Dynamic Studies on a Slide Chain Conveyor System

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ABSTRACT In slide chain conveyors vibrations often appear. These cause detrimental effects in conveying process and decrease the durability of chains. To study the vibrations, a multi-body simulation model has been developed, in which rheological elements are used to represent the dynamic effects. A focus was determining material values required for the model. These were identified by hysteresis experiments. Finally, the model was verified by comparing simulation results with measurements in the conveyor system.

KEYWORDS vibrations, sliding chain, multi-body simulation, conveyor system

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KURZFASSUNG *Dynamische Untersuchungen an einem Gleitkettenfördersystem:* In Gleitkettenfördersystemen werden häufig Schwingungen der Kette beobachtet, die einen zuverlässigen Förderprozess auf diesen Anlagen beeinträchtigen können. Ziel dieser Arbeit ist die Erforschung dieser Schwingungen mit Hilfe von einem Mehrkörpersimulationsmodell. Zur Abbildung der dynamischen Effekte wurden rheologische Elemente verwendet. Ein Schwerpunkt lag bei der Ermittlung der für das Modell notwendigen Materialkennwerte. Diese wurden mit Hilfe von Hystereseversuchen herausgefunden. Zum Schluss wurde das Modell über einen Abgleich zwischen Simulation und Messung im Fördersystem verifiziert.

SCHLAGWÖRTER Schwingungen, Gleitkette, Mehrkörpersimulation, Fördersystem

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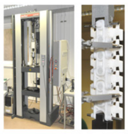
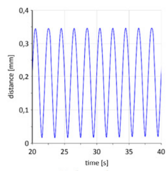
Test Setup

Conveying system

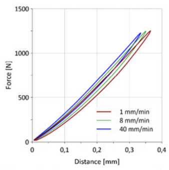


Chain in tensile testing machine

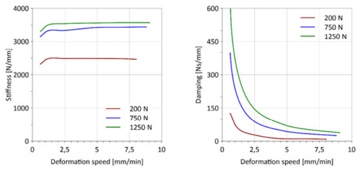
Experimental Studies to Determine the Material Characteristics



Deformation

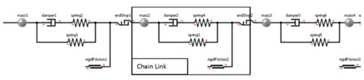


Force-displacement representation (hysteresis curve)

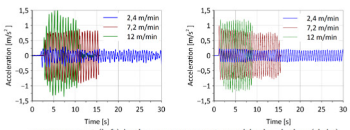


Stiffness and Damping at different maximum forces depending on the speed

Simulation Model



Detail of the simulation model



measurement (left) in the conveyor system with simulation (right)

Motivation

Chain conveyor systems with plastic chains are often used for flexible designs of material flow in many industrial sectors. External influences, e.g. loading and unloading the conveyor system with goods, can stimulate a slide chain conveyor system to vibrate.

Approach

Experimental studies on a complex conveyor system with Multilfex chains were carried out to investigate these dynamic phenomena. A multi-body simulation model has been developed and proofed with the test conveyor system. The model built up of mass-afflicted bodies and massless connection elements. The viscoelastic material properties of the slide chain are modeled by combinations of springs and dampers, a so-called rheological model.

Furthermore, the model includes the friction between the chain and the slide rail, the polygonal effect on the drive wheel, clearance between chain links and influence of the elements of conveyor layout.

Material Characterization

To determine the material characteristics, the chain was clamped in a tensile testing machine and conduct in a so-called hysteresis test. In this test, the chain is stressed to a cyclic load and the deformation is recorded. Experiments were carried out with different deformation rates and maximum forces. The material properties are obtained by the characteristic hysteresis curve. It was found that the material parameters of the chain depend on deformation speed and tensile force in the chain. For this reason, the $Zener_M$ model with a total of three elements was used as a material model. This model implicitly considers the deformation speed. To detect the force dependency, one of the two springs and the damper in the material model was provided with an additional parameter.

Summary

The model was compared with tests in a complex conveyor system. The most important results so far are:

- The amplitude increases with increasing conveying speed
- The frequency depends on the chain length and the mass load
- Vibrations in the first natural frequency of the chain members

With this practice-oriented simulation model, parameter investigations are currently being carried out in order to determine the precise influencing variables on the oscillation behavior.

TECHNISCHE UNIVERSITÄT CHEMNITZ

PROFESSUR FÖRDERTECHNIK

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1. Introduction

Chain conveyor systems with plastic chains are often used for flexible designs of material flow in many industrial sectors. These slide chain conveyors are used for internal transport of bulk goods and cover a wide range of applications due to their different chain sizes and versatile chain top. Due to its modular, track profiles, drives, redirections, wheels and sliding rails, their adaptation to the logistical processes is easy to cope with.

External influences, e. g. loading and unloading the conveyor system with goods, can stimulate a sliding chain conveyor system to vibrate. Experimental studies on a complex conveyor system with Multilflex chains were carried out to investigate these dynamic phenomena (see figure 1). A multi-body simulation model has been developed and proofed with the test conveyor system. With this model the source of vibrations in conveyor system can be examined.

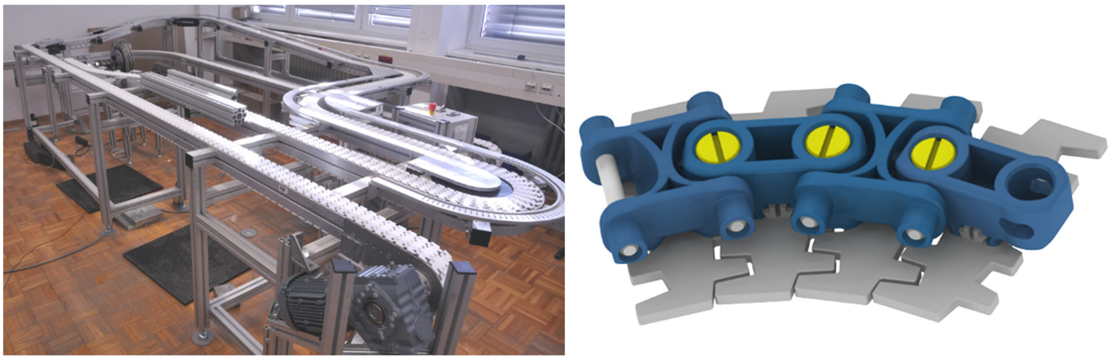

Figure 1: Test conveyor system (left) and used slide chain (right)

2. Problems Caused by Vibration

Vibrations of the conveyor chain result in a time-variable oscillating chain tractive force which can clearly exceed the statically calculated tractive force. These oscillation-induced load peaks can significantly influence the wear of sliding chains.

Dynamic effects in slide chain conveyors are largely unexplored and are not taken into account in existing calculation models. Calculations are limited to a static tractive force curve according to Auerbach [1], in which dynamic effects are not included.

The vibrations that occur in slide chain conveyor systems are mainly caused by longitudinal oscillations (green arrow in Figure 2). These can be seen visually depending on good load and chain length. Vibrations with large longitudinal amplitudes can be noticed especially at long distances. As a result, the conveying process can be so affected that the conveyed goods slip or tilt.

In contrast, transversal vibrations (red arrow in Figure 2) occur perpendicular to the direction of movement of the chain. Since the guiding system prevent a vertical chain movement, these transversal vibrations are less distinct.

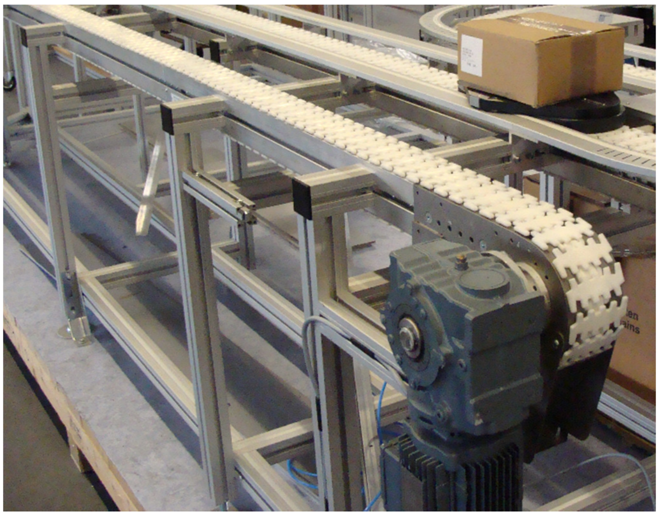

Figure 2: Slide chain conveyor system with schematic representation of the longitudinal (green arrow) and transverse (red arrow) vibrations

3. Proceedings

3.1. Model Approach

The slide chain conveyor system was abstracted, so that the chain can be transformed as a multi-body model. Since the chain is a multi-body system with many degrees of freedom that cannot be solved analytical, a simulation model was created using the software SimulationX. The model built up of mass-afflicted bodies and massless connection elements. The viscoelastic material properties of the slide chain are modeled by combinations of springs and dampers, a so-called rheological model [2]. The Zener$_M$ model, which is used, consists of two springs and one damper (see figure 3). Furthermore, the model includes the friction between the chain and the slide rail, the polygonal effect on the drive wheel, clearance between chain links and influence of the elements of conveyor layout.

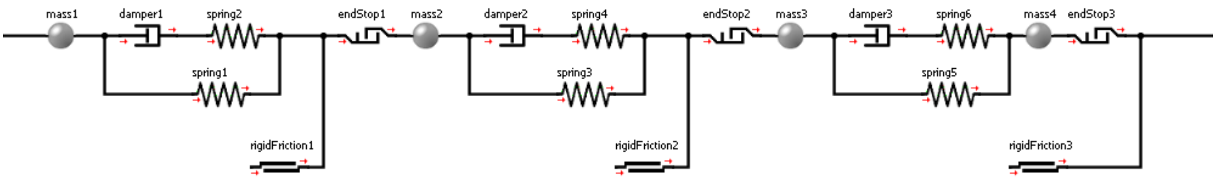

Figure 3: Detail of multi-body simulation model

3.2. Material Characterization

For the dynamic simulation of components made of non-metallic materials, more exact damping approaches are recommended [3, p. 235]. These consider internal damping forces due to the material deformation. Until now, no damping characteristics are known for plastic slide chains. The necessary material parameters are obtained by a hysteresis test. Figure 4 illustrates the experimental setup, in which the chain was clamped in a tensile testing machine and charged with a cyclic load, while the deformation was recorded with a distance measuring device.

Experiments were carried out with different deformation rates and different maximum forces. The material properties are obtained by the characteristic hysteresis curve [3, p. 237], shown in Figure 5. On the assumption of the simple rheological Kelvin-Voigt model (one spring and one damper parallel), the curves in figure 6 are determined for stiffness and damping.

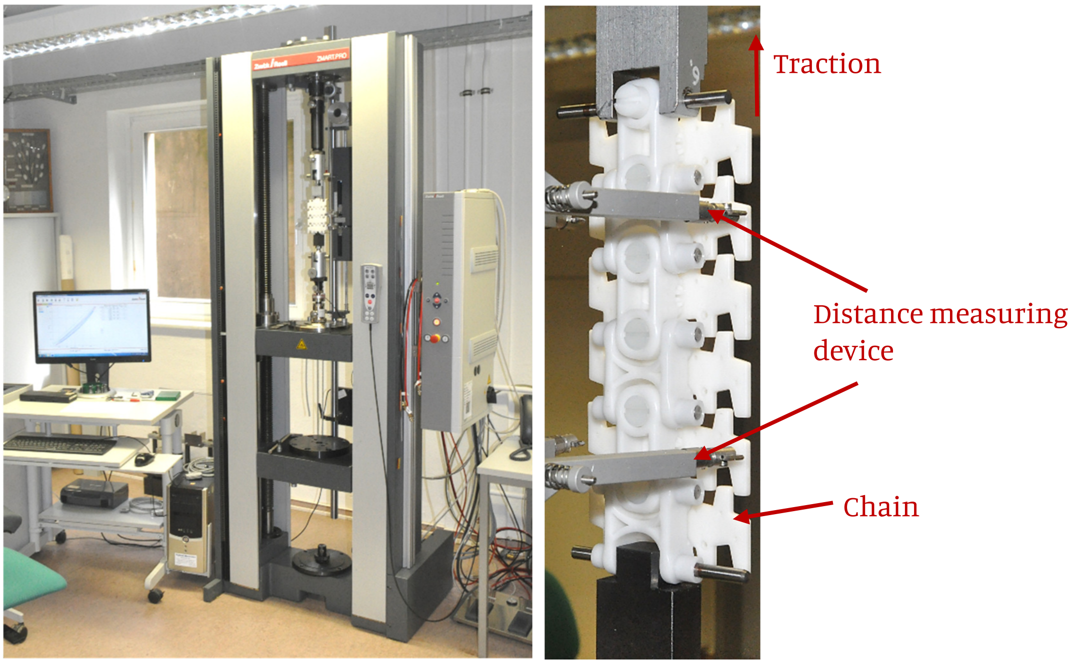

Figure 4: Test setup for determining the material characteristics

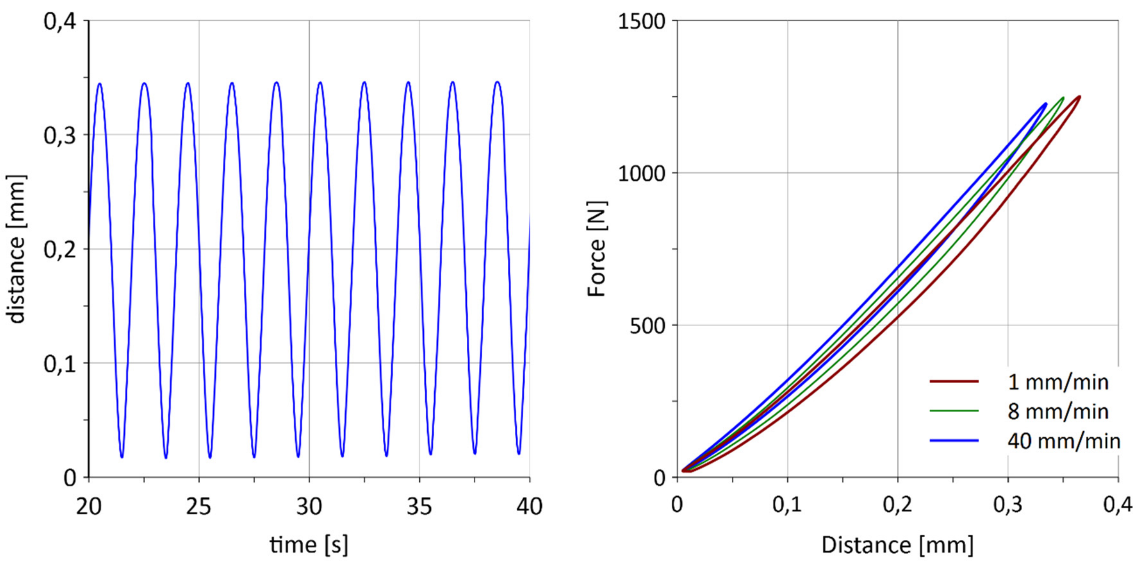

Figure 5: Deformation of a chain link (left) / force-displacement representation (right)

It was found that the material parameters of the chain depend on deformation speed and tensile force in the chain. For this reason, the Zener$_M$ model with a total of three elements was used as a material model. This model implicitly considers the deformation speed. To detect the force dependency, one of the two springs and the damper in the material model was pro-vided with an additional parameter. Finally, the material model has five parameters to characterize the viscoelastic material behavior. For the Zener$_M$ model, the parameters were obtained by an optimization calculation.

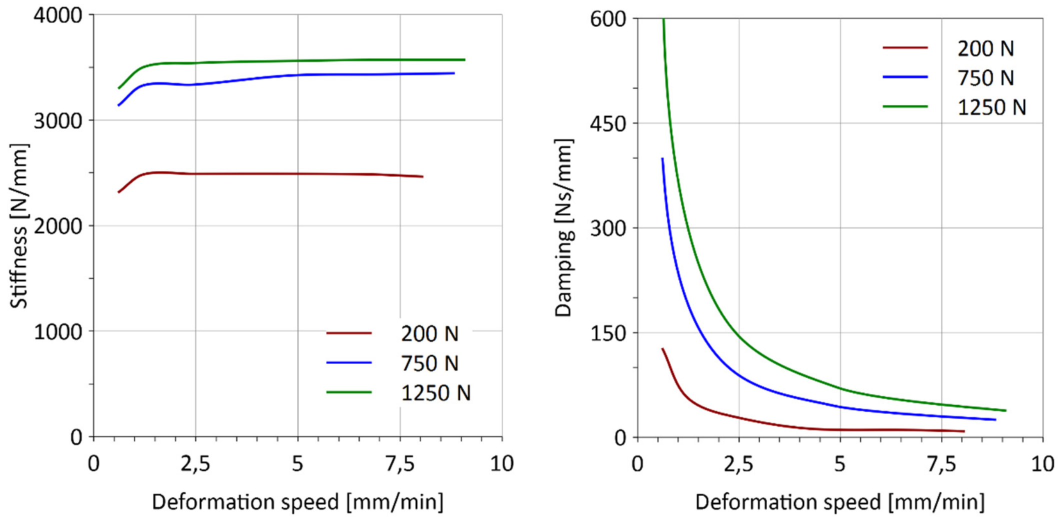

Figure 6: Stiffness (left) / damping characteristic at different forces and deformation speeds (right)

3.3. Model Validation

The simulation model was adjusted with the test conveyor system by measuring the acceleration. The conveyor chain of a length of 14 m was loaded at its end with a mass of 25 kg. An acceleration sensor was attached at the chain link in the end of the chain. The measured and the calculated acceleration are shown in figure 7 for three different conveying speeds.

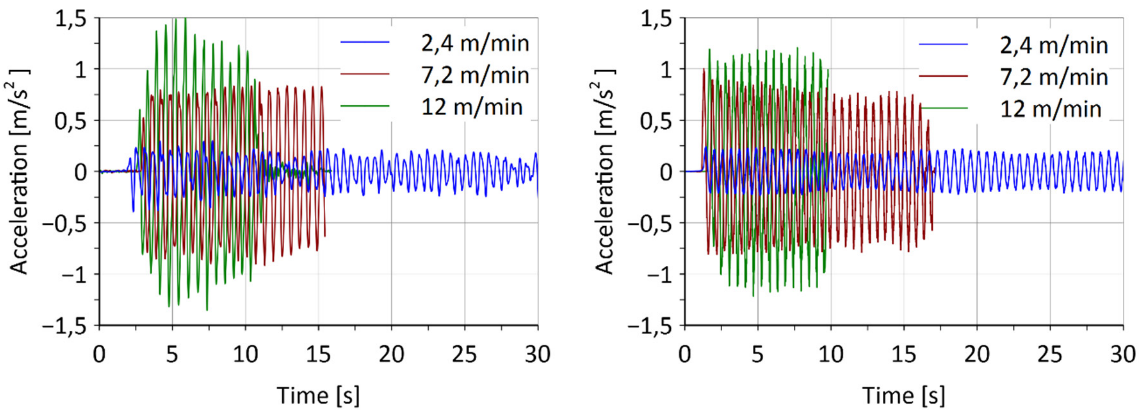

Figure 7: Measured (left) and calculated (right) acceleration

4. Summary

A multi-body simulation model has been developed and its model parameter determined by experimental studies. The model has been proven with a test conveyor system. The most important results so far are:

- The vibration amplitude rises with increasing conveying speed.
- The frequency depends on chain length and mass load.
- The chain vibrates in its first Eigen frequency.

With the practice-oriented simulation model, parameter studies are currently being carried out to determine the precise influencing variables on the oscillation behavior. These variables can be for example the excitation by the polygonal effect, the influence of the chain stiffness, the influence of the coefficient of friction or effects of the conveyor layout.

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