Advance Journal of Food Science and Technology 11(11): 750-753, 2016
DOI:10.19026/ajfst.11.2775
ISSN: 2042-4868; e-ISSN: 2042-4876

Submitted: August 5, 2015 Accepted: September 3, 2015 Published: August 15, 2016

Research Article

Design and Research on a New Vibrator-based Coin in Food Supermarket Sorting and Packaging Machine

[1]Caiqi Hu, [2]Xiaoqi Hu and [1]Jing Ji
[1]College of Mechanical and Electrical Engineering, Qingdao Agricultural University, Qingdao 266109,
[2]College of Engineering and Design, Lishui University, Lishui 323000, China

Abstract: In this study, a novel no-swing and dual-drive vibrator was proposed to be used in the design of coin in food supermarket sorting and packaging machine with large capacity. At present, in China one of key factors for restricting the coin in food supermarket circulation is the lack of a complete device with large capacity capable of sorting and packaging coin in food supermarkets. Some innovative design and development for functional parts to realize coin in food supermarkets sorting, counting, packaging and transporting were carried out based on optical electromechanical integration technology. Based on the experimental studies, the diameters of sieve holes and their layout were determined. The machine was proposed to realize high efficient automation of the process in sorting, counting, packaging and transporting for a large number of coins in food supermarkets, which can effectively reduce the labor intensity and improve labor efficiency.

Keywords: Coin in food supermarket, large capacity, sorting and packaging machine

INTRODUCTION

Coin in food supermarkets are widely used around the world for they are well characterized with fine look, durable wear and low issue cost. In recent years, with Chinese economic rapid growth, national income continues to increase and the commodity price level is also rising, thus the currency less than RMB 10 yuan in circulation is mainly playing a role of changing money. So putting small denomination currency into forms of coin in food supermarkets has become one of key tasks for the currency issue. In recent years, due to the increasing demand for coin in food supermarkets, in China the coin in food supermarkets have been issued a total amount over 150 billion. At present, there are, however, still various problems in issue and circulation of coin in food supermarkets, which have seriously hindered a healthy development of coin in food supermarkets in our country. Among them, lack of research and development on tools to sort coin in food supermarkets and no suitable and efficient device to sort and package coin in food supermarkets are the core issues to restrict the rapid development of coin in food supermarkets. According to an investigation, among 6 subsidiaries of Wuhan City Bus Group, for example, the third subsidiary's income is average 22 million yuan monthly, with about 8 million yuan of coin in food supermarkets (The People's Bank of China Wuhan Branch, 2009). Manually sorting such a huge amount of coin in food supermarkets undoubtedly requires high cost but in a low efficiency. The investigation from 12 small and mid-sized cities governed by Changzhi City in Shanxi province showed that by the end of March 2014, among 5874 bank branches in these cities, only 42 banks were equipped with coin in food supermarket sorting and packaging machines and the proportion is 0.7%, while other banks still manually sort and package coin in food supermarkets and the work efficiency was very low (Lin, 2007). Therefore, developing machines for automatic sorting and packaging coin in food supermarkets to replace manual operation has become the focus of public concern in the countries all over the world.

The researches on coin in food supermarkets sorting device were early conducted abroad and the products can be roughly divided into three grades: low, medium and high. The sorting speed range of the low grade is at 1000 coin in food supermarkets per minute or less, the sorting speed range of the medium grade is at 1000-1500 coin in food supermarkets per minute and the high grade is 1500 coin in food supermarkets per minute or more. There are two major categories for sorting methods: one is based on physical techniques and the other one is based on performance index. Domestic coin in food supermarket sorting is mostly based on physical techniques, including coin in food supermarket shapes and dimensions, material properties and so on. Most of the current coin in food supermarket

Corresponding Author: Xiaoqi Hu, College of Mechanical and Electrical Engineering, Qingdao Agricultural University, Qingdao 266109, China

sorting devices can only conduct sorting of different denomination coin in food supermarkets, while some ones have the capabilities of sorting and packaging coin in food supermarkets, but they can only deal with a small amount of coin in food supermarkets at a time. Domestic research and development of such an integrated device for automatically sorting, counting and packaging a large amount of coin in food supermarkets is far from enough.

In this study a novel sorting and packaging machine integrated with automatically sorting, counting and packaging coin in food supermarkets was proposed. This machine can sort coin in food supermarkets based on different diameters of coin in food supermarkets by a new type of vibrator driving the vibrating sieve and count and package coin in food supermarkets based on thickness of each coin in food supermarket. Besides its integrated features mentioned above, this machine has a simple structure, stable performance and enables the coin in food supermarket counting work more easy to operate, which not only saves labors, but also facilitates the coin in food supermarket storage and transportation. When the machine working a large number of coin in food supermarkets can be directly put into the large sieve box of the machine, then the coin in food supermarkets are going to be sorted by the vibrator vibrating the sieve box with many sieve holes. The shutter door will be open to let the coin in food supermarkets leave the sieve box only if the coin in food supermarket sorting has completed. The box is supported by cushioning springs, which can prevent the whole box from shaking caused by the sorting device and the cushioning springs can not only reduce the noise, but also improve the stability of the machine. Shutter door is connected with link rods and the reset springs are installed on the link rods, which can not only keep the unity of movement of the blades when the shutters work, but also improve the closing speed of the shutter door. In the machine the container conveying device equipped with a transporting guide mechanism can automatically export the coin in food supermarket container, which can further reduce manual work and improve work efficiency. Sorting, counting and packaging a large number of coin in food supermarkets can be realized with the machine used in public traffic system, shopping malls, supermarkets, farm product markets, banks and so on.

MATERIALS AND METHODS

Kinematics analysis of the vibrator: Self-synchronization vibrator was invented based on discovery of self-synchronization phenomenon. Boccaletti *et al*. (1999) is the first person who discovered the vibration synchronization phenomenon or self-synchronization phenomenon of mechanical system and he found that the two pendulums hanging side by side would just swing synchronously after they swung independently for a period of time. In the 1960s, Blekhman *et al*. (2002) put forward the synchronization theory for the vibrator with double eccentric rotors, that is to say, two induction motors installed on one vibrator can achieve run-in synchronism with certain conditions. Zhang *et al*. (2009) resolved the self-synchronization conditions and self-synchronization stability conditions for the vibrator by integral average method. Zhao *et al*. (2010) developed self-synchronization theory for the dual-motor-driven vibrator and four-motor-driven vibrator by using the improved method of average small parameter and deeply explained the coupling dynamic

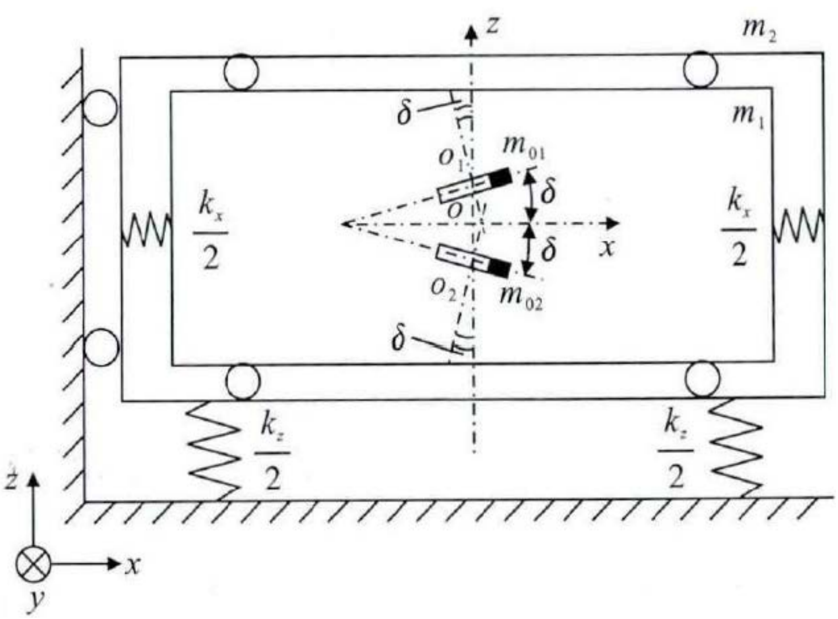

Fig. 1: Dynamic model of vibrator

characteristics and dynamic symmetry for the vibrator. So far, scholars at home and abroad have made many profound studies on the self-synchronization theory for a variety of vibration devices, but swing exists on all the proposed models, which makes the vibration device unable to move exactly in the desired direction. In this study, a novel swing-free and dual-drive vibrator was used to drive the coin in food supermarket sorting machine. This vibrator consists of two plastids inside and outside. And the rotation centers of two eccentric rotors are on the same vertical axis with the centroid of inner plastid. Torque exerted by inertial force of the eccentric rotor on this axis is zero, thus the swing of this vibrator was eliminated.

Figure 1 showed a dynamic model of the new vibrator. It consisted of inner plastid m_1, outer plastid m_2 and two eccentric rotors m_{01}, m_{02}. The inner plastid m_1 was connected with outer plastid m_2 through springs k_x and k_y in directions x and y, respectively. And outer plastid m_2 was supported by the elastic base k_2. The differential equations of motion for the vibrator was obtained based on Lagrange equations (Han *et al*., 2007):

$$\left.\begin{aligned} &M_1\ddot{x}+f_x\dot{x}+k_x x=r\cos\delta\sum_{i=1}^{2}m_{0i}(\dot{\varphi}_i^2\cos\varphi_i+\ddot{\varphi}_i\sin\varphi_i)\\ &M_1\ddot{y}+f_y\dot{y}+k_y y=r\sum_{i=1}^{2}m_{0i}(\dot{\varphi}_i^2\sin\varphi_i-\ddot{\varphi}_i\cos\varphi_i)\\ &M_2\ddot{z}+f_z\dot{z}+k_z z=r\sin\delta\sum_{i=1}^{2}(-1)^{i-1}m_{0i}(\dot{\varphi}_i^2\cos\varphi_i+\ddot{\varphi}_i\sin\varphi_i)\\ &(J_{01}+m_{01}r^2)\ddot{\varphi}_1+f_1\dot{\varphi}_1=T_{e1}+m_{01}r(\ddot{x}\cos\delta\sin\varphi_1-\ddot{y}\cos\varphi_1+\ddot{z}\sin\delta\sin\varphi_1)\\ &(J_{02}+m_{02}r^2)\ddot{\varphi}_2+f_2\dot{\varphi}_2=T_{e2}+m_{02}r(\ddot{x}\cos\delta\sin\varphi_2-\ddot{y}\cos\varphi_2-\ddot{z}\sin\delta\sin\varphi_2)\end{aligned}\right\} \quad (1)$$

where, M_1 was a vibration mass of the system in directions x and y, $M_1 = m_1+m_{01}+m_{02}$; M_2 was a vibration mass of the system in direction z, $M_2 = m_1+m_2+m_{01}+m_{02}$; k_x, k_y and k_z were spring stiffness in directions x, y and z; f_x, f_y and f_z were damping coefficients in directions x, y and z; f_1 and f_2 were damping coefficients of the two motors.

Self-synchronization conditions of two eccentric rotors: When the vibrator worked steadily the phases of the two eccentric rotors and their average phase were assumed as φ_1, φ_2, φ, respectively and the phase of eccentric rotor 1 was ahead of the phase of eccentric rotor 2 by 2α, that was to say:

$$2\varphi=\varphi_1+\varphi_2;\ \ 2\alpha=\varphi_1-\varphi_2 \quad (2)$$

Then the phases of eccentric rotor 1 and 2 were:

$$\varphi_1=\varphi+\alpha;\ \ \varphi_2=\varphi-\alpha \quad (3)$$

When the vibrator worked steadily, the average rotating speed of the two eccentric rotors was assumed

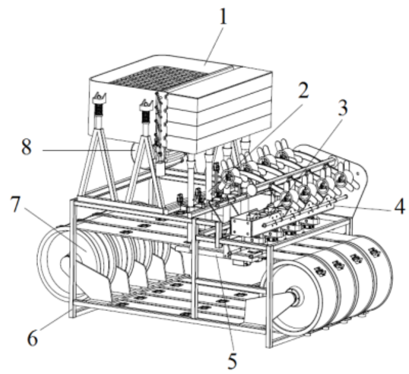

Fig. 2: Structure diagram of the sorting and packing machine with large capacity; 1: Vibration sorting device; 2: Buffer device; 3: Sealing device; 4: Supporting framework; 5: Counter; 6: framework; 7: Container conveying device; 8: Vibrator

as $\dot{\varphi}$ = $\omega_m(t)$. Since the movement of the vibrator changed periodically, which meant external load of the two motors changed periodically, then the average angular speed of the two eccentric rotors within a period ω_{m0} was constant. The instantaneous fluctuation coefficients of $\dot{\varphi}$ and $\dot{\alpha}$ were assumed as ε_1 and ε_2 (ε_1 and ε_2 were the functions of time t) and the relationships of them were shown as follows:

$$\dot{\varphi}=(1+\varepsilon_1)\omega_{m0};\ \ \dot{\alpha}=\varepsilon_2\omega_{m0} \quad (4)$$

Substituting the Eq. (4) into Eq. (3), then the angular velocity and angular acceleration of the two eccentric rotors were as follows:

$$\begin{aligned}&\dot{\varphi}_1=(1+\varepsilon_1+\varepsilon_2)\omega_{m0}\\ &\dot{\varphi}_2=(1+\varepsilon_1-\varepsilon_2)\omega_{m0}\\ &\ddot{\varphi}_1=(\dot{\varepsilon}_1+\dot{\varepsilon}_2)\omega_{m0}\\ &\ddot{\varphi}_2=(\dot{\varepsilon}_1-\dot{\varepsilon}_2)\omega_{m0}\end{aligned} \quad (5)$$

When t→∞, average fluctuation coefficients of $\dot{\varphi}$ and $\dot{\alpha}$ within a period $T = 2\pi/\omega_{m0}$ were 0 (that meant $\bar{\varepsilon}_1 = 0$, $\bar{\varepsilon}_2 = 0$), which meant the system's frequency had been captured, that was to say, the two eccentric rotors run synchronously. When the synchronous torque of the vibrator was greater than or equal to absolute values of the remained electromagnetic torque of the two motors, the two eccentric rotors in the vibrator would took a self-synchronization movement (Guo, 2007).

Overall structure of the coin in food supermarket sorting and packing machine with large capacity: The working principle of the coin in food supermarket sorting and packing machine with large capacity

Table 1: Test for the layout of sieve plate holes

Layout scheme	Correct rate of distinction (the number of misclassification)
Regular arrangement	88% (120 of misclassification)
Irregular discretely arrangement	97% (30 of misclassification)

proposed in this study is to sort different coin in food supermarkets according to different denomination coin in food supermarkets having different diameters and weights. The machine mainly consists of a drive part (a vibrator), framework, vibration sorting device, sealing device, buffer device, container conveying device, counter and other components (Fig. 2). The vibration sorting device is located in the rear of the machine, while the sealing device is in the front of the machine. The sorted coin in food supermarkets are transported to the container through the buffer device and the container conveying device which is controlled by the counter can not only transport the empty container to the place below the buffer device, but also transport the container filled with coin in food supermarkets to the sealing device for sealing.

RESULTS AND DISCUSSION

Experimental researches: The diameter of hole in sieve plate and sieve holes distribution can directly affect the efficiency and quality of sorting coin in food supermarkets.

Determination of the diameters of the sieve hole: The sieve hole in the first layer is taken as example and 6 different diameters of sieve holes were processed on six sieve plates for testing respectively, the sizes of sieve holes are 21, 21.5, 21.8, 22, 23 and 24 mm, respectively. When they were tested to sieve 1000 coin in food supermarkets, the times used to sort them completely were 150, 150, 140, 120, 80 and 50 sec, respectively. It means when the diameter of sieve hole is 24 mm, the efficiency is the highest among the 6 sieve plates in sorting the coin in food supermarkets of 1 yuan out from the other coin in food supermarkets. After tested in the same way, the diameter of sieve plate hole in the second layer was 21 mm and the diameter of sieve plate hole in the third layer was 20 mm.

Layout of sieve holes: 1000 coin in food supermarkets (250 for each denomination) were taken to test the layout schemes of holes and test results were shown in Table 1. It indicated that the irregular arrangement of holes on sieve plate can improve the efficiency and quality of sorting coin in food supermarkets.

CONCLUSION

Design and research on the coin in food supermarket sorting and packing machine with large capacity were conducted based on a new vibrator. The method of vibration sorting was adopted to make a quick and effective sorting among a variety of coin in food supermarkets. Based on the experimental studies, the diameters of sieve plate holes for each layer and their layout were decided to improve sorting efficiency and quality. In the packaging stage, the packaging method was improved. Plastic cups were used to fill with coin in food supermarkets and automatic sealing devices were used to seal plastic cup, which would not only solve the problem of sorting and packaging a large amount of coin in food supermarkets, but also realize the integration for sorting, counting and packaging coin in food supermarkets.

ACKNOWLEDGMENT

This project was supported by National Natural Science Foundation of China (No. 51475221, 51375227), Zhejiang Provincial Natural Science Foundation of China (No. LY13E050015) and Application Type University Construction Project of Qingdao Agricultural University.

REFERENCES

Blekhman, I.I., A.L. Fradkov, O.P. Tomchina and D.E. Bogdanovc, 2002. Self-synchronization and controlled synchronization: General definition and example design. Math. Comput. Simulat., 58: 367-384.

Boccaletti, S., J. Bragard, F.T. Arecchi and H. Mancini, 1999. Synchronization in nonidentical extended systems. Phys. Rev. Lett., 83(3): 536-539.

Guo, X., 2007. Modeling design of ST800A coin in food supermarket counting machine. Packag. Eng., 28(8): 164-167.

Han, Q.K., Z.Y. Qin, X.G. Yang, X.H. Chen and B.C. Wen, 2007. Vibration analysis of a self-synchronization system with dual rotors. J. Vib. Eng., 20(5): 354-358.

Lin, H., 2007. Coin in food supermarket sorting example introduction based on the separating disc. Mod. Bus. Trade Ind., 19(9): 280-281.

The People's Bank of China Wuhan Branch, 2009. Wuhan coin in food supermarket circulation state and proposal. Wuhan Financ., 11: 39-40.

Zhang, N., X.L. Hou and B.C. Wen, 2009. Cophase and synchronous characteristic of vibration machine under electromechanical coupling condition. J. Northeastern Univ. Nat. Sci., 30(10): 1477-1480.

Zhao, C.Y., B.C. Wen and X.L. Zhang, 2010. Synchronization of the four identical unbalanced rotors in a vibrating system of plane motion. Sci. China Technol. Sci., 53(2): 405-422.