Nonlinear and chaotic dynamics of a vibratory conveying system

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Abstract. In this work a 2D model of a vibratory conveying system is presented. This simulation model allows to understand previously unexplained phenomena as multiple feeding velocities at the same operation point which were observed in practical measurements. The parameters which have an influence on this effect are studied and a method is developed how to predict and adjust the occurrence of multiple solutions. It is shown that this effect makes the calibration of the conveyor difficult in practice. Furthermore, it is proven that the system may show chaotic behavior in some configurations. These chaotic states in the simulation model are also shown with parameter studies and different methods are applied to predict the point at which the system becomes chaotic. Therefore, this work provides a deeper understanding of complex conveying processes using a simple simulation model.

Introduction

In modern conveying processes, the efficiency of conveyor systems is becoming increasingly important. This is caused by advancing customer requirements and enormous competitive pressure. Therefore, one has to understand the feeding process more and more deeply which is why a simplified simulation model is created. A main component of a simulation model of a feeding process is the contact model which is developed in [1]. For a detailed resolution of the contact process it is modeled as continuous process in contrast to the bouncing ball problem in [2]. Next, this vertical contact model is extended to horizontal direction which enables a representation of a feeding process. From the analysis in [2] it is known that the bouncing ball may show chaotic behavior. Therefore, this chaotic behavior [3] in vertical direction is coupled with the horizontal direction wherefore the 2D simulation model may show such chaotic behavior, too.

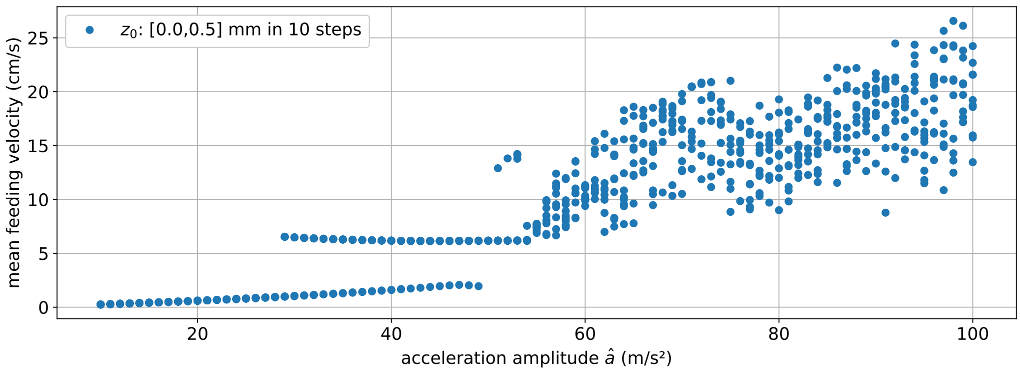

Figure 1: Multiple solutions of feeding velocity by varying initial conditions at certain operation points

Results and discussion

In Fig. 1 the results of the simulation of the conveying process are illustrated. The interesting variable is the mean feeding velocity in x-direction in a steady state motion. For different acceleration amplitudes of the conveyor, the initial position z_0 of the point mass is slightly varied. The results in Fig. 1 can be divided in 3 domains. In the first domain ($\hat{a} < 29\,\text{m/s}^2$), the mean feeding velocity is independent from the initial position z_0. In the second domain between $\hat{a} = 29\,\text{m/s}^2$ and $\hat{a} = 50\,\text{m/s}^2$, two stationary motions depending on z_0 appear. Therefore, a critical initial position z_0 exists which is responsible for the respective stationary motion. In the third domain ($\hat{a} > 50\,\text{m/s}^2$), we observe a fully chaotic behavior with sensitive dependence on z_0.

The chaotic behavior in the third domain is proven by computing Ljapunov exponent for continuous dynamical systems. A further method to visualize the chaotic behavior is to assess the curves in the phase space $\dot{x}(t)$ over $x(t)$. This shows non-closed contours if the system is in a chaotic state. Furthermore, the trajectories in the phase space are assessed with fractal dimensions which can be used as indicators for chaotic behavior, too. However, knowledge of the domains with multiple solutions and chaotic states can be used to adjust the conveyor. The verification of the statements may also be carried out in practice, which is part of future work.

References

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