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Model of the process of load unit stream sorting by means of flexible active fence

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Abstract

The paper presents results of simulation of a sorting process applied to a stream of unit loads (cubiform parcels) carried on a belt conveyer. The sorting was performed by means of an active fence (a springy arm, of one degree of freedom, making rotary motion over the conveyer). The examination was based on theoretical models, in which elastic-damping properties of the manipulated load were described by a modified Kelvin model, and those of the arm – with the use of the Timoshenko beam model. The equation describing the motion of the fence along with the interacting object was derived based on the method of rigid finite elements (RFE). The developed model makes it possible to assess the influence of the fence's constructional and exploitation parameters on the process of sorting, and evaluate dynamic forces exerted on the manipulated loads.

Keywords: Sorting process; Active fence; Unit load

1. Introduction

The process of sorting of unit loads (cubiform objects, parcels) belongs to typical operations carried out in the transport centres where concentration of transported goods is high (central post offices, transit stores, and airports). It consists in dividing the stream of load into new shipment directions according to the criteria recognized by the scanning system [1]. One of the ways to perform this operation is to apply scraping devices with active arms that make rotary working motion over the belt conveyer. An example of such a solution for a system of three intersecting shipment directions is shown in Fig. 1. The attractive features of this solution are simple structure that ensures high reliability, and low investment and exploitation costs.

The active systems applied in the sorting process are usually driven by crank rocker arm mechanisms and worm gears, and their structure is characterized by high stiffness. Owing to this property, they guarantee

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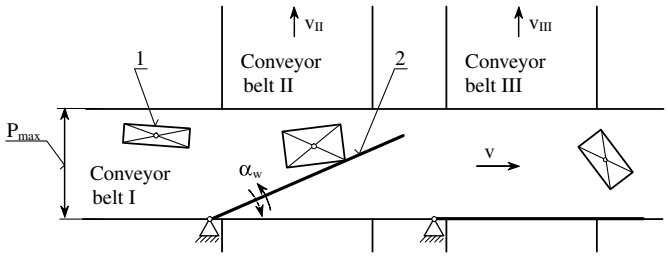

Fig. 1. Example of application of an active fence in sorting process of unit load stream: 1 – unit load, 2 – active fence, $P_{\max}$ is the conveyor width, v_{I}, v_{II}, v_{III} is the conveyor linear velocity, α_w is the angular position of fence.

reliability in realizing the assumed motion of the fence irrespective of the loading forces. Such a type of drive, however, does not meet the requirements of contemporary logistic processes in which objects move with higher and higher speed, and which are optimized for minimizing the dynamic interactions exerted on the objects. The consequence of application of manipulators characterized by very stiff structure is their inability to absorb and dissipate the collision energy released when the load enters in contact with the manipulator. In such a case, it is difficult to obtain high efficiency of the manipulation process, at the same time not exceeding admissible overloads in the objects.

Mechanical system consisting of a conveyor belt and an arm located above it (active rotary fence or a set of passive fences) is also used in the process of positioning, which consists in assigning a precisely defined destination position to each load unit (rotary and translatory – Mason [2]). In the works pertaining to this application of fences (e.g. [3–7]), the problem of interaction between the manipulator and the load is reduced to quasi-statistic events only – the inertia forces are neglected. In these works, one assumes that during the positioning process, the conveyor linear velocity is relatively low, and therefore dynamic reaction forces are negligibly low in comparison to friction forces.

The problem of mitigating reaction forces in the sorting process was considered in the work by Piatkowski [8], where a possibility of application of a pneumatic system in the drive system of the fence was discussed. In the work by Piatkowski and Sempruch [1], the authors considered replacing the classic rectilinear fence by a curvilinear one. These examples do not fully represent all the structural solutions aiming at reduction of dynamic reactions in the manipulated load units. Mitigation of the impact effects which appear in the sorting process can also be achieved by designing a fence with properly matched structural stiffness – the so-called flexible fence. In the present work, the authors discuss and analyse the concept of using such a fence. The application of a flexible fence capable of diminishing the impact effects 'frees' the fence enabling it to move around its equilibrium position.

In order to assess the behaviour of the flexible fence and the manipulated object in response to the applied sorting process parameters, it is necessary to develop an adequate theoretical model. This work concentrates on description and analysis of two stages of the sorting process – oblique impact of a load unit against the fence and motion of the load along the fence. These are the two most critical stages, as far as the sorting process reliability and dynamic interactions in the manipulated loads are concerned [9,10].

2. Impact model

Oblique collision is the predominant phenomenon in the process of sorting of unit loads by means of an active fence. One of the most popular approaches to modelling inelastic collision of bodies, which allows one to investigate time functions of forces, accelerations, velocities, and strains, and to determine the time of impact, is the application of linear Kelvin model [11,12] to description of the colliding bodies. In this model, there are two elements joined in parallel: a spring of stiffness k_1 and a damper with damping coefficient b_1. During the impact, the spring simulates the springy deformation forces of the bodies, and the damper – the forces associated with absorption and dissipation of kinetic energy of the bodies. The impact force exerted on the objects is the sum of elastic and damping forces: