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Research on Effect of Cashew Kernel Traveling in Color Sorting Machine

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Abstract: Cashew is an agricultural product that plays an essential role in the developments of the economy of Viet Nam, since foreign revenue from cashew products is ranked as one of the top agricultural exporting commodities. By implementing the vision system of machines in food processing, the quality and price of cashew will be improved. Using image processing technology in sorting process, products obtain high accuracy and performance. For that purpose, the machine is equipped with CCD cameras and high-velocity pneumatic separation system. This study is going to present effect of cashew kernel traveling in color sorting machine by identifying velocity of conveyor and airflow, and the height between conveyor belt and air nozzle. The simulation is used to predict the motion of cashew in sorting zone of the machine.

Keywords: Sorting machine, Pneumatic separation, High pressure airflow.

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I. INTRODUCTION

Vietnam's export performance for nuts over recent years is impressive, especially for cashews, by far the main exported nut. In the first five months of this year, the cashew industry exported more than 118,000 tons of cashew nuts, bringing in about 1.1 billion USD, exceeding the export plan in terms of both volume and value. Cashew processing actually includes the various steps and the processing methodology used varies from region to region. In Viet Nam, cashew nut processing includes ten major steps, as follows: collected cashews, drying cashew in the sun, sorting out the size of raw cashew, teaming raw cashew, taking out the shell, drying cashew nut kernels, peeling the testa, color sorting cashew nuts and quality control cashew nuts and metal detectors & packaging.

Under the traditional method, product classification are performed by workers so the result is that the produce is of bad quality and results in low productivity. The poor classification and sorting methodology has caused a reduction of exported product. Automatic cashew nuts sorting system based on machine vision can improve the quality of the product, abolish inconsistent manual evaluation, and reduce dependence on available manpower. Therefore, it is necessity to develop a sorting system for automatic quality assessment of cashew nuts before packaging. Cashew sorting system or sorting machine is based on the machine vision system, which is an integrated technology using computer image processing technology and analysis technology to identify the target of various patterns of seeds. Machine vision system of recognition cashew can be divided into the following steps: (1) Read digital image gotten from the camera by computer; (2) Determine the identification characteristic of seed; (3) Find seed based on the identification algorithm; and (4) Determine the color of seed, then then convert these information to the control single of high pressure air nozzle. With the development of computer technology, video-signal on-line transition and processing technology has been perfected and raised, machine vision system have got great success in many fields. Many researchers have been applied increasingly for product quality evaluation using sorting machine in recent years. In agriculture, Lee et al. [1] used Robotic weed control system by machine vision for tomatoes. Majumdar and Jayas [2] and Paliwal et al. [3] classified cereal grains using machine vision and color models. Shahin et al. [4] used machine vision to determine the rice quality. Zhang Junxiong et al. [5] described a method that seeds are separated by high pressure airflow in the air. Xu M. et al. [6] proposed an effective mechanical process including impact crushing from printed circuit boards (PCB) and pneumatic separation for metal recovery scraps was investigated.

In the mining industry, S. Al-Thyabat [7] took into account some well known problems associated. With imaging moving particles such as camera location, particle overlap, image blurring, conveyor speed, dust generation and treatment. Hamzeloo E. et al. [8] introduced a method to estimate the particle size distribution on the industrial conveyor belt. Then Zheng et al. study pneumatic separation of coal and gangue with large size (lager than 50 mm) in green mining based on the machine vision system using DEM (Discrete element method).

The objective of this paper was to design an automatic sorting. We have carried out calculations based on the fundamental physics, aerodynamics, with the implementation of simulation to ensure the correctness of those calculations.

II. Principle

The process of pneumatic separation which is based on machine vision is shown in Fig. 1. Firstly, cashew nuts are transported on the belt conveyor (3). Then, the objects (4) are transported on the conveyor until they dispersedly drop from the belt conveyor. While they are dropping, they are scanned horizontally along a straight scanning line by the laser beam scanning apparatus (5), and reflected light from them is detected by a CCD image sensor (8) of the CCD camera (6) by way of a polarizing filter (7). Outputs of the image sensor (8) are analyzed by the computer (10) to judge whether the individual objects scanned are good object or bad object, and the nozzle (9) is controlled by the computer (10) in accordance with such judgment. Then, in case an object is judged as a "good object" (4a), it is allowed to drop into a regions accepting (11a), but on the contrary in case the object is judged as a bad object (4b), air is jetted from nozzle (9) to blow off the bad objects so that they may drop into a regions rejecting (11a).

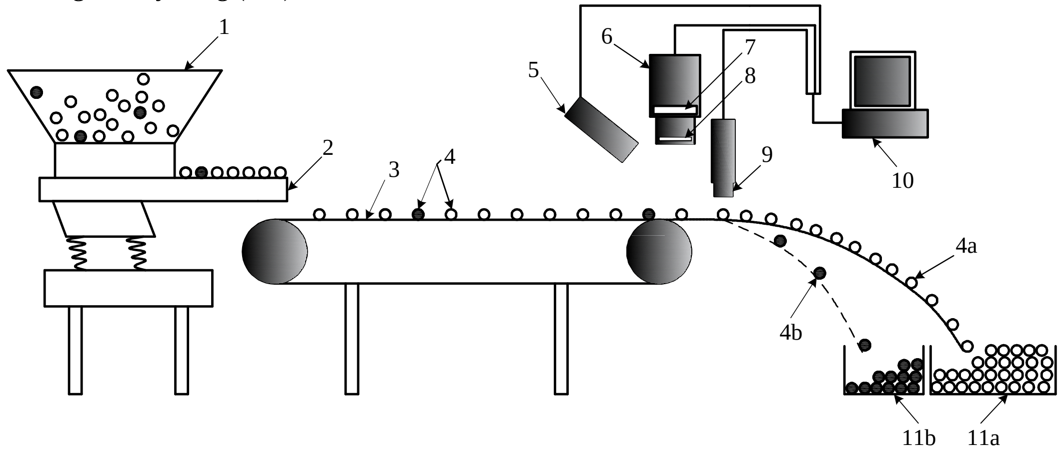

Figure 1. Principle construction of Belt-type cashew color sorting machine
(1) Hopper, (2) Dispersing feeder, (3) Belt conveyor, (4) Cashew, (5) Laser beam scanning apparatus, (6) CCD camera, (7) Polarizing filter, (8) Image sensor, (9) Nozzle, (10) Computer, (11) Trays

III. METHODOLOGY

Objects will do horizontal projectile motion when they are thrown from the conveying belt. The trajectory of object without the affect of high pressure airflow is shown in Fig. 2 of curve 1. And the trajectory of objects with the effect of high pressure airflow is shown in Fig 2 of curve 2. Air flow directions of high pressure value are perpendicular to object movement. Motion diagram is shown by Fig. 2.

As shown in Fig 2, S_1 represents the pneumatic separation distance between primary product stream and secondary product stream (bad object), h_p represents the height between object center on the conveyor belt and the upper boundary of the airflow domain, t_p represents the motion time of object before falling into the air flow domain, v_p represents the velocity in direction y of object before falling into the air flow domain; h_j represents distance in direction y of object affecting by force into the air flow domain; S_i represents the displacement in x direction of object before affecting by the airflow; t_j represents the time of object moving in airflow domain, S_j represents the displacement in x direction of the object in airflow domain; v_f represents the velocity in y direction of the object in airflow domain; t_f represents the time of object after the object has left the airflow domain; S_f represents the displacement in x direction of the object movement after leaving the airflow domain.

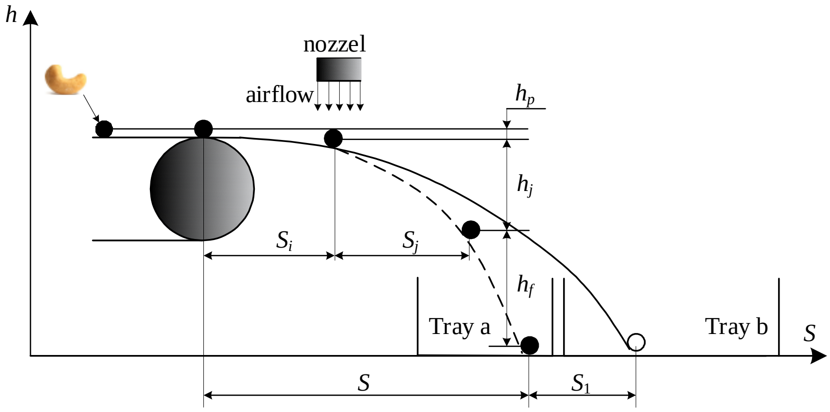

Figure 2. Cashew pneumatic separation model.

3.1 Object trajectory without affect by pressure value

When objects is thrown from the conveying belt, it will be recognized by the machine vision system, then image sensor will send the information to computer that will control the high pressure value. At last, objects will fall freely from the conveyor belt without the effect of high pressure value. The primary stream consists of particles which follow a parabolic path described by Newtonian equations of motion.

In order to calculate the key parameters of the movement, assumptions are made as follows: velocity of conveyor belt is v_0, the total motion height is equal to $h_p + h_j + h_f$, the motion time of good object is t_0, and good objects displacement in x direction is S_0.

Thus t_0 and S_0 can be obtained by Eqs. (1) and (3), respectively, as below

$$t_0 = \sqrt{\frac{2(h_p + h_j + h_f)}{g}} \quad (1)$$

$$S_0 = S + S_1 \quad (2)$$

or,

$$S_0 = v_0\sqrt{\frac{2(h_p + h_j + h_f)}{g}} \quad (3)$$

3.2 Object trajectory with affect by pressure value

If objects are unsatisfactory quality, image sensor will send the information to computer that will control the high pressure value. When activated, the value produce jets of high velocity air which create sufficient force to affect the motion of particles and re-direct them into the reject stream objects.

The process can be divided into threes stages: (1) leaving out belt conveyor – before falling airflow domain; (2) movement of objects falling into the air flow domain; and (3) movement of objects after falling into the air flow domain

3.2.1 Motion of objects before falling into the air flow domain

After leaving out belt conveyor, before falling air flow domain, objects motion diagram is shown in Fig. 3, S_i and v_p can be calculated as the formulations.

$$S_i = v_0\sqrt{\frac{2h_p}{g}} \quad (4)$$

$$v_p = g\sqrt{\frac{2h_p}{g}} \quad (5)$$

3.2.2 Motion of objects in air flow domain

This process occurs in a very short time (several milliseconds). To study the effect of air flow classification to trajectories of objects, we need to calculate the force of high pressure air on objects. The force can be calculated by Eq. (6)

$$F = \iint_A P_d dA = \sum_{i=1}^{m} P_{di} A_i \tag{6}$$

where, F represents the force of the high air flow that acts on objects, P_{di} represents the high pressure head of the ring area i, A_i represents the area of i, and m represents the total number of the ring.

When gangue particles fell into air flow domain objects will be affected by two forces, the one is gravity, and the other is the dynamic pressure. Air flow dynamic pressure is converting to static pressure on the condition that the velocity of airflow u is greater than the object's vertical velocity $\dot{y}$, and airflow must keep dynamic pressure $p_d = \rho \frac{\dot{y}^2}{2}$. It can be converted to dynamic pressure difference $\Delta p_d = \frac{\rho\left(u^2 - \dot{y}^2\right)}{2}$, u is speed of air flow. According to Eq. (6), the force of airflow can be obtained as Eq. (8)

$$F = \iint_A p dA \tag{7}$$

$$F \approx \sum_i p_i A_i = \frac{1}{2} \rho \sum_i \left(u_i^2 - \dot{y}^2\right) A_i \tag{8}$$

It can be seen approximately as a plane when curvature of objects surface is not too large, so $\forall u_i = u$, Eq. (8) can be changed to Eq. (9).

$$F = \frac{1}{2} \rho \left(u^2 - \dot{y}^2\right) A \tag{9}$$

According to Newton’s Second Law, Eq. (9) can be rewrite as Eq. (10)

$$F = \frac{1}{2} \rho \left(u^2 - \dot{y}^2\right) A = m\ddot{y} \tag{10}$$

Solve Eq. (10), at the beginning $t = 0$, the initial position of the objects is $y(0) = 0$ and $\dot{y}(0) = v_p$

$$y(t) = \frac{C - D}{A\rho} \tag{11}$$

where,
$$C = 2.m.\log\left(u + v_p + \frac{u - v_p}{e^{\left(\frac{A.\rho.t.u}{m}\right)}} \right) \tag{12}$$

$$D = 2.m.\log\left(2u\right) + A.\rho.t.u \tag{13}$$

and,
$$\ddot{y}(t) = E - F \tag{14}$$

$$E=\left(\frac{2A^2\rho^2u^2\left(u-v_p\right)}{m.\mathrm{e}^{\left(\frac{A\rho tu}{m}\right)}.\left(u+v_p+\frac{u-v_p}{\mathrm{e}^{\left(\frac{A\rho tu}{m}\right)}}\right)}\right) \tag{15}$$

$$F=\left(\frac{2A^2\rho^2u^2\left(u-v_p\right)^2}{m.\mathrm{e}^{\left(\frac{2A\rho tu}{m}\right)}.\frac{\left(u+v_p+\frac{(u-v_p)}{\mathrm{e}^{\left(\frac{A\rho tu}{m}\right)}}\right)}{A\rho}}\right) \tag{16}$$

Direction x, during the process of analysis, air drag and the increment of horizontal momentum of air flow domain are ignored. In direction x, object moving at constant velocity, it is velocity of belt conveyor $v_0=\dot{x}$

$$S_j=\dot{x}.t_j=v_0t_j \tag{17}$$

$$h_j=y\left(t_{j_1}\right)-y\left(0\right) \tag{18}$$

3.2.3 Motion of objects after falling into the air flow domain

When objects left the lower boundary of air flow domain, it can be considered as horizontal movement in a short distance. The formula of h_f is shown in Eq. (19)

$$h_f=\frac{1}{2}\ddot{y}(t_j)t_f^2 \tag{19}$$

where, t_f can be obtained by Eq. (20) and result is shown in Eq. (21)

$$t_f=\sqrt{\frac{2h_f}{\ddot{y}(t_j)}} \tag{20}$$

$$S_f=\dot{x}.t_f=v_0t_f \tag{21}$$

3.3 Result and analysis

To sum up, the separation distance S_1 can be calculated through Eq. (1). From Eq. (21), we can choose the design parameter of sorting color machine as Eq. (23).

$$S_1=S_0-(S_i+S_j+S_f) \tag{22}$$

$$S_1=v_0.\sqrt{\frac{2(h_p+h_j+h_f)}{g}}-v_0.\left(\sqrt{\frac{2h_p}{g}}+t_j+\sqrt{\frac{2h_f}{\ddot{y}(t_j)}}\right) \tag{23}$$

Table 1. Materials properties

Parameter	**Value**	**Unit**
Density Air	1.205	kg/m^3
Area	2.10^{-4}	m^2
Velocity, u	300 ~ 600	m/s
Pressure of nozzle	400 ~ 900	kPa
Time, t_j	1	ms
Height, h_p	0.1	m

In Table 1, the system is setup with the conveyor velocity $v_0 = 2 \div 6\ m/s$, the air flow velocity $u = 300\ m/s$, and the height between conveyor belt and nozzle $h_p = 0.1\ m$. We can design and select suitable parameters to achieve highest efficiency for the system.

Fig 3. Simulated velocity of airflow at nozzle, about $300\ m/s$ and Fig 4. Simulated pressure of airflow, about $500\ kPa$. The effect of nozzle pressure and velocity are significant.

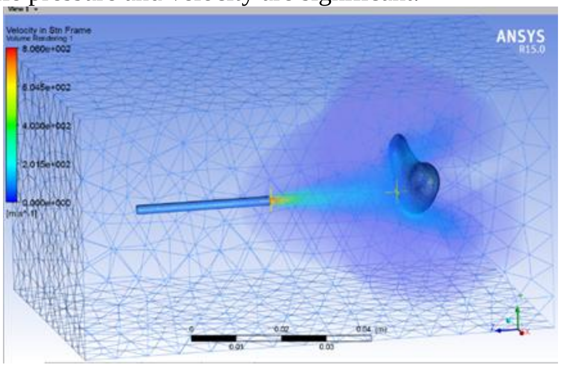

Figure 3. Results of numerical simulation of air flow's velocity.

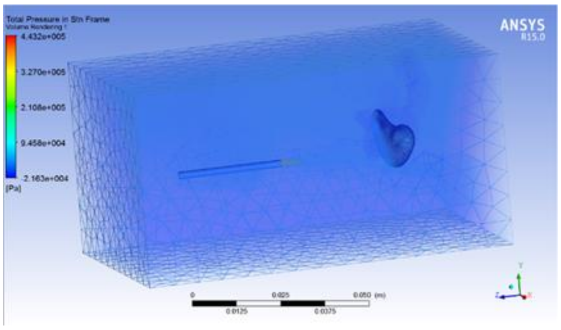

Figure 4. Results of numerical simulation of air flow's pressure.

IV. CONCLUSIONS

In this study, theoretical studies of modeling object classification using image processing system and high-velocity pneumatic separation system was employed to predict the cashew traveling and to simulate the sorting process. The theoretical formula of objects pneumatic separation distance is derived. The formula reflects the basis of motion law of reject objects influenced by airflow field and good objects without influenced of airflow field. Base on the above analysis, all the three factors the air flow velocity u, the conveyor velocity v_0 and the height h_p between conveyor belt and air nozzle have great influence on trajectories of objects in sorting machine. On the basis of this calculation, we can design the operational structure of the sorting color cashew machine.

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