Mechanism and Machine Theory 44 (2009) 1795–1805

Contents lists available at ScienceDirect

Mechanism and Machine Theory

journal homepage: www.elsevier.com/locate/mechmt

A novel simulation model for the dimensioning of cover band conveyors

Thorsten Schmidt [a,*,1], Lars Leiking [b,2]

[a] Technische Universität Dresden, Chair of Logistics Engineering, D-01062 Dresden, Germany
[b] Jungheinrich AG, Steinbockstraße 38, D-85368 Moosburg, Germany

ARTICLE INFO

Article history:
Received 30 October 2008
Received in revised form 6 March 2009
Accepted 16 March 2009
Available online 19 April 2009

Keywords:
Cover belt drive
System modeling
Simulative parameter analysis

ABSTRACT

Cover bands are a rather seldom deployed conveying technology having nevertheless a lot of potential for industrial applications. Especially for the vertical transportation, for the handling of a large article range, or for the achievement of a highly dynamic goods behavior cover bands own distinct advantages compared to classical means of transportation. However, the adjustment of belt tensioning forces is a highly crucial element that has not yet been studied in depth. This paper introduces two models (geometric and physical) and a simulation based upon these for the determination of system inherent forces and for finding design parameters.

1. Introduction

Cover bands are traditionally used to convey bulk goods in the form of packages, piece goods, sacks, or gravel-like material in order to cross mainly vertical distances of several meters, e.g., when unloading a freight hold of a ship or conveying cases inside a racking structure ([6], p. 24 et sqq.). Fig. 1 shows some examples of these applications and depicts their basic elements. The required conveying forces are actuated by adherence: The goods are covered by two driven flat belts or a driven flat belt and a (folding) plate. Pressing force is applied by the tension of the belts and additional pin rollers. A possible effect of this conveying method, which is sometimes made use of, is that the objects are being turned upside-down when they arrive at the output side of the conveyor, e.g., for the production of deep-drawn parts such as cans or cups described in [4]. As is implied by the above examples, different sizes of the cover band drive are possible depending on the case of application.

As for the vertical conveying of boxes, the belt statics of a cover band conveyor have been extensively studied in [6]. Equivalent studies analyzing highly dynamic load cases and inhomogeneous goods to be conveyed have not been conducted yet. Particularly in trying to achieve high feed rates the system designer is faced with the problem of how to properly adjust the belt tensioning system in order to avoid effects of force impacts by goods moving under the belt resulting in loss of pretension and uncontrolled slippage.

In this paper, the development of a simulation tool for analyzing dynamic effects on the cover band system is described. A geometric-physical model is chosen which is verified by experiments on a cover band test rig. The analyses are based on a case example in which a cover band is used to convey pouch chains. The cover band is of a relatively small size and requires only a basic set-up. The standard folding plate is partly (or can be completely) replaced by a guide pulley so that an increase in the wrap angle of the pouch chain by the cover band is achieved, thereby also increasing the transmissible force. Further

* Corresponding author. Tel.: +49 351 463 32538; fax: +49 351 463 35499.
E-mail addresses: thorsten.schmidt@tu-dresden.de (T. Schmidt), lars.leiking@jungheinrich.de (L. Leiking).
[1] During compilation associated with the Fraunhofer-Institute of Material Flow and Logistics, Dortmund.
[2] During compilation associated with the Graduate School of Production Engineering and Logistics of the Technische Universität Dortmund.

0094-114X/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.mechmachtheory.2009.03.004

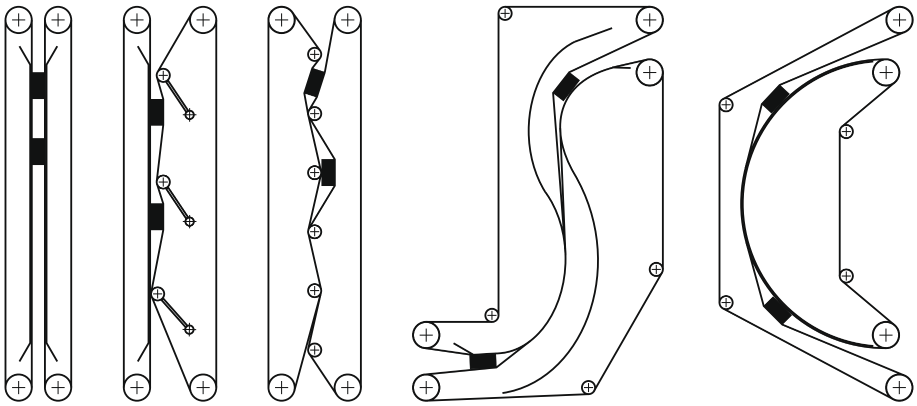

Fig. 1. Overview of different design concepts for standard cover belt systems (cp. [6], p. 23, [1,9]). From left to right, the characteristic of the conveying trajectory changes from straight to alternately radial to radial.

increasing of the force can be achieved by endowing the back of the belt with a special friction cover providing improved traction. Slack-side tension of the belt is imposed and maintained at a constant level by a floating tension pulley which compensates for belt elongation and changes in the thickness of the pouch chain inside the mechanism.

2. Simulation of the drive

A pouch chain can be a highly inhomogeneous object due to its fillings and their random arrangement. This circumstance is modeled in the following geometric simulation approach.

2.1. Geometric model

As shown in Fig. 2, the cover band system can be depicted two-dimensionally as a set of system-immanent pulleys and additional circular elements representing the pouch fillings between the cover band and the guide pulley. The cover band is—for the time being—assumed to be an ideally angular flexible, but inextensible string. Note that circles can also be used to model any type of edges of, e.g., boxes or cases so that the subsequently used term "pouches" in a general context can be interpreted as a synonym for an arrangement of circles describing a certain object type.

Given these conditions, a geometric simulation model can be derived: The pretension pulley by definition has one DOF (degrees of freedom) in order for the belt system to be able to conform to the shape of the pouch chain. Its position $y(t)$ as well as the poses and lengths of the belt sides are determined by the length of the belt $L_{s,0}$ and the position of the other pulleys and the objects under the cover belt. Given that the position of the objects under the belt is known for subsequent time steps of size Δt, the position of the pretension pulley $y(t)$ and the belt line can be updated for each of these steps. The required geometric and kinematic information can be generated as described in the following. Note that since they have equal properties regarding the computations, pulleys and objects will both be referred to as circles.

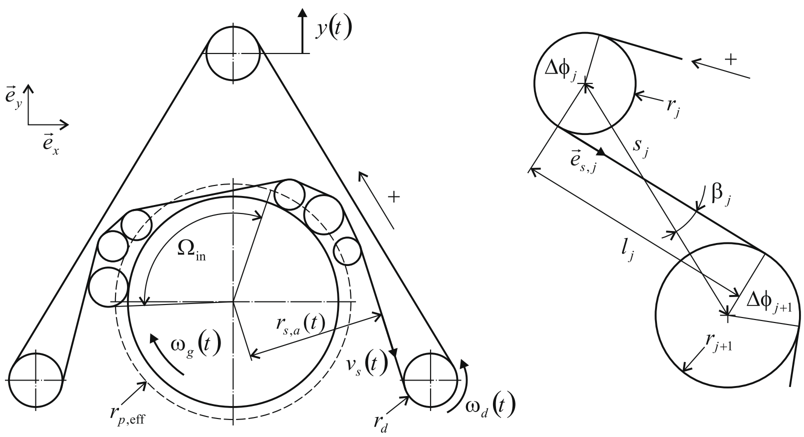

Fig. 2. Two-dimensional representation of the cover band system. The left figure shows an exemplary arrangement of pulleys and the basic kinematic factors. The arbitrarily chosen two-pulley arrangement on the right explains further basic parameters used for the geometric modeling.