euspen's 16th International Conference & Exhibition, Nottingham, UK, May 2016

www.euspen.eu

Separation strategies for a feeding system with modular coupled piezoelectric vibration conveyers

Juergen Fleischer[1], Martin Krause[1]

[1] *wbk Institute of Production Science, Karlsruhe Institute of Technology (KIT), Germany*

Martin.Krause@kit.edu

Abstract

Microassembly is characterised by a large variety of small parts. An approach to supply those variety of different parts with precise and gentle movements is the principle of sliding conveyance. Detected by a vision system, the parts can be separated automatically, sorted and precisely positioned underneath the handling device with independently operating piezoelectric vibration conveyors, which form a kind of panel-carpet. The challenge here is represented by parts showing, different position-dependent feeding velocities and therefore a part specific behaviour. However, these varying feeding velocities can be predicted by a double staged model, which comprises the process of sliding conveyance as well as the behaviour of the phase flexible piezoelectric conveyor system. Based on the predicted velocities of the fed parts, the article outlines an optimisation procedure utilising evolutionary algorithms to determine the optimal separation strategies. The separation process is achieved by individually switched on feeding units of dedicated panels of the conveyor system, an optimal choice of feeding directions as well as by selected process parameters for the sliding conveyance process describing the target function. A further constraint is required by straighten out parts at the junction of the feeding units to ensure reliability of the separation process.

Keywords: microassembly, precision control, conveyance

1. Introduction

This paper describes how to optimize a feeding system for a fully automated and flexible supply of small parts. The addressed feeding tasks can be structured into four major steps: separation, transfer, orientation and positioning [1]. An application is found in micro assembly, where very different small parts have to be supplied. Parts differ in shape, size, weight and material, for example. A typical task is the automated separation of faulty parts from the bulk. Moreover, logistic can be simplified, by providing parts in bulk and sorting parts right at the handling station.

In large-series production, the feeding tasks are performed by specialised feeding systems like vibratory bowl feeders [2]. However, customized mechanical devices which need to be adapted to the fed parts have to be applied for orientation and separation tasks [3]. Recent developments in robot technologies led to an improved flexibility in small parts supply. Nevertheless, flexibility is limited by the need of part specific gripping systems. A further challenge is the phenomenon of micro parts sticking to the gripper because of adhesive forces [4]. Driven by shorter product life cycles and decreasing batch sizes, importance of adaptive or flexible production systems is still increasing. As a result, efficient feeding systems that flexibly adapt to different parts and adjust to their feeding task take on greater significance.

A promising approach for an automated flexible feeding of micro parts is the automated modular and part flexible feeding system that has been developed at the wbk Institute of Production Science (figure 1, a)). The system consists of four independently operating piezoelectric vibratory conveyors, which allow the parts on each conveyor panel to be conveyed in any direction. In combination with a camera-based object detection, parts can not only be conveyed, positioned and partly actively oriented but also separated and sorted [5]. The vibration conveyor operates on the principle of sliding conveyance, where the parts are in continuous contact with the conveyor panel. Using suitable horizontal and vertical vibrations smooth, precise and predictable feeding motions can be achieved by utilising a process model [6]. To further increase efficiency and productivity of the feeding system, separation strategies are to be optimised based on this process model. An approach is outlined in this paper.

2. Approach

The Basis for optimising the separation strategies is to predict the feeding motion by using a process model [6], see figure 1, b). Then, the best path and control parameter can be derived (figure 1, c)) by an optimisation utilizing genetic algorithm as shown in figure 1, d).

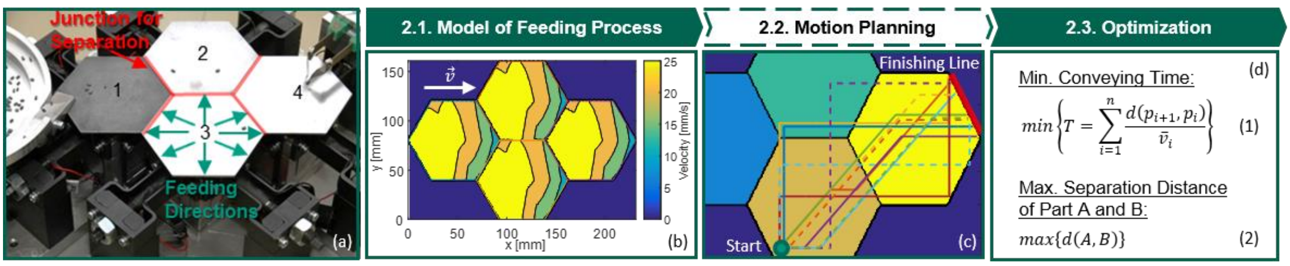

Figure 1. Approach to optimize separation strategies for a feeding system with modular coupled piezoelectric vibration conveyers.

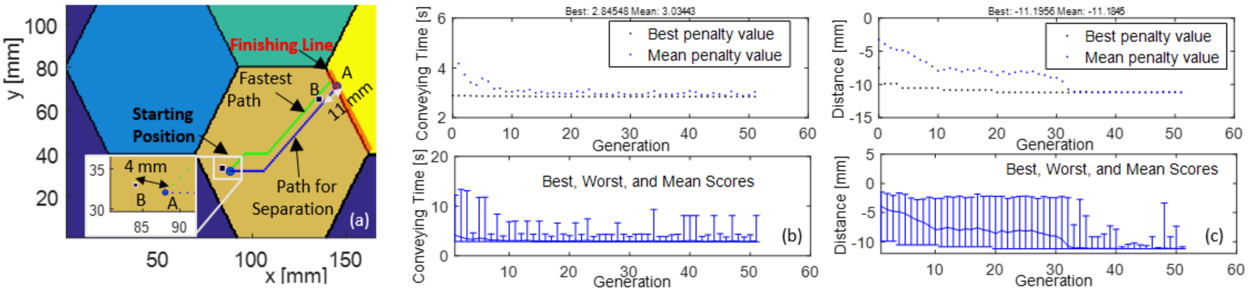

Figure 2. Simulation results for fastest track and separation of two parts.

2.1. Feeding process model

The feeding motion of sliding conveyance can be predicted by a part specific process model. A typical velocity field of the modular coupled piezoelectric vibration conveyers is presented in Figure 1, b). The non-uniform velocity field is calculated using a mathematical model based on local feeding parameters that can be described by the amplitudes of the horizontal $\hat{a}_{L,h}$ and vertical $\hat{a}_{L,v}$ harmonical oscillation as well as by the phase angle $\varphi_{L,a_h a_v}$ of the vibrating panel [6]:

$$v = \beta_1 \hat{a}_{L,h}\left(1 - e^{-(\hat{a}_{L,v}/\beta_2)}\right)\cos\left(\varphi_{L,a_h a_v} - \beta_3\right) \qquad (1)$$

The part-specific parameters β_1, β_2, β_3 are identified by an initial feeding procedure. To predict the velocity, the position depending local feeding parameters need to be given. Therefore, a characteristic map of the feeding parameters was identified by measuring the oscillation at different positions of the vibratory feeder for a set of control parameters. This map was learned by an artificial neural network, which allows to calculate any local feeding parameter for arbitrary control parameter. The controlled parameters are the horizontal and vertical amplitude as well as their respective phase angle. By alternating the direction of the horizontal oscillation, feeding directions can be changed in steps of 45°. Individual control of each vibration panel allows the separation of parts.

2.2. Path planning

Initially alternative feeding paths have to be found. For this purpose, starting and finishing positions (p_0 and p_n) of the fed parts are set. Then, milestones that are constrained by limited feeding directions (0°, 45°, …), are generated. The milestones define alternative feeding paths as shown in figure 1, c). A further interpolation of the milestones is necessary to calculate the objective function. Finally, the algorithm optimises the feeding paths by maximising or minimising an objective function.

2.3. Optimisation of separation strategies

For optimisation problems, an objective needs to be defined. An obvious objective of feeding systems is the transfer of parts in the shortest time. In case of the modular coupled piezoelectric vibration conveyer optimal feeding paths as well as control parameter need to be found. With the model of the feeding process (1), the conveying time is identified by calculating the velocity $\bar{v}_i$ at the interpolated data points and its distances $d(p_{i+1}, p_i)$ as outlined in figure 1.d. The best path and its control parameters for transferring a part from start to end position in shortest amount of time can be found by minimising the time function.

In case of optimising separation strategies, the feeding path and control parameters need to be found to ensure the distance of two parts between the transition of the conveyor panels to reliably separate them. The distribution of the velocity field along a panel is characterised by different gradients. This way parts are fed with different velocities. Objective of the optimisation procedure is to produce a positive velocity gradient in a way that the leading part is gaining distance with respect to the following part. This is done by deriving a feeding path for which the control parameter can be adjusted according to the described pattern.

Therefore, the simulation determines a part that is taking the leading position with respect to another part next to it. Feeding path and control parameters are set for the leading part. The following parts are exposed to the feeding parameters that origin from the set control parameters. The optimisation procedure now maximises the distance $max\{d(A,B)\}$ between part A and B.

For the multimodal optimisation problem, genetic algorithms are particularly appropriate for finding find a global solution.

3. Results

To illustrate the separation problem, the start positions of the two parts A and B are defined exemplarily as shown in figure 2.a. The distance of their centre measures 4 mm. The red marked transition of two conveyor panels is defined as finishing line. Figure 2, a) shows the result of the feeding paths with the shortest conveying time as well as the path to maximize the distance between part A and B. Figure 2, b), c) illustrates the tendency of convergence of the optimisation procedure. The algorithm gives a maximum separating distance of 11 mm. However, its conveying time of 6.5 s is too long compared to the fastest path with 2.8 s. To further optimise separation strategies, a trade-off between both objectives needs to be found, by defining a distance for reliable separation.

4. Conclusion

The paper shows that feeding strategies for increasing the efficiency and productivity of the feeding system with modular coupled piezoelectric vibration conveyers can be found by using a model and an optimisation algorithm. The next steps are the verification of the optimised separation strategies and the definition of reliable separation distances on the modular coupled piezoelectric vibration conveyer.

References

[1] Krüger J, Lien T and Verl A 2009 *CIRP Annals-Manufacturing Technology* **58 (2)** 628–646

[2] Schmid S 2005 *Automatisierte Ordnungs- und Kommissionierzelle zur hochflexiblen Bereitstellung von Werkstücken in der Montage* Heimsheim

[3] Loy M and Reinhart G 2010. *Production Engineering* **4**, 357–362.

[4] Fearing R S 1995 IEEE/RSJ International Conference on Intelligent Robots and Systems 212–217

[5] Leberle U and Fleischer J 2014 *International Journal of Automation Technology* **8** 282–290

[6] Krause M, Bauer J and Fleischer J 2015 *wt-online* **9** 627–632