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Analysis of translational positioning of unit loads by directionally-oriented friction force fields

T. Piatkowski *

University of Technology and Life Sciences, Department of Postal Technology, Al. prof. S. Kaliskiego 7, 85-796 Bydgoszcz, Poland

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ABSTRACT

The objective of this study was numerical simulation and experimental examination of the process of translational positioning of a stream of unit loads (i.e. postal parcels) transported on conveyors. A system of two inversely-oriented fields of friction forces was used to perform the task of load positioning. In numerical investigations, one applied theoretical description of the positioning process based on the Karnopp's model of static friction and the dynamic friction model of LuGre. In the Karnopp's model, two classic friction coefficients were used (based on one or two parameters, respectively) and a nonlinear coefficient defined by a B-spline curve of third order (determined based on experimental results). The results of numerical investigation were verified by experiments, which consisted in translating the objects by a system of two inversely-driven belts. The analyses of numerical and experimental results indicated that the effectiveness of the positioning process is mostly influenced by nonlinearity of friction coefficient of the transported loads.

1. Introduction

Conveyor systems that transport unit loads (i.e. postal parcels) perform, besides of the fundamental function of translating the objects, a number of automated manipulating actions on these objects, like: merging several streams into a one, dividing a stream into several flows (sorting [1]), rotating and arranging loads in a stream. These actions are realized by highly-efficient manipulators constituting a part of conveyor structure, which act on the transported objects by pushing, knocking, or by applying a series of pushes and strikes [2–4].

Some of the manipulating actions play a supportive role, i.e. prepare the object for the principal actions that should be performed later. Among the first ones, one can mention, for example, the process of translational positioning consisting in locating the objects in precisely defined positions, i.e. forcing the objects to take the position in the conveyor axis (centring, Fig. 1). This process is carried out before realization of the sorting process, and it facilitates scraping the loads towards both sides of the conveyor.

The positioning process can be carried out by means of manipulators, whose executive elements have the form of passive fences. Alternatively, this task is realized by active surfaces of the conveyor, on which lie the transported loads [5–7]. A practical realization of this concept is the manipulator equipped with a system of powered rolls (or disks) allowing it to control the direction of the field of friction forces exerted on the load [7–9].

Most of the contemporary research works on the application of programmed friction force fields to the process of load manipulation concentrate on the analysis of the microactuator systems operation. The mentioned systems consist of powered rolls

* Tel.: +48 052 3408145.
E-mail address: topiat@utp.edu.pl.

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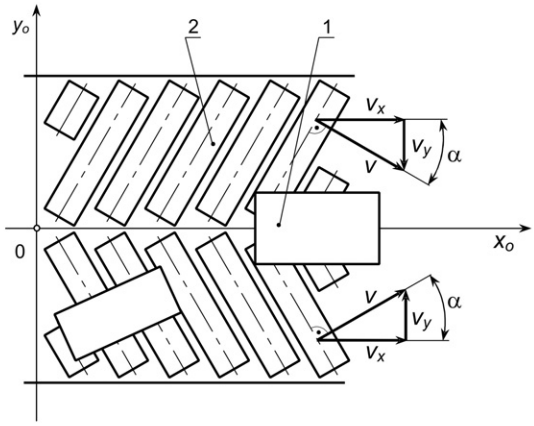

Fig. 1. Example of manipulator centring the stream of unit loads by means of a system of two oblique friction force fields: 1 — unit load, 2 — system of powered rolls, v — tangential velocity of rolls, α — inclination angle of conveyor rolls.

of two degrees of freedom equipped with a complicated sensor system that controls the position of load, and allows for placing it in a precisely defined destination position [7–9]. However, in the subject literature, one can hardly find any description of the course of object positioning on the conveyor axis (centring) for the case, when this operation is performed by a system of two oblique friction force fields (Fig. 1). The advantage of such a system is that it can work without any sensors, because the information on instantaneous position of the manipulated load is not needed.

One of the essential elements of the models describing the course of manipulation of unit loads transported on conveyors is proper description of dry friction force [10–12]. Presently, in the literature concerning dry friction theory one can find several such models. They differ, first of all, in the method of representing the processes occurring in the conditions of static friction [13,14]. Besides, in the state of kinetic friction, individual models use various characteristics of friction coefficients (in the function of sliding speed of the bodies) in which one applies different numbers of parameters [15–18]. Along with the increase of complication of the coefficients' formulae and friction models grow the difficulties in determining their parameters (because of increased number of parameters). With growing complication of the model, simulation of motion of the examined mechanical systems becomes more time-consuming.

In this study, we carried out a number of experiments and numerical investigations aimed at determining the influence of the assumed description of friction forces on the course of simulation of load positioning. During numerical investigations on the positioning process, we applied the Karnopp's static friction model, and the dynamic model of LuGre. In the Karnopp's model, two classic friction coefficients were used (with one and two parameters, respectively), and a nonlinear friction coefficient, approximated by a B-spline curve of third order determined based on experimental data. The experiments consisted in performing tests of translating unit loads by a system of two inversely-driven belts. Based on the obtained results, we could decide which of the friction models would make it possible to identify the examined process, and guarantee that its fundamental characteristics would not be misrepresented.

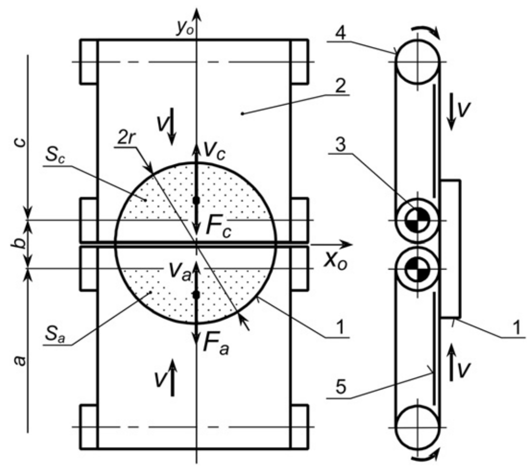

Fig. 2. Scheme of forces acting on object positioned by system of two inversely-oriented friction force fields: 1 — examined object, 2 — conveyor belt, 3 — system of powered rolls, 4 — tension roll, 5 — bed; v — linear velocity, F_a and F_c — friction force exerted on object in zone a and c, respectively, v_a and v_c — sliding velocity of object in zone a and c, respectively, S_a and S_c — contact surface of object in zone a and c, respectively, r — object radius, b — length of conveyor zone with no carrying surface.