ANALYZING THE PARTS BEHAVIOR IN A VIBRATORY BOWL FEEDER TO PREDICT THE DYNAMIC PROBABILITY PROFILE

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Abstract:

The vibratory bowl feeder is used in automated assembly to sort and orient variety of parts. To design a part feeder the engineer needs knowledge related to the tendency of the parts to fall in different positions or aspects as well as the complexity of the feeder, and the number of parts. Currently, the design of a feeder is based in heuristics rather than sound manalytical models. The investigation proposes the development of a model that predicts the influence or the effect of the vibration amplitude in the orientation efficiency. For that reason, the model will be based on the identified parameters, such as part's geometry and part's orientation at the end of the bowl feeder, to optimize the design and performance of the vibratory bowl feeder.

In addition, experiments will be conducted using five different parts in the bowl feeder test-bed to estimate the probabilities that the parts have when resting in all possible aspects while moving through a surface in movement. The set of these probabilities is called the Dynamic Probability Profile. With these experiments, any deviation between the Dynamic Probability Profile and the Static Probability Profile obtained from static models and static experiments will be compared. These experiments will provide information that will help in the development of the model. This paper summarizes the status of the investigation so far.

1. Introduction

The vibratory bowl feeder is the preferred choice for many machine builders as well as companies in industry such as automotive, pharmaceutical, cosmetics, electronics, fasteners and plastics. They used the vibratory bowl feeder to sort and orient parts before automated assembly.

The most important factor to consider when selecting a parts feeder is the type of parts to be fed. Bowl sizes and types are determined through a variety of factors such as: part size and configuration, part abrasiveness, condition of the part when handled, required feed rate and bowl direction.

The design of industrial parts feeders is a long, trial and error process that can take months. To design a part feeder the engineer needs to have in mind some significant problems with the parts. Some of those problems are the complexity of the parts and the feeder, the number of the parts, and the absence of good impact friction models in the literature.

This investigation proposes to develop a model that predicts the influence or the effect of the vibration amplitude in the orientation efficiency. For that reason, the model will be based on the identified parameters, such as part's geometry and part's orientation at the end of the bowl feeder, to optimize the design and performance of the vibratory bowl feeder.

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There are researchers that have studied the natural resting tendency of different shape parts. In the work of Ngoi, Lim, Lye and Lee, several methods to analyze the natural resting aspect of a component were used. Each method has a hypothesis to describe the purpose of the method and also they compare each one of them with the Boothroyd's Energy Barrier Method. These methods are: centroid solid angle, and displacement centre of gravity.

2. The Energy Barrier Method

Boothroyd described the development of the energy barrier method, which could analyze all types of geometries. The analysis was extended to other regular prisms such as triangular and hexagonal prisms by circumscribing a cylinder round the prisms. The use of the energy barrier method to analyze the probability profile of parts on soft surfaces is based on the hypothesis that, the probability for a part to come to rest in a particular natural resting aspect is a function of two factors: the energy tending to prevent a change of aspect and the amount of energy possessed by a part when it begins to fall into that natural resting aspect.

The energy barrier for a change in aspect of a part is represented by the area E_{ab} formed by the projection of the change of center of mass height in aspect b during a change of aspect form aspect a to b. This would be illustrated for a squared-sectioned prism. Aspect refers to the part resting on the end (square face) and aspect b refers to the part resting on the side. Let E_{ab} represent the area of change in aspect from end a to side b and E_{ab} represent the area of energy barrier for a change in aspect form side b to end a. According to Boothroyd, the energy barrier areas are constructed as shown in Figure 1. The expressions for the areas are:

$$E_{ab} = x^2\left(a_2 p^2 + q - a_1 q^2 - \frac{y}{x}\right) \qquad (1)$$

$$E_{ba} = x^2\left[a_2 p^2 + q - \frac{p}{2} - 1\right] \qquad (2)$$

Where,
x represents the horizontal distance between the center of mass and the part sides,
y represents the vertical distance between the center of mass and the part base (in the case of a square section x = y),

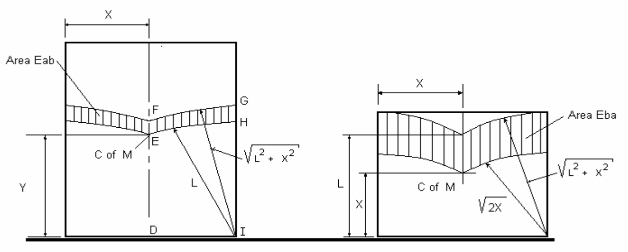


Figure1. Energy barrier for a squared prism [1].

Taking in consideration the number of each possible part aspects, the probability for aspect is given by:

$$P_a = \frac{2E_{ab}}{2E_{ab} + 4E_{ba}} \qquad (3)$$

And for aspect b

$$P_b = 1 - P_a \qquad (4)$$

The energy barrier method effectively analyzes simple shaped parts with constant cross-section and having two resting aspects. However, for complex parts the method becomes computationally intensive and requires a clear visualization of the energy barrier of the given part; hence, making the method less attractive. [1]

3. Centroid Solid Angle Method

The centroid solid angle has been used to analyze the probabilities of the natural resting aspect of small parts in a vibratory bowl feeder. This method is based on the premise that the probability that a part would come to rest in a particular resting aspect or surface is directly proportional to the solid angle subtended by the centroid to that surface and inversely proportional to the height of the centroid from that surface.

$$P_i = \frac{nQ_i / h_i}{\sum_{j=1}^{n} nQ_i / h_i} \qquad (5)$$

where P_i is the probability of the part resting on aspect *i*, n is the number of resting aspect, Q_i is the centroid solid angle subtended by aspect *i* from the centroid and h_i is the height of the center of gravity from aspect *i*.

The centroid solid angle can be determined constructing a pyramid in which the apex is coincident with the centroid of the prism. A solid sphere was then constructed with its center at the apex and whose radius was chosen so that it did not exceed the half of the height. This was necessary to ensure that the sphere did not overwhelm the pyramid. The common volume of intersection of the sphere and the pyramid is the enveloped volume. The enveloped volume may then be used in an alternative method for the computation of the centroid solid angle. [3]

4. Displacement Centre of Gravity Method

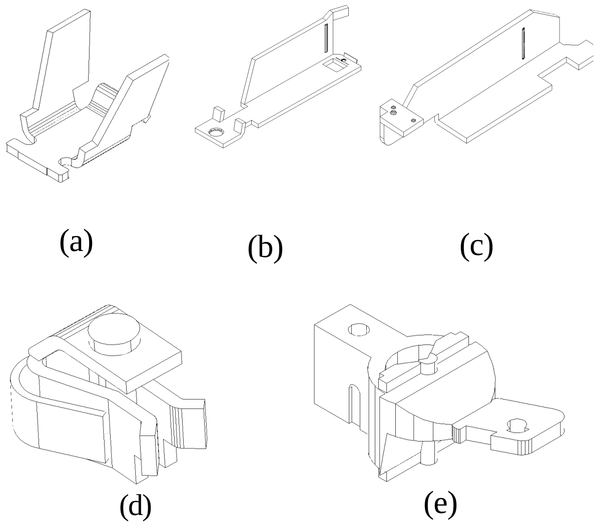
This method is based on the hypothesis that the probability of a part coming to rest in a particular aspect is proportional to the centroid solid angle and inversely proportional to the height of the center of gravity from the aspect in question. This method is applied to a part with a displaced center of gravity. Lee, Lim and Ngoi used a CAD computation of the centroid solid angle to determine the enveloped volume.

The main advantage of this method is that it uses very basic, well-defined geometric properties of the component being analyzed, the location of the center of gravity and the solid angle. [4]

5. Description of the Experiment

Rosario and Hernandez-Coronas [5] developed experiments to determine if there was an impact of the feeder vibration amplitude in the dynamic orientations of parts belonging to a family. The experiments consisted of testing how five different parts those were unlike in shape and different in proportion behaved in the feeder. The five parts are component of the circuit breaker and those are shown in Figure 2.

By experimenting with a part family, the intent was to establish and generalize in the near future a relationship between the tendency of the parts to fall in certain orientations, the amplitude of vibration in the feeder, and the geometric features or mass properties. The data could then be used to attempt to establish a relationship between these parameters within part families.


(a) (b) (c)

(d) (e)

Figure 2. The five parts are (a) arc chute, (b) latch, (c) magnet, (d) stab & contact and (e) arc chute.

The study of the five parts was performed according to the two feeding test described by Boothroyd and Murch [2]. These are the modified dynamic bowl test and the modified dynamic feeding test. The tests, which have been performed on the parts, have being designed in a way that they will always be forward conveying. Forward conveying of a part occurs when the force of vibration acting on the part overcomes the frictional resistance between the part and the feed track.

Both tests were performed on each one of the five parts for the vibration amplitudes of 78%, 80% and 82%. The sample sizes were 200 for the modified dynamic feeding and modified dynamic bowl-feeding test, respectively for the five parts.

The modified dynamic bowl-feeding test (MDBF) consists of dropping a batch of parts inside the bowl feeder to study the effect of parts recirculation. The parts were dropped on the bowl bottom and allowed to climb up the track. The parts advanced up the track and recirculated back in the bowl. During this time it was ensured that all parts are recirculated at last once. After this time, the feeder mechanism was stopped and parts were counted according to their orientation. This test will be performed ten times.

In the modified dynamic feeding (MDFT) test the components are dropped at the bottom of the bowl feeder. The system is turned on and parts are allowed to climb up the track. Once all parts entered the track, the system is turned off and parts are counted according to their position. It is assumed that the modified dynamic feeding test provides the distribution probabilities for all possible positions that can be initially adopted by the part when initially dropped in the bowl feeder. This test was performed ten times.

The experiments still in progress and the main plan for the future are using the data and the results of those experiments, to develop a model that predict the influence or effect of the vibration amplitude in the orientation efficiency.

Reference

[1] Boothroyd, Geoffrey. 1992, “Assembly Automation and Product Design”, Marcel Dekker Inc.

[2] Boothroyd, G. and Murch, C. 1977. “Analysis of Feeding and Orienting Systems for Automatic Assembly”. Journal of Engineering for Industry, Vol 89, pp. 308-313.

[3] Ngoi, B.K.A., Lee, S.S.G., Lim, L.E.N. 1995a, “Analyzing the Natural Resting Aspects of a Component by its Centroid Solid Angle”, Journal of Electronic Manufacturing, Vol. 53 No 3, pp. 193-197.

[4] Ngoi, B.K.A., Lee, S.S.G., Lim, L.E.N., Lye, S.W. 1995c. “Analyzing the Natural Resting Aspects of a Component for Automated Assembly”. Journal of Engineering Manufacture, Vol. 209, pp. 125-135.

[5] Rosario, L.M. and Hernández-Coronas, J.D., 1997. “Study of the Behavior of Certain Connectors in Vibratory Bowl Feeder”, Proceeding of ASME Design Engineering Technical Conference, Sacramento, CA