OPPONENT REVIEW OF PHD THESIS

Dissertation thesis: **DESIGN OPTIMIZATION OF LINEAR VIBRATORY CONVEYORS**

Author: **M.A. Martin STURM**

Opponent: **prof. Ing. David HERÁK, Ph.D.**

Department of Mechanical Engineering, Faculty of Engineering, Czech University of Life Sciences Prague

Summary

This dissertation deals with the functional and performance optimization of vibratory conveyors in conjunction with the reduction of vibration to the ground with reference to the needs of practice. Based on an analysis of the current transport process of bulk materials, dynamical models have been developed. With regards to the results of the developed modification possibilities, an efficient model for the optimum transport of the goods by simultaneous reduction of vibration transmission to the ground has been developed too. A comprehensive dynamic analysis and optimization of the transport process have been done, both with regard to the correct tuning of the vibratory conveyor and maintaining the required dynamic parameters, as well as with regard to the mechanical properties of the transported objects. Based on the results of the optimization the dynamic parameters have been proposed and measured.

Objectives

In this PhD thesis the following main objective has been set.

The main objective of this dissertation is to determine design methods and selected structural measures for building linear vibratory conveyors in a way that their application achieving operational reliability, sufficient and uniform performance during transport of objects and bulk materials.

In my opinion, it can be stated that all the objectives of this PhD thesis have been successfully fulfilled.

Analysis of the current state

For analysis of the current state the author used scientific works, professional books, conference proceedings, publications in prestigious international scientific journals and also patent files. He described the current state in a concise and comprehensible form. Discussion has been supported by appropriate references.

Theoretical impact of this thesis

The author has consistently described the creation of several models of linear vibratory conveyors based on different mass systems in order to optimize their dynamical behavior.

Practical impact of this thesis

The author has demonstrated the possibility to use simulation models to solve the practical industrial problems and to verify these models on the conducted experiments. Its results show the possibility of using numerical analysis for optimization of linear vibratory conveyors.

Comments on solution process and used methods

The solution process is logical and systematic. In the introduction the author formulates the objectives of his work, which are gradually fulfilled in the next chapters of this thesis. The used materials and methods are fully in line with the research needs. The materials and methods were appropriately chosen and suitably applied, which led to successful solution of the solved problem. As a weakness of this dissertation thesis I see its unconventional division into chapters which are not in accordance with traditional concept of scientific work such are Introduction, Materials and Methods, Results, Discussion, Conclusion. It is also inappropriate that the chapter "discussion" is not included before the chapter "conclusion". In chapter "discussion" the gained results should be compared and commented with already published studies. In my opinion the gained results should be statistically verified and compared.

Assessment of the importance of PhD thesis for the scientific field

This PhD thesis significantly extends knowledge in the scientific field "Machine and Equipment Design" as well as in related scientific fields, and author has demonstrated excellent knowledge in this scientific field.

Comments on results and concrete benefits

In this PhD thesis, the original results have been presented. Author used quoted sources and appropriately used his knowledge in the scientific field of " Machine and Equipment Design".

Formal level

PhD thesis has been done carefully, logically, clearly and at a very good technical level with a large number of clear color graphs and pictures. As I mentioned before the structure of thesis didn't follow traditional concept of scientific works. In the text of this thesis there are also some minor formal irregularities that do not diminish the professional importance of the presented PhD thesis.

Overall appreciation

The author has demonstrated a high level of scientific qualifications and he has proven that he can apply his knowledge practically. The presented PhD thesis brings new scientific knowledge.

Questions for defence

1. Did you use any statistical analysis to verify your gained data?
2. Did you try to use FEM for optimization of linear vibratory conveyors?
3. There is any practical application of your system of optimization?

Concluding statement

Based on the submitted PhD thesis, according to Act No. 111/1998, and after a successful defense I recommend to grant the academic degree **doctor** abbreviated as **"Ph.D."** to **M.A. Martin STURM.**

In Prague, 4. 3. 2018

prof. Ing. David Herák, Ph.D.

prof. Ing. Vojtěch Dynybyl, Ph.D.
České vysoké učení technické v Praze
Fakulta strojní, Ú 12113, Ústav konstruování a částí strojů
Technická 4, Praha 6 – Dejvice

Opponent Review

Dissertation

Design Optimization of Linear Vibratory Conveyors

Author: Dipl. - Ing. (FH) M.A. Martin Sturm,
University of Applied Sciences Zittau / Görlitz

Supervisor: Prof. Ing. Lubomír Pešík, CSc., Technical University of Liberec

The main aim of the dissertation is to optimize the construction of linear vibration conveyors with regard to their performance and stability of kinematic conditions in the transport process of articles and bulk materials. In addition, the work is devoted to minimizing the dynamic forces acting on the conveyor.

The processing methods are based on the optimization of the functional and thus the performance characteristics of the representative vibration conveyor, the identification of its dynamic parameters and the construction of a mechanical model for which a dynamic analysis is then performed. The theoretical solution is aimed at determining the effect of the position of the center of gravity and the stiffness of the conveyor relative to the driving force effects on the kinematic values of the conveying member. In order to reduce the dynamic force effects transmitted to the conveyor bed, the principles based on a two-mass dynamic system are observed using operating conditions with the effect of a dynamic vibration absorber. This is the theoretical contribution of the Work.

In both cases of vibration conveyors, the results of the theoretical solutions were verified on functional samples of vibration conveyors by measuring the values of kinematic quantities during the transport process.

The solution of the objectives of the dissertation can be divided into four areas.

The first area deals with linear vibration transport systems and their parameters. Basic dynamic parameters that directly affect the function and performance of vibration conveyors are defined. Their identification is carried out on a selected representative type of vibration conveyor based on the measurement of kinematic quantities.

In the second area, dynamic parameters are analyzed in terms of their effect on the functional and performance characteristics of the vibratory conveyors. Due to the significant complexity of the computational models, Maple numerical methods have been used to solve them.

The third area is devoted to design proposals and measures to optimize the operation of vibratory conveyors. The procedures for determining the center of stiffness of the dynamic system of the single-vibrating vibratory conveyor are defined as a major factor influencing the fluidity of the transport process.

The fourth part of the dissertation deals with two-mass systems with guiding mechanisms used to unify the values of kinematic quantities in the entire transport area of the transport member. These systems also consider the possibility of reducing the dynamic force effects transmitted to the subsoil using the dynamic vibration absorber principle.

The conclusion of the doctoral thesis deals with the assessment of the effectiveness of solved and realized measures for smoothness and performance of the transport process.

The dissertation solves the current problem of technical practice consisting in optimization of the transport process of components and loose materials. The workflow is chosen logically and the steps that produce the partial results are gradually implemented into the final solution.

At the beginning of the dissertation, single- and double-mass vibration conveyors are solved, of which single-wires have or do not have a guide member. Here, it would be more appropriate to divulge in greater detail the advantages and disadvantages of both design solutions. The theoretical calculations of the mechanical models are solved numerically and the results are presented in the form of time or frequency waveforms. This fact, however, requires the assignment of specific values of the dynamic parameters, which is not always documented in the respective calculation, thus losing the more general significance of the influence of the individual parameters. At this point it would be advisable to always specify the default parameters of each calculation, eg Figure 12.

Identifying dynamic parameters based on measurement, which is reasonably supported by mechanical models, is the right method. The measurement of the time courses of the forced and free oscillations of the selected conveyor is handled carefully but in some cases insufficiently readable, e.g., Figure 24. In addition, the notion of resonance and its own frequency is formally mistakenly represented below figure 32.

Constructive modifications on a selected conveyor based on theoretical calculations focused on the mutual position of the center of gravity, the stiffness center, and the excited forces result in very good results in limiting the rotation of the conveying member and unifying the values of its kinematic variables at the beginning and end of the transport path. Here, however, I must note the incorrectly indicated coordinate axes of Figures 43 and 44.

The introduction of a two-mass vibration conveyor model using the principle of a dynamic absorber to minimize dynamic forces transmitted to the subsoil shows itself as a path in the right direction, where the author rightly exploited the fact that the vibration conveying force of the vibration conveyors usually has a constant frequency.

The objectives of the dissertation are solved successfully.

It can be stated that the doctoral thesis respects the established procedures of scientific research work consisting of modern computational and measuring procedures, which allow to solve and to optimize the design of machines and equipment.

Questions for defense:

1. What is the effect of the amplitude and frequency of the driving force on the speed of the transport process?

Based on my assessment about the thesis of Mr. Dipl.-Ing. (FH) M. A: Martina Sturm I note that the submitted doctoral thesis meets the requirements of the law No. 111/1998 and I recommend following the successful defense to award the Ph.D.

Prague, 5th March 2018

doc. Ing. Václav Vaněk, Ph.D.
Západočeská univerzita v Plzni
Fakulta strojní, Katedra konstruování strojů
Univerzitní 8, 306 14 Plzeň

Review of the dissertation

Martin Sturm

with the title

„Design Optimization of Linear Vibratory Conveyors“

Study branch: 2302V010 – Machine and Equipment Design

University: Technical University of Liberec (TUL), Faculty of Mechanical Engineering

Analysis of work

The dissertation deals with ensuring the good functioning of the vibratory conveyors (optimized and fluid flow of the transported material) in connection with the optimization of their performance characteristics while reducing the transmitted vibrations to the surroundings and to the base. It is demonstrable that all of the above is very desirable in technical practice and therefore the PhD student in his DisP deals with this issue. On the basis of analyses of the transport process of bulk materials, dynamic models, procedures and methodologies are designed to apply the principles of systematic design of technical systems directly into practice. The result is a flexible and fast implementation of CAD and computational modelling results in conveyor design, thus achieving an optimized and efficient way of transporting the required material and reducing vibrations transmitted to the environment.

DisP is divided into the following chapters

- **Introduction** – In the introduction, the author commented on what is the subject of DisP and states that vibration technology is currently used in many industries. It is an integral part of manufacturing and assembly lines and is a means of transporting components to a place of processing or assembly. Nowadays, mining, metallurgy, processing plants and other primary types of industrial production cannot be imagined without vibration techniques. Vibratory conveyors often associate into large units (functional groups) that are part of automated production and assembly processes. Due to the interaction of simultaneous operating subsystems and resulting synergic effects, the dynamic properties of the entire transport system may deteriorate and thus the deterioration in the spread of its undesirable dynamic effects on the environment may occur. Vibration conveyor manufacturers are still working to increase conveyor capacity and reduce the energy intensity of the entire transport process (resonant area operation). However, this requirement requires high demands on the correct tuning of the dynamic properties of the transport system. Although vibrational research has been in progress for many years, there are still problems in designing and determining the optimal parameters of dynamic vibratory conveyors, taking into account their mechanical properties and the characteristics of the objects being transported. Operating problems also concern their operational reliability, power stability and adverse effects of vibration and noise on the environment and the working environment.
- **Objective of the dissertation** – Here are the DisP objectives. The primary objective is to create suitable methods for optimized construction of the vibratory conveyor system and tools for designing a suitable design so as to achieve high operational reliability, sufficient and stable transport performance of the conveyed material (both bulk and loose). A partial goal is also to minimize the spread and transmission of vibrations to the environment.
- **Vibratory conveyors and their underlying systems** – In this chapter, the author analyses the individual vibratory conveyors that are used in different areas, where transport of lumps and loose

material (including sorting and compaction ...) is necessary. The main advantage of vibration conveyors is their relative design simplicity, reliability and easy maintenance. When vibrating conveyors are used in buildings and assembly halls, their main disadvantages associated with vibrations and noise are gradually shown. The chapter also discusses factors that significantly affect conveyor performance and performance (amplitude and carrier frequency, elevation, transport surface properties and material transported, vector size and direction FE ...). The author notes that there are a number of design variants and linear vibratory conveyors and selects the four organ structures of the conveyors (in DisP marked A to D) which are most commonly used in technical practice. Option C is of little importance. The General Organic Configuration A, B and D is given special attention in DisP. Furthermore, the author deals in more detail with individual parts of the conveyors (frame, carrier, guide, flexible and damping links, exciter, etc.).

- **Kinematic schemes and mathematical models of vibratory conveyors** – In this chapter, kinematic schemes and their mathematical models for A and B linear vibration systems are created. In the chapter it is shown that B variant conveyors are less sensitive to adequate differences in spring stiffness and the change in the centre of gravity position (material centre) caused by the material, to be transported during the actual transport process. In the case of applications where sudden changes in load during the transport process, especially on one side of the transport carrier, can be expected, variant B appears to be more resistant to these adverse external influences compared to variant A and is thus able to reliably provide the required transport of material in the given direction. Further, the two-mass system (variant D) is solved. The system consists of excited mass and an absorption mass, which is also a transport carrier. This design option makes it possible to minimize vibration transfer into the subsoil. The author also mentions the issue of the material being transported and states that the problem is mainly bulk material or material that is transported in the layers. It is important that the layers are not removed during transport and do not interfere with the transport process. The author does not pay much attention to this issue in DisP and assumes that the properties of the material for transport by the vibratory conveyor are met. The weight and structure of the material to be transported affects the properties of each of the presented variants A through D, but with each variant in some other way. Furthermore, the consequences of undesirable vibration transmission on the subsoil and hence on the building as well as their distribution to the environment are mentioned, which has a negative impact especially on the working environment. The author states that the aforementioned adverse effects greatly deteriorate when the conveyors work in groups and their operating frequencies are close.
- **Analysis and optimization of the transport process** – The initial step in the system optimization process is the analysis of the current system. PVA 050.012 P conveyor was chosen, a product of VIBROS s.r.o., Příbram. First, the dynamic parameters of the vibratory conveyor are identified in DisP. These are parameters of mass and inertia (individual parts of the conveyor are considered and in the first step without the material being transported). Then the determination of the stiffness of the helical springs used in the vertical and horizontal directions, the damping of the free-oscillating system (the author notes that too high damping would adversely affect the continuous transport of the material and would also aggravate the unfavourable oscillation around the conveyor's mass point (variant A)) of the system's own frequencies (the results of the analysis show that no system frequency does not correspond to the excitation frequency of 16.00 Hz, and it is therefore possible to assume that the conveyor properties are not fully utilized to achieve maximum transmission capacity), transporting the transport carrier (analysis showed that the motion trajectory the transport carrier is not of the desired shape, which is probably due to the fact that the centre point of the weight and the centre of elasticity are not located in the geometric centre of the system and do not pass through the force excitation vector) (analysis has shown that the exciting force does not pass through the centre point of mass and elasticity, which leads to uneven movement of the carrier and thus the material transported), the movement of the transported material (the movement along the transport path is analysed, where the direction the output increases the amplitude in the direction of the axis, it degrades the fluency of the movement of the transported material - everything is shown on the video), the vibration transfer to the subsoil (the analysis shows the significant frequencies that are transmitted to the subsoil). Further, the author analyses the dynamic parameters of the conveyor. The result of the "Maple" calculation is a graph showing the dependence of the offset in the z-axis direction (caused by tilting around the centre of gravity) to the stiffness of the springs. The calculation and graph confirm the results obtained during system testing, suggesting that the proposed mathematical model can be used as a useful tool for general analysis of linear A vibration conveyors. In the next step, the proposed model will be used to determine a pairwise spring configuration so that the minimization of vibration around the mass point is achieved. Further, based on the results of the calculation model, it is shown that the analysed conveyor exhibits a considerable oscillation in the direction of rotation around the mass point. The transmitted vibrations into the subsoil are not eliminated in any way. The author of DisP has shown that increased

damping between the carrier and the frame would reduce the capacity of the transported material and increase the rotation around the material point. Another possible solution would be stripping the conveyor frame from the subsoil using rubber shock absorbers, but the author considers this solution less effective. As a possible effective solution, the author presents the re-construction of variant A into variant D. With this modification of the conveyor, the author deals further in this DisP.

- **Improvement of the conveyor** – In the first step, the author deals with the modification of one mass system in order to optimize the movement of the carrier. Previous analyses have shown that this can be achieved by appropriately relocating the centre of elasticity in several ways. The author does not prefer to change and move the weight. Changing the spacing of the flexible links from the geometric centre would be a significant impact on the structure and, if shortened, the increased sensitivity to the distribution of the transported material along the length of the carrier. The author of DisP opted for the possibility of modifying the stiffness of the binding springs. He used commercially available springs on the market, which required an extension of the shorter springs by means of an embedded compensating member. Numerical simulations have shown that there has been a significant reduction in oscillation in the direction of rotation around the mass centre. Another possibility of eliminating vibrations around the mass centre is the use of a guiding lever mechanism. Due to the collected degrees of freedom, there is no turning around the mass centre. Numerical simulations have confirmed that the advantage of the variant B solution, compared to the variant A conveyor, is the lower sensitivity and dependence on the individual stiffness of the springs mounted at points A and B of the conveyor. Also, sudden changes in the weight of the items transported do not greatly affect the quality of transport over the length of the carrier. Given that it was not possible to modify the design of the linearized vibration conveyor to such an extent, and that no significant elimination of the vibration transfer to the subsoil was achieved compared to Variant A, this variant was not subjected to practical tests. On the basis of the analysis, however, B can be recommended for those cases where the reduced conveyor sensitivity is required for the uneven distribution of the conveyed material, and at the same time we do not require a reduction in vibration transfer to the conveyor. Furthermore, the influence of modification of the structure of the analysed conveyor (mounted on springs with other stiffness and compensator of their length) on the transport process was experimentally verified. There has been a change in the system's own frequencies, but again the conveyor has not been able to work in a near-resonant state. The centre of elasticity is considerably closer to the driving force vector, but unfortunately some deviation from the desired position remains. The difference between the calculated and the real value lies above all in the deviations of the mass and the accuracy of the production of the individual parts, as well as in the deviations of the functional parameters such as springs. It is therefore expected that the movement of goods along the entire length of the conveying element will be much more uniform, but small differences in the amplitudes of the trajectory of movement in the z-axis direction will still occur. Furthermore, the movement of the transport carrier at the inlet, centre and outlet of the conveyor has been mapped using reference elements. It has been found that deviations of the carrier movement trajectory from the elevation angle are much smaller compared to the unmodified conveyor and the difference between the amplitudes of the carrier movement in the z-axis direction is also considerably smaller. This resulted in a more stable and more uniform movement of the material along the length of the carrier. The resulting improvement is also shown on the enclosed video. Furthermore, it is shown by simulations and practical measurements that the optimization of motion and the simultaneous reduction of vibrations transmitted to the substratum of a linear vibration conveyor designed as a mono-mass system is not possible. In order to eliminate the transfer of vibrations into the subsoil, a functional model of the two-mass conveyor was designed and tested for this purpose. In the second step the author deals with the design and verification of the two-mass system in order to optimize the movement of the carrier and reduce the transfer of vibrations into the subsoil. Based on numerical simulations, the conveyor has been designed so that the motion energy is passed from the pumped mass $m1$ to the absorption mass $m2$, which is the transport carrier. The weight $m1$ remains stationary and vibrations to the subsoil are eliminated. Numerical analysis has shown that the pulsed mass $m1$ is almost static with very low amplitude while the transport carrier $m2$ operates in resonance, which is in line with the requirement for an efficient and energy-less transport of material. Inaccuracies in the production of the machine parts from which the conveyor is composed, the use of a simple bearing type and the weak fixation of the springs cause the undesired movement of the drawn mass $m1$. It can be assumed that optimization of construction and refinement of production could lead to further reduction of vibrations into the subsoil. Furthermore, the impact of the material transported on the transport process and the transfer of vibrations into the subsoil is assessed in DisP. The observed traversing characteristics of the material to be conveyed show that the two-mass vibration conveyor does not respond sensitively to weight gain (tested at 0.5, 2, and 5.00 kg), which is already a 78% increase in mass of the mass of the conveying element. The higher the weight of the transported goods causes lower amplitudes of the

trajectory of the transport carrier. The described effect can be offset by increasing the force of the FE if necessary to avoid a decrease in the transport capacity of the conveyor. The magnitude of the mass trajectory $m1$ will also grow, but due to expected, very small changes can be expected to remain very low and have no significant effect on the transmission of vibrations into the subsoil.
- **Conclusion** – At the end of the thesis, the author evaluates proposed numerical models of individual design variants of linear vibration conveyors and their universal applicability in the design of vibration conveyors in practice. Furthermore, the author commented on the verification of the proposed numerical models by experimental determination of the dynamic properties on the analysed industrial conveyor modified by one mass conveyor and the designed and constructed two-mass test conveyor.

Achieving the goals set in the DisP

The primary goal of DisP was to develop appropriate methods for optimized vibration transport system design and tools for designing a structured structure design to achieve high operational reliability, sufficient and stable transport performance of the conveyed material (both bulk and loose). A partial goal is also to minimize the spread and transmission of vibrations to the environment. Based on DisP performed numerical simulations and practical tests, it can be assumed that even rapid changes in the load caused by, for example, gradual filling of the conveying element will not have a significant effect on the transport properties of the linear two-mass vibration conveyor. This result confirms the suitability of designing conveyors using proposed computational methods in DisP and thus achieving their more efficient deployment and use in industrial applications. By using the proposed design tools in the DisP, the two-mass conveyor can be designed in such a way that vibration transfer to the subsoil is greatly eliminated. Based on the above mentioned facts it can be stated that the general objective of this DisP is achieved, ie the optimization of the transport process while reducing the vibrations transmitted to the subsoil as well as proving and confirming the correctness of the developed calculation models and their usability in the numerical simulations of the proposed vibratory conveyors in industrial practice.

The objectives and sub-objectives of the dissertation, which are listed in Chapter 2 DisP, I find it fulfilled

Level analysis of the current situation in DisP solved problems

The analysis of the present state of the problem is presented in the proposed DisP in a comprehensible and, in my opinion, exhaustive way. The author states that vibration technology is currently used in many industries. Although vibrational research has been in progress for many years, there are still problems in designing and determining the optimal parameters of dynamic vibratory conveyors, taking into account their mechanical properties and the characteristics of the objects being transported. Operating problems also concern their operational reliability, power stability and adverse effects of vibration and noise on the environment and the working environment. The author analyzes and analyses typical constructions of linear vibratory conveyors, explains their operating principles and describes the most used principles of exciters. In DisP, four types of conveyor design variants are identified, from which three of the most commonly used variants of linear vibratory conveyors are analysed in practice.
In DisP, it is shown that the proposed design support methodology has considerable potential for deploying in industrial practice and thus achieving the production of conveyors whose properties are closer to the required properties according to the requirements specification and which will ensure more efficient transport of the required material and will be less energy consuming.

Theoretical contribution of the dissertation

In the DisP, mathematical models of both single-mass conveyors in variants A and B as well as two-mass conveyors in variant D were developed. The properties of different types and forms of the transported material were analysed theoretically and its influence on the dynamic behaviour of the vibratory conveyor and reliable and smooth transport material over the entire length of the transport carrier. An analysis and numerical simulation of an industrial conveyor PVA 050.012 P has been carried out, on the basis of which the causes of uneven transport of material along the transport carrier were revealed. Due to the fact that the centre point of mass and the centre of elasticity are not located in the geometric centre of the system and do not pass through the force excitation vector, a modification of the springs used has been proposed to achieve a displacement of the centre of elasticity in such a way as to approximate as closely as possible to the excitation force vector. Based on the numerical simulations, the proposed modified system was practically implemented and experimentally verified some selected properties and its behaviour. The experimental results confirmed numerical simulations of the expected change in the dynamic behaviour of the conveyor. The movement of the material along the entire

length of the conveying element was much more uniform, but small differences in the movement trajectory amplitudes appeared in the z-axis direction. Furthermore, the movement of the transport carrier at the inlet, centre, and outlet of the conveyor was mapped through the reference elements. It has been found that deviations of the carrier movement trajectory from the elevation angle are much smaller compared to the unmodified conveyor and the difference between the amplitudes of the carrier movement in the z-axis direction is also considerably smaller. This resulted in a more stable and more uniform movement of the material along the length of the carrier. Due to the expected unsatisfactory results regarding the transfer of vibrations into the subsoil, a two-mass vibration test conveyor is designed. It works on the basis of the results obtained from the previous numerical experiments and simulations that are used in the design of the test conveyor. The underlying idea is that motion energy is transferred from the exited mass $m1$ to the absorption mass $m2$, which is the transport carrier. The weight $m1$ remains stationary and vibrations to the subsoil are eliminated.
This idea is verified and confirmed by the experimental analysis of the movement and vibration of the test conveyor.

Practical contribution of dissertation

The practical benefit of DisP is the creation of methodology and support tools and means suitable for numerical simulations of dynamic behaviour, either newly proposed or based on the requirements for their properties of modified vibration conveyors. The aim of this effort is to design conveyors with stable, fluid, reliable and efficient transport of the required material at as low operating costs as possible and possibly reducing the transmission of unwanted vibrations to the environment and the subsoil.
An important result of this DisP is also the recommendation for designing vibration conveyors with optimized properties.
The author states that
- Designers will have to choose the optimum conditions for each individual vibration system depending on the shape and weight of the material being transported.
- Designers must pay particular attention to the rotation and individual design of the conveyor structure.
- Fastening the springs to the vibratory conveyor is essential. The springs should be selected with respect to the correct preloading imposed especially by the transport carrier.
- It is useful to prioritize certain basic assumptions about the material being transported for the design and calculation of the transport carrier. The goal is to achieve optimal transport capacity while respecting the maximum upper load tolerance limit.

For a more flexible adaptation of linear vibratory conveyors to changes in the properties of the transported material, the author suggests the possible implementation of pneumatic springs into the two-mass vibration conveyor system. By simply adjusting the spring pressure, it would then be possible to create similar conditions for the transport of different materials to achieve an efficient transport adapted to the changing material.
In conclusion, the results of DisP offer significant potential for their use by the industrial sphere, especially for the design of optimized linear vibratory conveyors. Based on the methodology, the design of existing conveyors can also be analysed, evaluated and modified.

How the methods have been applied

The chosen methods and, above all, the proposed simulation tools (experimentally verified) have been applied appropriately and correctly following the logic of the development, design and optimization of the linear vibratory conveyor.

Proving of relevant knowledge in the field

I think that the author is very well oriented in the solved problems, which follows from the previously acquired both theoretical and practical knowledge and experience.
In the given field, he has unequivocally demonstrated the appropriate knowledge that he used for the design of DisP of his own solutions.

Formal level of work

DisP is systematically processed. Its language level and graphic processing have an appropriate level. In DisP there are only minor errors especially in the references to images and in the confusion of the designation of some variables in the mathematical relations mentioned in DisP.

Dissertation queries

1. Were the results obtained by analysing the product of VIBROS s.r.o., Příbram and its subsequent modifications aimed at ensuring more efficient transport of materials, implemented in design processes and whether they have led to structural changes in the products of the mentioned company or other company?
2. It is mentioned in the DisP adversely affect linkages with clearance on the final properties of a vibrating conveyor. Would it be recommendable to replace the line formed by rotary link levers with another suitable system without clearance (e.g. rigidly attached elastic lamellas)?
3. Due to the fact that the conveyor operates a number of external and to ensure optimal transport capacity and to minimize the vibration transfer to the subsoil, most of the adverse effects, it is considered suitable for vibration conveyors to use such "active" machine elements as would be able to change the input conditions respond appropriately?

Closing statement

Based on the above, I recommend the dissertation work of **Martin Sturm** for the defence and in the case of a successful defence, I recommend to give the Ph.D. student an academic title

„Ph.D. "

doc. Ing. Václav Vaněk, Ph. D.

In Pilsen 6. 3. 2018