KINEMATICS OF OBJECTS IN VIBRATORY CONVEYORS

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Abstract

Vibratory conveyors are used especially in serial productions that concentrate on the transport of both assembly parts and diverse materials. They are designed for two main motions which are translational and spiral motion. As for the first mentioned motion the carrying element can be a chute or a pipe, whereas the second motion is relevant to cylinders having an integrated spiral carrying surface. The oscillating movement is accomplished by the exciting force, of which frequency is equal or very close to the own natural frequency of the carrying element. Exciting force is created by the rotation motion of an eccentrically placed mass resp. an electromagnet.

Kinematic motion of transported elements in vibratory conveyors is the topic of the following article. Kinematic motion is a major factor in the functionality and performance evaluation of transport devices such as the vibratory conveyor.

Introduction

Even if there are two main constructions of vibratory conveyors, based on translational (Fig. 1 a) or spiral motion (Fig. 1 b), we can generalize the basic movement equation of transported objects while ignoring the curvature of the trajectory and its ascents relevant to the relatively short movement distances. The following calculation of kinematic quantities was done for translational conveyors without carrying surface ascent.

a)

b)

Source: Manufacturer internet presentation

Fig. 1: *Vibratory conveyor with translational motion (a), with spiral motion (b)*

1 Mechanical model

The mechanical vibrating conveyor model with a translational motion of the object (Fig. 2) represents a two mass system where the carrying element ② is connected to the ground ① with a moveable and elastic constraint. Fig. 2 describes the mass and inertial parameters of both elements as well as their movement.

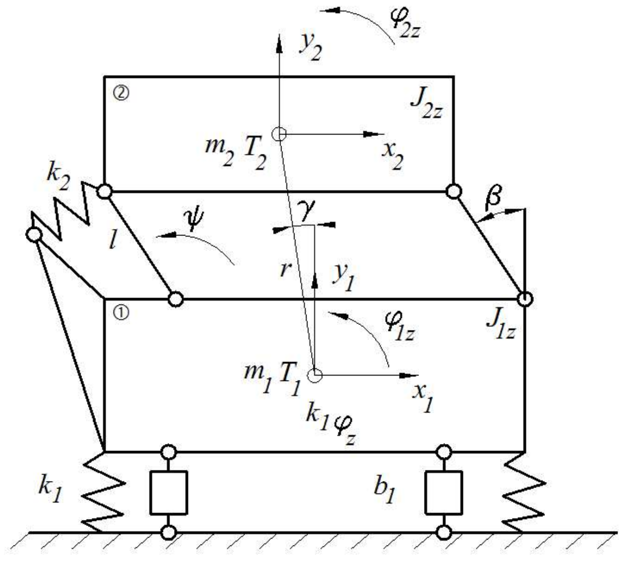

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Fig. 2: *Mechanical vibratory conveyor model with translational motion*

While exciting force impacts on carrying element ②, a nearly harmonic movement of the carrying element will come up on a circular trajectory, which is given by the length of the parallelogram arm. As the movement amplitude is negligible to the arm length, the movement can be seen as translational in tangent direction to the circular trajectory. The conveyor base has a negligible oscillation around axis *z*, therefore the presumption can be accepted.

Due to the mentioned presumptions, the kinematic quantities of transported objects ③ are solved in a simplified one-mass mechanic model (Fig. 3) which follows.

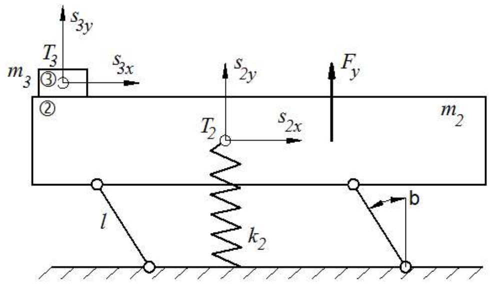

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Fig. 3: *Simplified mechanical model of vibratory conveyor with translational movement*

Exciting force *Fy* is created by a controlled electromagnet and follows a characteristic time line as demonstrated in Fig. 4.

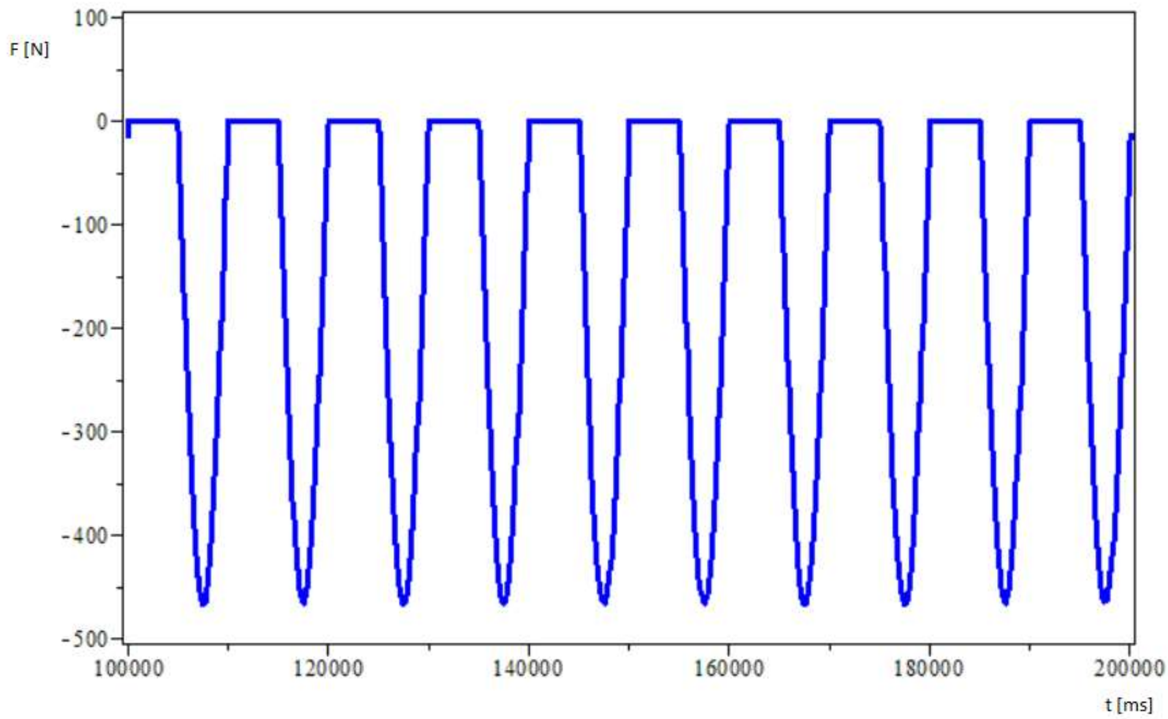

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Fig. 4: *Exciting force [N] of the vibratory conveyor carrying element*

We can split the kinematic system quantities, as illustrated in Fig. 3, into 3 parts (Touch/start – Flying – Impact) as shown in Fig. 5.

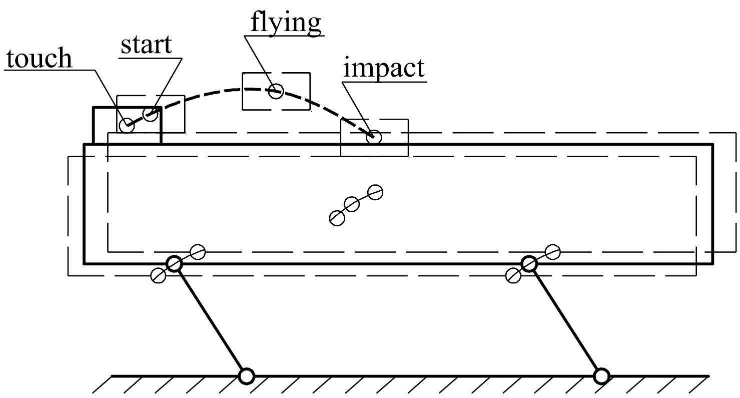

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Fig. 5: *Movement of transported objects*

The first part (Touch) implies the carriage of transported objects ③ by the carrying element ②.

For the kinematic quantities (distance, velocity, and acceleration) applies

$$s_{3x} = s_{2x}, v_{3x} = v_{2x}, a_{3x} = a_{2x}, s_{3y} = s_{2y}, v_{3y} = v_{2y} \text{ a } a_{3y} = a_{2y}. \tag{1}$$

When achieving the requirements

$$a_{3y} < -g \tag{2}$$

whereas g is the gravity acceleration, the object moves away from the carrying element. This point is marked as t_{Start}.

After this point the object moves like an angled throw with initial speed given through the instant coordinates $v_{3xStart}$ and $v_{3yStart}$ after losing the touch contact with the carrying element. There are two equations defining the flight of the object:

$$s_{3y} = -\frac{1}{2} g (t - t_{Start})^2 + v_{3Start} (t - t_{Start}) + s_{3yStart} \tag{3}$$

and

$$s_{3x} = v_{3xStart} (t - t_{Start}) + s_{3xStart} \tag{4}$$

The flight ends when contacting the carrying element. From a mechanical point of view an impact of two solid bodies takes place, which is hereby solved with a zero restitution coefficient. This statement is based on the presumption that vibratory conveyors transport only small parts in such groups influencing each other and absorbing movements of particular objects. It is a bulk without unable to renew its form, so that the bulk cannot create any force during impact. The equality of momentums leads to the following equation, valid for the velocity of the carrying element and objects after impact:

$$v_{23y} = \frac{v_{2y} m_2 + v_{3y} m_3}{m_2 + m_3}. \tag{5}$$

After impact the object moves together with the carrying element and the entire action starts from the beginning.

2 Harmonizing of the vibratory conveyor

Vibratory conveyor harmonization has an essential effect on its transport performance. Conveyors perform at the resonance of minimizing supplied energy. The dynamic system is set up on the frequency of the exciting force. In case of electromagnetic excitation the frequency is 50 Hz.

The natural frequency of the system depends on the multiple masses of: oscillating bodies, carrying element, transported parts. As the entire mass of transported objects change during the operation, the natural frequency changes as well.

The scope of natural frequency relevant transported objects mass can be best defined by measurements. Figures 6 to 9 illustrate the frequency spectrum of the carrying element oscillation while transporting objects during the operation for low, middle and high charge. Which means: low charge = a few transported parts, middle charge = average amount of transported parts, high charge = a lot of transported parts. As indicated in the charts, the natural frequency moves within a scope of 5 Hz.

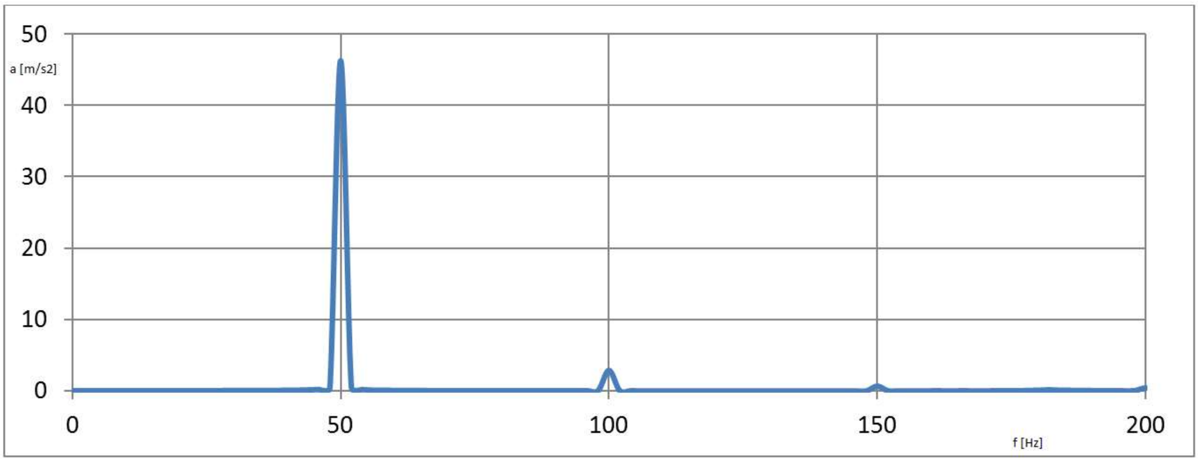

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Fig. 6: *Frequency spectrum of the oscillating carrying element with transported object during the conveyor operation*

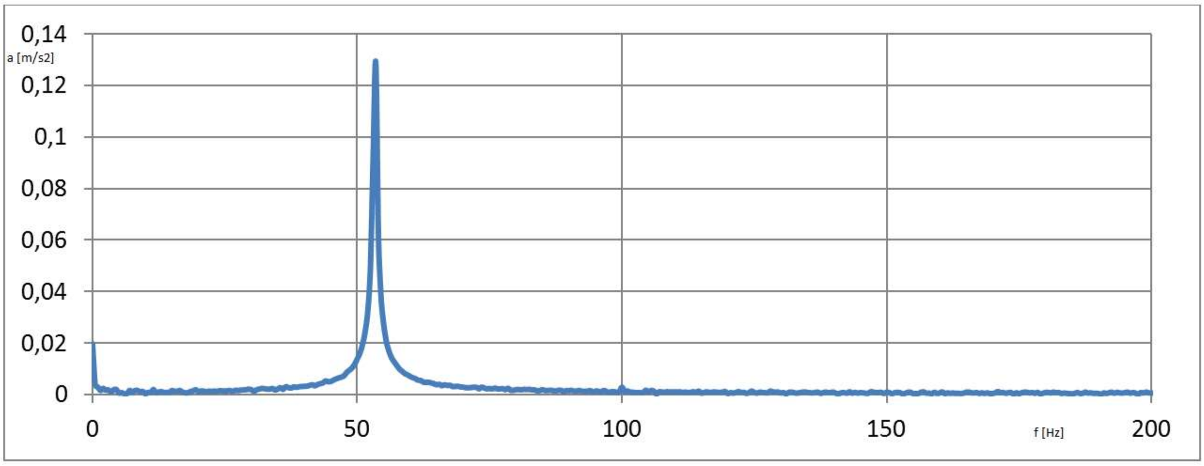

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Fig. 7: *Frequency spectrum of the natural oscillation of the carrying element with low charge*

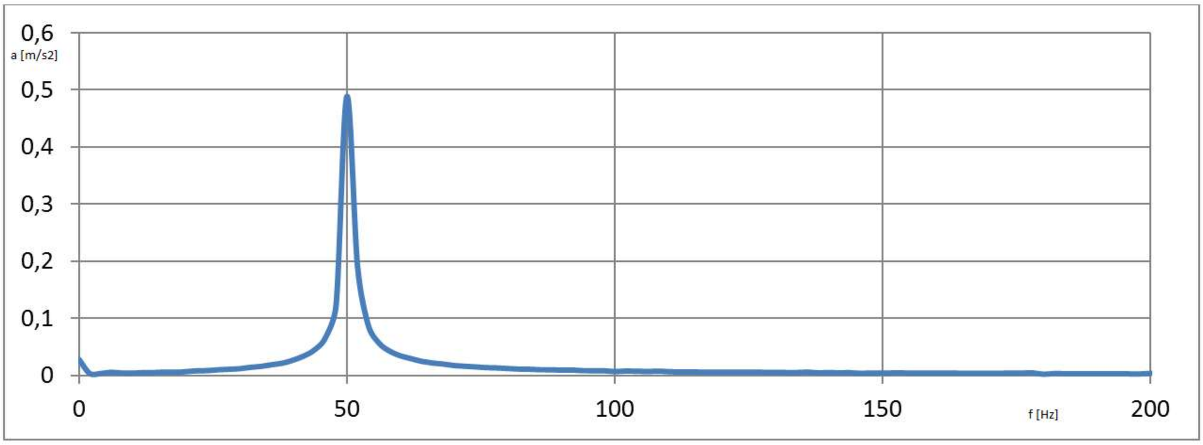

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Fig. 8: *Frequency spectrum of the natural oscillation of the carrying element with middle charge*

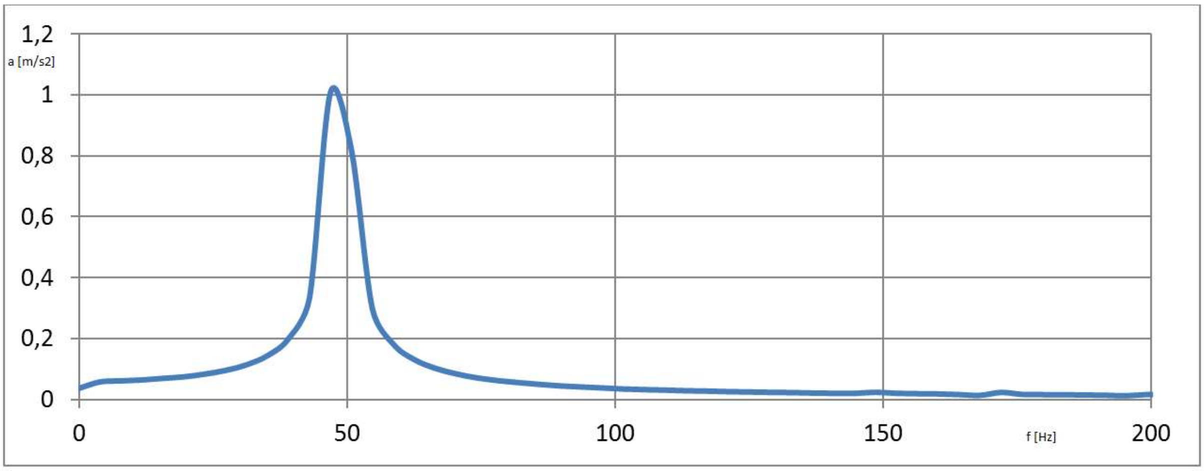

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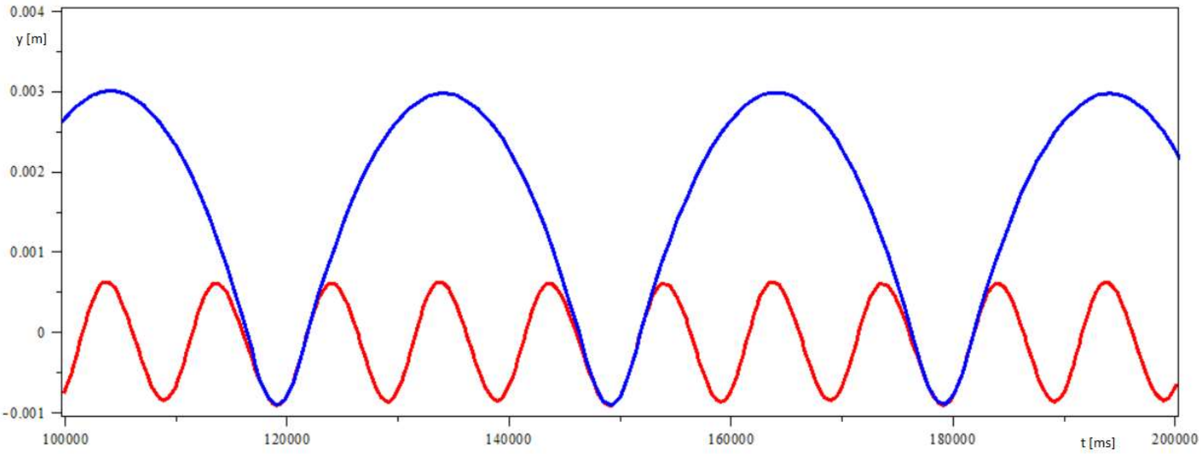
Fig. 9: *Frequency spectrum of the natural oscillation of the carrying element with high charge*



a)

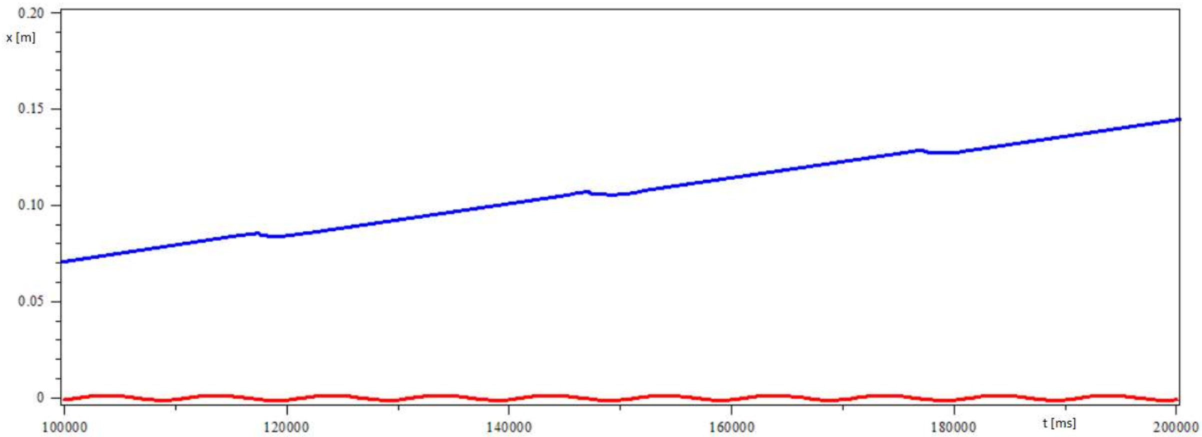


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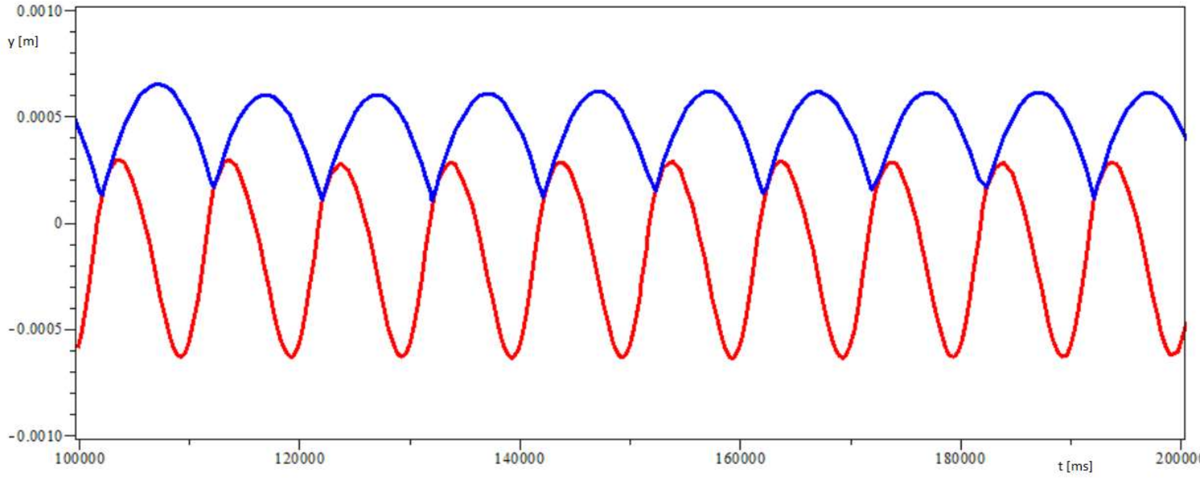
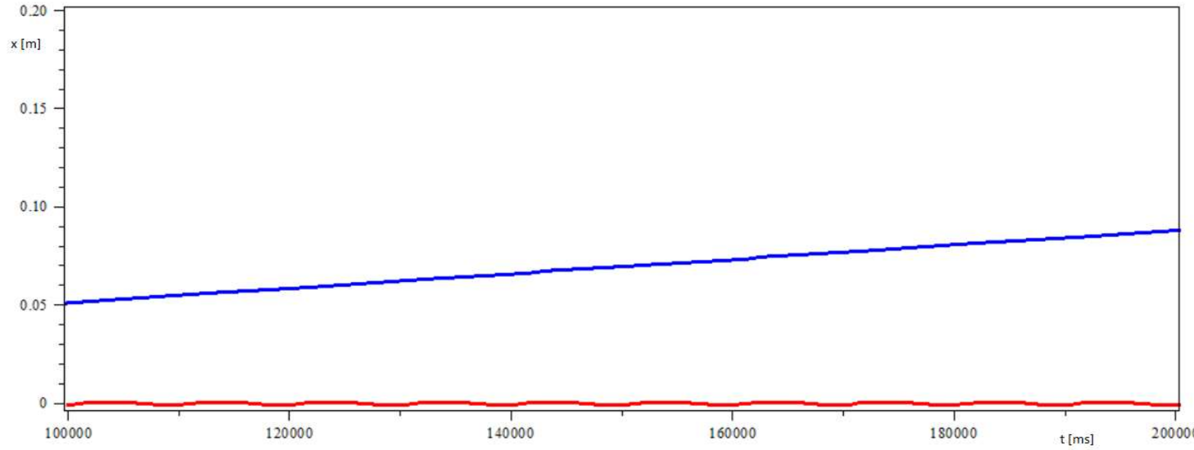
Fig. 10: *Time behaviours of the carrying element (red) and object (blue) distance coordinates [m]: a) coordinate y, b) coordinate x*



a)



b)

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Fig. 11: *Time behaviours of the carrying element (red) and object (blue) distance coordinates [m] with height charge: a) coordinate y, b) coordinate x*

3 Motion simulation of objects in vibratory conveyors

The stimulation of object motions within vibratory conveyors was performed by differential equation systems using various mass parameters. In compliance to the task character the four-point numeric method Runge-Kutta was applied. Distance, velocity and acceleration measures of transported objects and the carrying element have been recorded. As the result of the carried out simulation shows, an optimal exciting force setting as well as operating at resonance frequencies lead to highest transport performances and lowest value variances between the velocity of the falling object and the carrying element before impact. This fact has an impact on the vibratory conveyor noise minimization. Figures 10 and 11 demonstrate time behaviours of both, the carrying element as well as object coordinates during the optimal operation status and with high charge of the object.

Conclusion

The kinematic and dynamic analysis of vibratory conveyors justifies why transport processes need to be adjusted properly. The research demonstrates that various operation circumstances can lead to difficulties with the effect on the optimal adjustment of the functional conditions. Knowledge gained in both analysis and operation simulation enables not only the proper design of vibratory conveyors, but it even shows possibilities of effective engineering arrangements for conveyor natural frequency regulations.

Literature

[1] KOŽEŠNÍK, J.: *Kmitání mechanických soustav*. Praha, 2008.

[2] HARRIS, C. M.: *Shock and Vibration Handbook*. Fifth edition. McGraw-Hill. NewYork, 2005.

[3] BRADSKÝ, Z., VRZALA, R.: *Mechanika III. Dynamika*. Liberec, 1986.

[4] DRESIG, H., HOLZWEIßIG, F.: *Maschinendynamik*. 8. Auflage.Springer Verlag. Berlin, 2008.

[5] NĚMEČEK, P., PEŠÍK, M.: PUV 2011-24384 *Kruhový vibrační dopravník*.

KINEMATIKA OBJEKTŮ VE VIBRAČNÍCH DOPRAVNÍKÁCH

Vibrační dopravníky jsou ve velké míře využívány v sériové výrobě pro dopravu součástí a materiálu. Jsou konstruovány pro hlavní pohyb přímočarý nebo šroubový. Nosným členem může být v prvním případě žlab nebo trubka, ve druhém případě se obvykle jedná o buben s vestavěným šroubovým vedením. Kmitavého pohybu se dociluje budící silou, jejíž frekvence je rovna nebo se velmi blíží vlastní frekvenci kmitání nosného členu. Budící síla je vyvolána například rotačním pohybem excentricky umístěné hmoty nebo elektromagnetem. V příspěvku je řešena kinematika pohybu unášeného objektu ve vibračním dopravníku, která je určujícím kritériem pro hodnocení funkčnosti a výkonosti takového dopravního zařízení.

DIE KINEMATIK VON OBJEKTEN IN VIBRATIONSFÖRDERERN

Vibrationsförderer werden vor allem in der Serienproduktion zur Beförderung von Bauteilen und Materialien genutzt. Sie wurden für zwei Hauptbewegungsarten entwickelt: der geradlinigen als auch der spiralen Bewegung. Das tragende Element kann im ersten Falle eine Rinne bzw. ein Rohr sein, während es sich im zweiten Falle primär um eine Trommel mit spiralförmiger Tragfläche handelt. Die Schwingung wird mittels Erregungskraft erzielt, deren Frequenz gleich oder nahe der Eigenfrequenz des Tragelements liegt. Die Erregungskraft kann beispielsweise mit Hilfe einer exzentrisch rotierenden Masse oder mit einem Elektromagneten hervorgerufen werden. Der nachfolgende Artikel löst die Bewegungskinematik des beförderten Bauteils in einem Vibrationsförderer. Die Bewegungskinematik ist das grundlegende Kriterium für die Funktionalität und Leistung von Transportanlagen wie dem Vibrationsförderer.

KINEMATIKA MATERIALÓW TRANSPORTOWANYCH W PRZENOŚNIKACH WIBRACYJNYCH

Przenośniki wibracyjne są używane przede wszystkim w produkcji seryjnej do transportowania elementów budowlanych i materiałów. One zostały rozwinięte dla dwóch głównych sposobów ruchu: ruchu prostoliniowego jak również ruchu spiralnego. Elementem nośnym w pierwszym przypadku może być rynna lub rura, zaś w drugim przypadku jest to głównie bęben o spiralnej powierzchni nośnej. Drganie uzyskuje się za pomocą siły wymuszającej, której częstotliwość jest taka sama lub zbliżona do własnej częstotliwości elementu nośnego. Siła wymuszająca może być wywołana przykładowo za pomocą ekscentrycznie wirującej masy albo elektromagnesem. Kolejny artykuł rozwiązuje kinematykę ruchu transportowanego elementu budowlanego w przenośniku wibracyjnym. Kinematyka ruchu jest podstawowym kryterium na funkcjonalność i wydajność urządzeń transportowych jakim jest przenośnik wibracyjny.