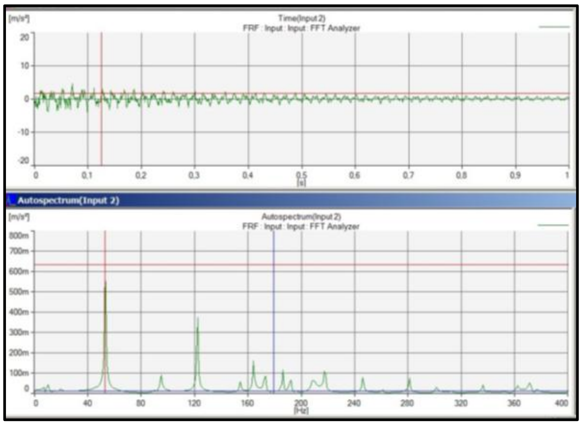

Fig. 4: Result of tangential excitation in vertical direction (own source).

The diagram shows the resonance frequencies of the conveying element (bowl) as part of the ready-to-go system with very different parameter values of the acceleration compared to the first and the second trial. It is obvious that the resonances of the system are nearly precisely matching the excitation frequency of the excitation device and multiples of it. Especially on 50Hz, which is the double of the excitation frequency, the graph has its strongest peak.

2.2 Determination of amplitudes of the operating conditions tested

For the identification of forces and tensions of the spring packages used in the bowl feeder it is necessary to do tests under working conditions. Therefore the excitation devices of the conveyer are used to get the system into vibration. Doing a pre-test it has been identified, that the maximum level to be selected is position 6 of the control dial. Trying to turn the dial furthermore up has a periodic appearing touch between spring package and exciter as result, which will influence the whole conveying characteristic of the bowl feeder negatively. The displacement of the spring package s has been measured during the vibration test by using and oscilloscope that has been turned up to the frequency of the spring package of 50 Hz. The gap between excitation device and spring package is 3 mm in non-operating condition. Turning the dial up to optimal level, the minimum gap between excited spring package and excitation device is approximately 0,3 mm. Due to the measuring possibilities and equipment a more precise measuring is not possible. This means, the maximum displacement of the spring package is 2,7 mm from the non-operating (neutral) position.

2.3 Determination of amplitudes of the operating conditions tested

To find the correct equations for the determination of the characteristic values of the spring package, the motion model of the conveying element at its mounting position to the spring packages will be described. The conveying element does a flat screw-motion as shown in the following sketch.

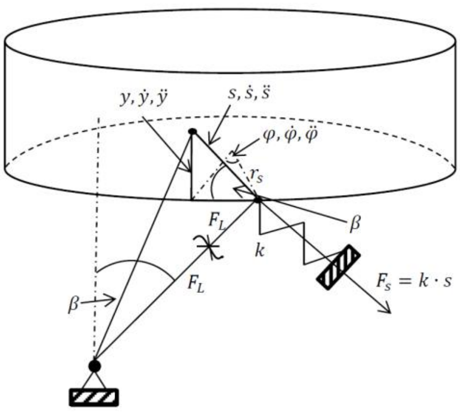

Fig. 5: Motion model of the fix point of the conveying element.

This model shows that a combined motion of rotation and vertical translation takes place after exciting the conveying element. The displacement of the point P, which describes the fixation point of the conveying element to the spring package, takes place in vertical direction by distance y and horizontal direction by the rotation angle φ. The total covered distance s finally takes place under the angle β.

$$\left(m \cdot sin^2 \beta + \frac{J}{r_s^2} \cdot cos^2 \beta\right) \cdot \ddot{s} + k \cdot s = 0 \tag{1}$$

m is the mass to be accelerated, i.e. 1/3 of the total mass per spring package and decelerated by the 50 Hz frequency f of the system, ω = the pulsatance of the system, described as $2\pi f_{0,}$. J is the mass moment of inertia and m is the mass. J and m are taken from a CAD model - m = 33 kg and $J = 3{,}9$ kg m²

k is the total spring rate of the three spring packages and can be divided by 3 to get the spring rate k_1 of one spring package later.

$$k = (2 \cdot \pi \cdot f_0)^2 \cdot \left(m \cdot \sin^2 \beta + \frac{J}{r_s^2} \cdot \cos^2 \beta\right) \tag{2}$$

Determination of the force and the moment of force:

$$F_{s1} = k_1 \cdot s_0 \tag{3}$$

and

$$M_1 = F_{s1} \cdot l = 543\ Nm \tag{4}$$

The bending stress finally can be determined by

$$\sigma_b = \frac{M}{W} = 339 \frac{N}{mm2} \tag{5}$$

3 Determination of the spring tensions by simulation

The simulation will provide a confirmation respectively a variation of the displacement and the maximum bending stress in the spring package and the results will be compared and verified to the calculated results by the test.

3.1 Generation of the ANSYS model

ANSYS is a common used FEM-software, which can be used for creating the model of a complex structure to be analyzed and for the analysis process afterwards.

To get useful results it is necessary to create the model in a logical and close to reality way and to use certain material data corresponding to the real conditions existing. In case of the conveyer tested, the necessary information for modeling and analyzing the spring package are

- The dimensions of the spring package
- The force effecting the spring package
- E-module of the spring material
- Poisson-figure of the material

The dimensions of the spring package have been taken by measuring. The spring length is individually slightly modified for each bowl feeder depending on its application.

The E-module and the Poisson-figure are linked to the spring material “Durstone”. This type of glass-fiber reinforced Polyester material is still available, but the manufacturer has no precise information anymore on the E-module of the approximately 5 years old material type, having been used specially for the springs. Based on the manufacturers experience, the Poisson-figure of 0,25 from the presently available “Durostone” UPM S16 and an E-module of app. 58500 MPa is selected for the simulation. The creation of the ANSYS model is done in the following steps:

- Generation of the single springs made of “Durostone”
- Generation of the distance elements and end plates made of steel
- Selection of the FEM-element type
- Generation of the FEM-screen
- Generation of the clamp situation of the spring package
- Generation of the force application
- Analysis operation

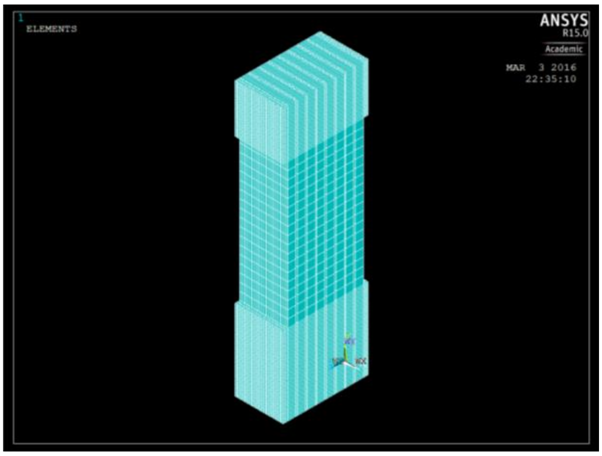

Fig. 6: Simulation of spring package with screen based on ANSYS FEM-element “solid185.

The displacement in z-direction is 2,71 mm after rounding and represents nearly the full displacement value of the simulation. This displacement represents the tangential component of the total displacement and is most interest.

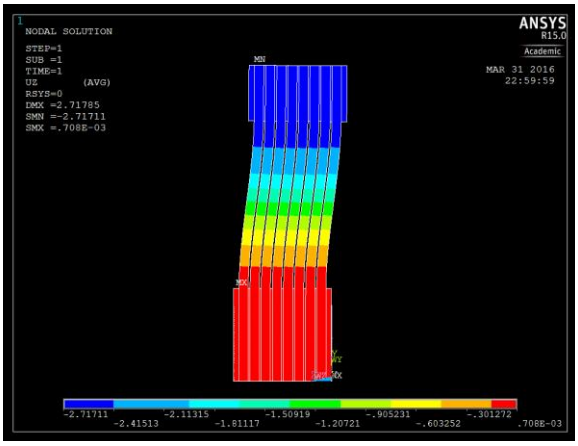

Fig. 7: Displacement in z-direction.

Looking to the existing stresses, the first stress to be analyzed is the bending stress. This is the stress that is already calculated and can be identified in the ANSYS nodal analysis as stress in y-direction, based on the coordinate system of the spring package model.

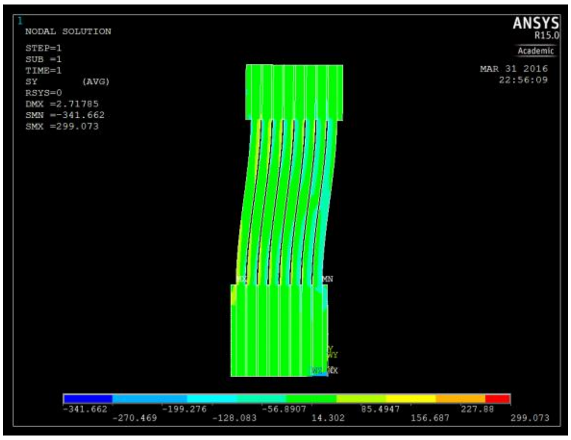

Fig. 8: Bending stress.

4 Comparison and interpretation of the results

Based on the manual calculation in chapter a bending stress of 339 N/mm² has been determined. The bending stress of the simulation supplies a value of 299 N/mm² respectively 341 N/mm² situated at the bottom clamp position of the string package. The different results seem to be mainly explained by the difference of the models used for the determination of the results. Analyzing the calculation model can be seen that the equation for the Bernoulli model. This model is different from the model used for the ANSYS simulation, particularly because the top end of the spring package in the calculation has an additional rotation degree of freedom compared to the model used in ANSYS.

5 Conclusion

This paper deals with the experimental determination and simulation of characteristic values of a bowl feeder with a focus to the displacement and stresses taking place under working conditions of the empty conveyer. It consist of an experimental determination of data of the bowl feeder such as operating frequencies and amplitudes, resonance frequencies and accelerations under different exciting situations as well as the determination of the resonance frequencies of the spring package belonging to the conveyer drive. Based on the determined maximum force, the maximum acceleration and the displacement of the spring package, bending stress of each spring package is calculated.

The determined maximum force is used to simulate displacement and stresses by the finite element software ANSYS. Differences to the previous calculations are shown. Differences between test results and simulation results are pointed out.

Finally it can be realized that the ANSYS simulation confirms the conditions measured during the test, with reference to the maximum displacement respectively amplitude of the spring package. A comparison to the simplified model of Bernoulli is done and its differences to the real installation are pointed out. The theoretical amplitude of a spring package based on the Bernoulli model is quantified

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