JJMIE

Volume 16, Number 1, January. 2022
ISSN 1995-6665
Pages 73 - 78

Jordan Journal of Mechanical and Industrial Engineering

Theoretical Research of Corn Orientation Device

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Received 14 July 2021 Accepted 28 December 2021

Abstract

Orientation of corn is an essential step in the corn product processing. Corn processing mainly includes cutting root, tip, segment, and grain, and the whole ear packaging, etc., and at each step, the ear needs to be operated in a straight direction. In this paper, the physical parameters of three kinds of corn have been measured, and combined with the characteristics of corn shape geometry, the corn orientation solutions have been put forward. The corn orientation device has been designed, and its working principle has been introduced. When the primary belt speed was 1.426 m/s, all of corn can come off the belt. In order to ensure the requirements of corn processing technology, the orientation device can solve the following problems. When the corn was transmitted in the front of corn small diameter, corn orientation device could make the corn flip in the former of corn big diameter. The corn was transmitted in the front of corn big diameter; corn orientation device keeps its original direction remains the same.

Keywords: corn; orientation device; physical parameters; the primary belt speed;

Name

L_1	length of swinging rod, m	L	length of corn, m
L_3	the length between gravity of the swinging rod and point A, m	F_{AX}	the stress what swinging rod at point A was in horizontal, N
F_{AY}	the stress what swinging rod at point A was in vertical direction, N	F_{BX}	the stress what swinging rod at point B was in horizontal direction, N;
F_{BY}	the stress what swinging rod at point B was in vertical direction, N;	G_1	the gravity of the swinging rod, N
α	angle between swinging rod and the vertical direction, °	L_4	length between corn centroid and the big diameter end, m
F_{bX}	the stress what corn in point B was in horizontal direction, N	F_{bY}	the stress what corn in point B was in vertical direction, N
F_{cX}	the stress what point C was in horizontal directions, N;	F_{cY}	the stress what point C was in vertical directions, N;
β	angle between corn and horizontal plane, °	m_1	the mass of the swinging rod, kg
m_2	the mass of corn, kg	P_0	momentum of collision of corn and swinging rod, N·m
v_0	the primary belt speed, m/s	J	the rotational inertia of swinging rod
ω	angular velocity after collision of swinging rod	h_1	center height of gravity of swinging rod from natural state to graphic state, m
h_2	height of the focus from corn ever collide with the swinging rod to chart the critical state, m		

1. Introduction

Fruit and vegetable classification system is an important part of fruit and vegetable commercialization treatment after picking. It can reduce the production cost of fruit and vegetable storage, packaging, processing and so on. It plays an important role in increasing farmers' economic income and improving enterprises' economic benefits. In the corn grading system and production process, it is imperative to study corn ear orientation. Many institutions have carried out research on the directional mechanism of fruits and vegetables. Such as, in 2008, in Nanjing Forestry University, Huang et al. researched that in apple automatic grading production line, an automatic orientation system has been installed. It can make the apple stem in a vertical position, and implemented apple's direction [1]. It was composed of apple transportation system, automatic orientation trolley, computer visual control system and grading execution equipment. The grading of apple was judged according to the national standards and the location information of apples was confirmed. By computer recognition control system, the grading of apples was completed. In Xinjiang Agricultural University, a research study demonstrated that the automatic orientation device of apricot, it was through the two-conveyor belt of apricot to realize the direction [2, 3]. It was reported that in South China University of Technology, the orientation device of automatic pencil sharpener was studied, and the pencil sharpener automate assembly was made [4, 5]. And there's some literature that shows that in the analysis of the directional device, the theory of position degrees of freedom

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and gesture coefficient theory respectively were put forward [6].

To sum up, in the paper, the study of corn ear orientation device was proposed to better solve the problems of corn classification and processing.

2. Physical Parameters Experiment of Corn

Physical parameters of corn include appearance size, quality of corn. They are important parameters, which determine the scheme and structure of the corn orientation device.

2.1. Experimental instruments and materials

Experimental instruments: vernier caliper and ruler;

Experimental materials: three kinds of fresh corns including sweet 6, jin cui wang and Heji waxy 3 with widely planted area in Jilin province. (These are 3 kinds of corns.)

2.2. Experimental method

In this paper, 50 ears of each corn ear were taken for measurement. Their big diameter, small diameter, length and quality have been measured. Because the small diameter of the corn at the top end is too small, and the value changes very big, the section diameter was taken the top 10 mm distance from top end. Length of corn didn't include the length of corn handle. Each product was measured three times and took its average as the measured results [7].

2.3. Experimental results

In the paper, measurement results of three kinds of corn were analyzed. Extreme value range of length, big diameter, small diameter and quality of corn was as shown in Table 1. Distribution table of length, big diameter, small diameter and quality of corn was as shown in Table 2.

In Table 1, the variation range of corn appearance size and the mass were illustrated. In Table 2, the corn with big diameter between 46 and 58 mm was 85% of the total corn. The corn with small diameter in the range of 34-40 mm was 85% of the total corn. Corn with length in the 170-200 mm was 87% of the total corn. The corn in mass of 200-230 g was for 87% of the total corn. These four parameters are the basis for designing corn orientation device and building entity model of corn. Therefore, the establishment of mathematical model among diameter, diameter, mass and length has a certain guiding significance for the design and research of the corn orientation device.

Table 1. Extreme value table of appearance size and the mass of corn

Project	Big diameter (mm)	Small diameter (mm)	Length (mm)	The mass of corn (g)
Maximum value	61.7	41.5	218.7	238.7
Minimum value	39.1	31.2	161.4	181.4

3. Structure and Working Principle of Corn Orientation Device

Corn orientation is an important step in corn grading. According to the physical parameters of corn, the structure of corn orientation device was designed and its working principle was described in detail.

3.1. Structure of corn orientation device

Corn orientation device was mainly composed of two belts and a swinging rod mechanism. The swinging rod mechanism was the core. Three-dimensional modeling diagram is shown in Figure 1.

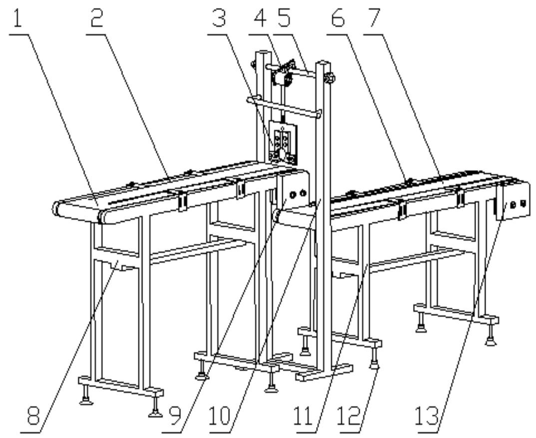


Figure 1. Three-dimensional modeling diagram of corn orientation device

1. primary belt; 2. guide bar of primary belt; 3. swinging rod; 4. swinging shaft; 5. beam; 6. guide bar of auxiliary belt; 7. auxiliary belt; 8. the primary belt frame; 9. primary belt motor; 10. swinging rod frame; 11. the auxiliary belt frame; 12. supporting foot of the belt frame;13. auxiliary belt motor

Table 2. Distribution table of appearance size and quality of corn

No	Big diameter		Small diameter		Length of corn		Quality	
	Value range (mm)	Proportion (%)	Value range (mm)	Proportion (%)	Value range (mm)	Proportion (%)	Value range (g)	Proportion (%)
1	38-42	1	30-32	1	160-170	6	180-190	1
2	42-46	5	32-34	6	170-180	12	190-200	6
3	46-50	12	34-36	13	180-190	38	200-210	13
4	50-54	39	36-38	42	190-200	37	210-220	36
5	54-58	34	38-40	30	200-210	5	220-230	38
6	58-62	9	40-42	8	210-220	2	230-240	6

Note: Proportion is the ratio of corn with different parameters to the total amount of corn. Such as corn diameter value in the 38-42 range of corn accounted for 1%.

(1) Guide bar

Figure 1 shows, the guide bar (2) (6) was fixed belt rack to make the corn motion on the belt adjusted for the axial and horizontal velocity in the same direction. Guide bar. It's the structure that is shown in Figure 2.

(2) Swinging rod

Figure 1 shows, the role of the Swinging rod (3) was to connect beam and support beam. It consisted of a terminal with a threaded shaft and with a notch plate welding, is shown in Figure 3.

(3) Primary belt

Figure 1 shows, the role of primary belt (1) was for swinging rod institutions conveying corn grain, and make corn grain out of the primary belt.

(4) Auxiliary belt

Figure 1 shows, the role of auxiliary belt (7) was to help the corn orientation and down a workstation.

(5) Swinging rod frame

Figure 1 shows, swing rod frame (10) has two roles, one was the fixed beam; The other was to use gear lever of the welding rod placed in the swing swinging frame consumption of energy, to make the swinging rod to rest as soon as possible, for the next downstream.

(6) Swing rod

Figure 1 shows, swinging rod (3) was the key to achieve corn orientation. It consists of a total of five plates, a rod body and a number of fasteners, its structure is shown in Figure 4.

3.2. Working principle of corn orientation device

Speed of corn on the primary belt was equal with speed of the primary belt tape, and through the role of the guide bar, direction of the axis of the corn was same with the speed of the horizontal motion [8]. At this time, big diameter of the corn may be in the front, or small diameter of the corn may also be in the front.

In Figure 5, when small diameter end of the corn was in the front, because the diameter of small diameter end of the corn was less than the diameter of the hole of the swinging rod, the corn would be inserted to the hole of the swinging rod, then as seen if Figure 5(a). Under the action of corn, the swing rod was swinging, and small diameter end of the corn was swinging with swinging rod movement, then as seen if Figure 5(b). When swing rod was a certain angle, corn would drop out the primary belt, then as seen if Figure 5(c). At same time, under the action of the swing rod and auxiliary belt, corn was flipped and the big diameter end of the corn was in the front to delivery, then as seen if Figure 5(d). When the swinging rod was swinging back, the swing rod would be collided with the pendulum rod rack of swing rod to consume mechanical energy of swinging rod and make it static fast. When small diameter end of the corn was in the front, the process diagrams of orientation device were shown in Figure 5(a-d). In the Figure 5, the direction of the arrow was the movement direction of the corn in horizontal direction.

In Figure 6, when the big diameter end of the corn was in the front, because the diameter of big diameter end of the corn was larger than the swinging rod, the big diameter end of the corn couldn't insert into the hole of the swinging rod, then as seen if Figure 6(a). Under the action of corn, the swinging rod was rotating then as seen if Figure 6(b), and then the corn was on auxiliary belt. At the time, the corn was delivered at big diameter end of the corn before as seen if Figure 6(c). When the swinging rod was swinging back, it would collide with the rod rack of the swinging rod frame to consume mechanical energy of the swinging rod and stop it quickly. The process diagrams of orientation device were shown below in Figure 6(a-c). In the Figure.6, the direction of the arrows was for the movement direction of the corn in horizontal direction.

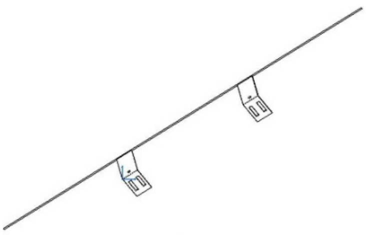


Figure 2. Guide bar

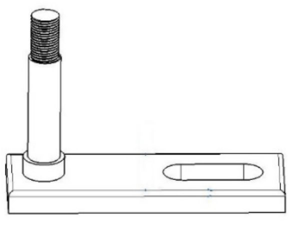


Figure 3. Swinging rod

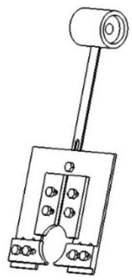
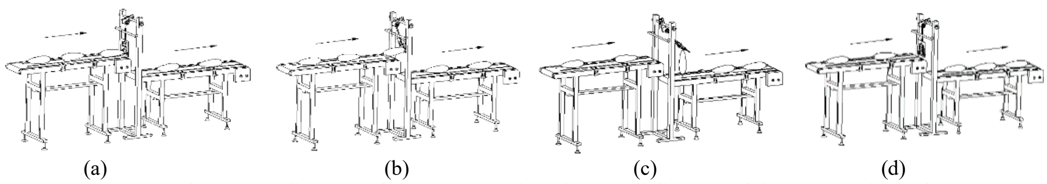
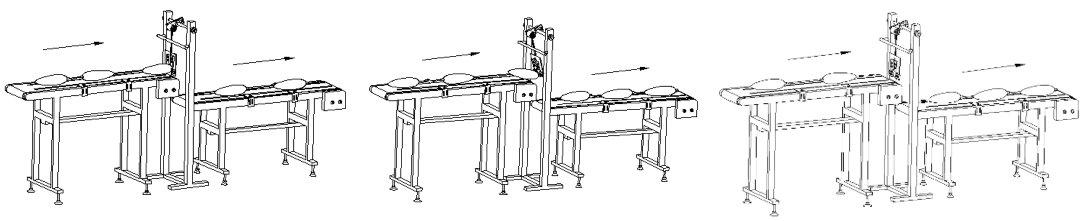


Figure 4. Structure of swinging rod



(a) (b) (c) (d)

Figure 5. The process diagrams of orientation device when small diameter of the corn was in the front



(a) (b) (c)

Figure 6. The process diagrams of orientation device when big diameter of the corn was in the front

4. Mechanism of Corn from the Primary Belt

During the separation of corn from the primary belt, there might be two things: Firstly, static friction force was large enough between corn and the belt, on which the corn could be out of the primary belt by the static friction force between corn and the primary belt; Secondly, the static friction force is not big enough between corn and the primary belt. The relative sliding would be produced between corn and the primary belt. Corn could be out of the belt mainly depending on its own momentum.

4.1. Analysis idea

In order to determine the mechanism of the corn from the primary belt, which belongs to the first kind of case or to the second case. In this paper, "friction" in critical state of the corn needed to be analyzed. The flow chart of analysis idea was shown in Figure 7.

4.2. Analysis process

When small diameter end of the corn was in the front, diameter of small diameter end of the corn was less than the diameter of swinging rod hole. Small diameter end of the corn would be inserted to hole of the swinging rod. Then it was swinging with the swinging rod movement, until corn was out of the primary belt. In this process, the contact between corn and swinging rod was simplified. The corn was simplified to connecting rod. When corn was in the critical state, the following result was shown in Figure.8, in which A was articulated point of the swinging rod and swinging shaft, B was hinged point of corn and swinging rod, C was application point of the primary belt and corn, α was angle between swinging rod and the vertical detection in the critical state, β was angle between corn in the critical state and horizontal plane, h_1 was gravity elevated height of swinging rod from the state of nature to graphic state, h_2 was gravity elevated height of corn from the state never in contact with the rocker to graphic state, direction of the arrows was the direction of rotation for the pulley in Figure 8.

When the corn would be out of the primary belt, length of the corn was ignored which plug into swinging rod hole. At the time, the length of the corn was its overall length in Figure.8. By the geometric relationship, the formula was taken.

$$\cos\alpha = \frac{L_1^{\ 2} + L_1^{\ 2} - L^2}{2L_1^{\ 2}} \tag{1}$$

In the formula, L_1 was length of swinging rod, m; L was length of corn, m.

$$\beta = \frac{\pi}{2} - \frac{\pi - \alpha}{2} \tag{2}$$

After the linkage was decomposed to analyze in Figure 8. The stress of swinging rod and the corn were shown in Figure 9 and Figure 10 respectively.

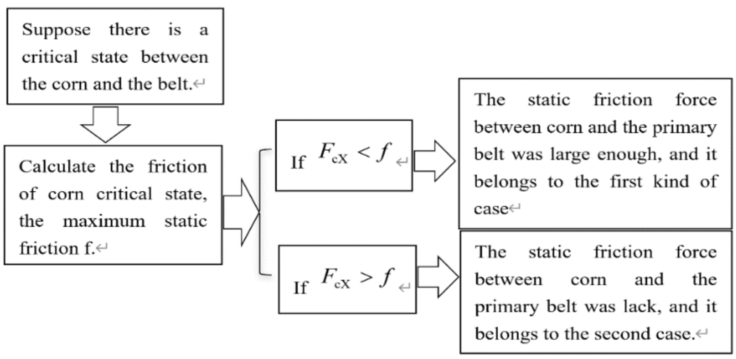


Figure 7. The flow chart of analysis idea
f: the maximum static friction, N. F_{cX}: the friction force between corn and the primary belt, N.

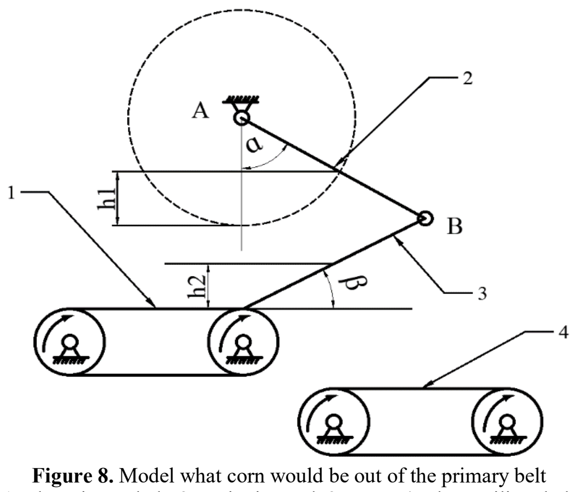


Figure 8. Model what corn would be out of the primary belt
1. The primary belt; 2. Swinging rod; 3. Corn; 4. The auxiliary belt

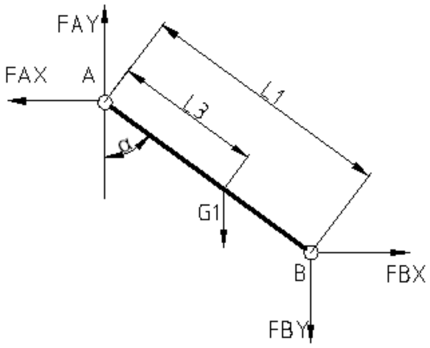


Figure 9. Stress analysis diagram of swinging rod

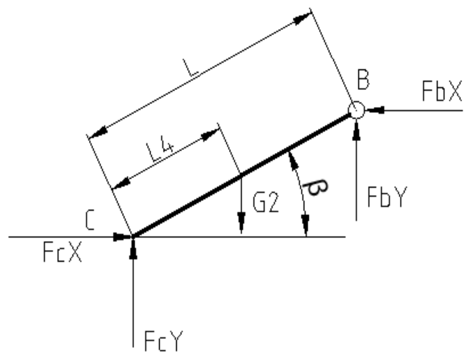


Figure 10. Stress analysis diagram of corn

According to Figure 9 and Figure 10, by mechanics knowledge, they were known:

$$F_{BX} \cdot L_1 \cdot \cos\alpha - F_{BY} \cdot L_1 \cdot \sin\alpha - G_1 \cdot L_3 \cdot \sin\alpha = 0 \quad (3)$$

$$F_{BX} - F_{bX} = 0 \quad (4)$$

$$F_{BY} - F_{bY} = 0 \quad (5)$$

$$F_{bX} - F_{cX} = 0 \quad (6)$$

$$F_{bY} \cdot L \cdot \cos\beta + F_{bX} \cdot L \cdot \sin\beta - G_2 \cdot L_4 \cdot \cos\beta = 0 \quad (7)$$

By type (3), (4), (5), (6) and (7), they could be obtained:

$$F_{CX} = \frac{G_1 \cdot L_3 \sin\alpha \cdot L \cdot \cos\alpha + G_2 \cdot L_4 \cos\beta \cdot L_1 \sin\alpha}{L \cdot \sin\beta \cdot L_1 \cdot \sin\alpha + L_1 \cdot \cos\alpha \cdot L \cdot \cos\beta} \quad (8)$$

Length of the swinging rod was L_1, $L_1 = 0.236$ m; By suspension line method, center of gravity of the swinging rod was measured, taking $L_3 = 0.19$ m; The mass of the swinging rod was m_1, $m_1 = 0.450$ kg; Assume that center of gravity of the corn was focus on its axis, so $L_4 = \frac{1}{2}L$. The values of m_1, L_1 and L_3, and limit length and quality of maize corn in Table 1 respectively have been plugged into type (8).

When length of corn was $L = 0.1614$ m, the mass of corn was $m_2 = 0.1814$ kg, $F_{cX} = 2.095$ N. When length of corn was $L = 0.2187$ m, quality was $m_2 = 0.2387$ kg, $F_{cX} = 2.350$ N. By experiments, maximum static friction coefficient between the corn and belt A was measured to be 0.42, then:

$$f = m_2 g \mu = 0.2387 \times 10 \times 0.42 = 1.00254 \text{ N} \quad (9)$$

Obviously $F_{cx} > f$, it belonged to the second case. When small diameter end of the corn was in the front, corn would depend mainly on its own momentum from the primary belt. At the same time, it was not necessary to analyze the case that big diameter end of the corn was in front.

4.3. Determination of the primary belt speed

Through the above analysis, there was a critical value V for the primary belt speed. When the primary belt speed was greater than V, corn could be separated from the primary belt; When the primary belt speed was less than V, it could not guarantee that all corn could be separated from the primary belt. In this paper, critical speed V of the primary belt has been estimated. From collisions between corn and swinging rod to the corn out of the primary belt, three stages have been divided into: the first stage was before the collision of corn ear and swinging rod; the second stage was collision moment between corn and swinging rod; in the third stage, corn was out of the primary belt after collision between corn and swinging rod.

The first stage was the corn grain and swinging rod before the collision. The corn with the belt on the primary belt was at synchronous movement, namely the size of the corn grain rate is equal to the size of the primary belt speed. In order to simplify the calculation, quality of maize grain is simplified to homogeneous cylinder, the swinging rod was simplified to the rod body (uneven quality), and the center axis of maize grain and the end of the rod body were in the same horizontal plane. Schematic diagram before collision of corn and swinging rod was shown in Figure 11. Directions of the arrows in figure were the direction of corn grain. At this time, maize grain has momentum for P_0, then:

$$P_0 = m_2 v_0 \quad (10)$$

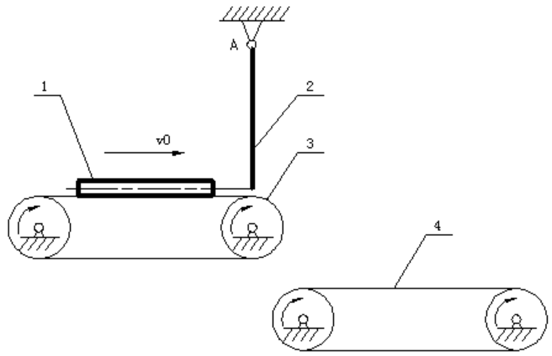


Figure 11. Schematic diagram before collision of corn and swinging rod
1. corn; 2. swinging rod; 3. the primary belt; 4. the auxiliary belt

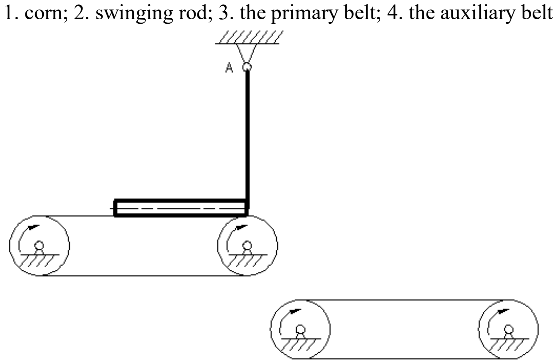


Figure 12. Moment of collision of corn and swinging rod

The second stage was the moment of collision corn and swinging rod. The system of corn and swinging rod was as the research object, at the moment of collision, the small diameter end of corn was interacted with swinging rod. Because at the moment of collision of corn and swinging rod, the displacement couldn't occur, external forces didn't affect the system, and momentum of the system was conservative, as shown in Figure 12. At this moment, the speed direction of the corn was horizontal. And because the small diameter end of corn was turned together as the swinging rod, the constraint between the small diameter end of corn and swinging rod was simplified to hinge. To sum up, at the moment of collision, the momentum of the system was conservative, and corn was hinged to swinging rod [9].

$$m_2 v_0 L_1 = m_2 \omega L_1^2 + J\omega \tag{11}$$

In the third stage, after collision of the corn and swinging rod, it would be coming off the primary belt. In the process, the system of corn and swinging rod still was the research object. Because the critical speed was solved, when the corn was separated from the primary belt, the kinetic energy of corn and swinging rod was converted into all their potential energy, and the internal energy between swinging shaft and swinging rod. At this stage, the external force of the system was friction F_1 between corn and the primary belt, friction F_2 was between swinging rod and swinging shaft. On the system, what F_1 did was positive work W_1, what F_2 did on system was negative work W_2. According to the law of conservation of energy, the formula was taken:

$$\frac{1}{2}m_2\left(\omega L_1\right)^2 + \frac{1}{2}J\omega^2 + W_1 - W_2 = m_1 g h_1 + m_2 g h_2 \tag{12}$$

In order to simplify the calculation, the corn was simplified to rod. When it was in the critical state, it was as shown in Figure 4. By the geometric relationship, the formula was taken:

$$h_1 = L_3 \times \left(1 - \cos\alpha\right) \tag{13}$$

$$h_2 = L_4 \times \sin\beta \tag{14}$$

By type (1), (2), (13) and (14), the calculated results were $L = 0.2187$ m, $L_3 = 0.19$ m, $L_4 = 0.10935$ m, $h_1 = 0.0802$ m, $h_2 = 0.0231$ m.

Because W_1 could make corn from the primary belt, without considering the circumstances, the primary belt speed could guarantee corn from the primary belt. Because the friction force between the swinging rod and the swinging shaft was enough small, it was neglected. In the case of ignoring W_1 and W_2, the system of corn and swinging rod was as the ideal model. By vertical type (12) (11), the formula was taken:

$$v_0 = \sqrt{\frac{2\left(m_1 g h_1 + m_2 g h_2\right) \times \left(m_2 L_1^2 + J\right)}{m_2 L_1^2}} \tag{15}$$

In CATIA, the rotational inertia of the swinging rod were that $J = 0.0195$ kg·m², $h_1 = 0.0802$ m, $h_2 = 0.0231$ m, $L_1 = 0.238$ m, $m_1 = 0.45$ kg and $m_2 = 0.2387$ kg. They were plugged into type (15), taking $v_0 = 1.426$ m/s.

Under the influence of ignoring the frictions between the primary belt and corn and between swinging rod the swinging shaft, the primary belt speed was v_0, $v_0 = 1.426$ m/s. The corn could be separated from the primary belt. So, the primary belt speed should not be less than 1.426 m/s.

5. Conclusions

In this paper, the following conclusions are drawn through measurement test and analysis.

1. The big diameter, small diameter, length and the mass of corn were measured. The four parameters are the basis for designing corn orientation device and building entity model of corn.
2. Combined with the physical parameters of corn, A corn orientation device was designed and manufactured, and the function of the main components was explained.
3. In order to be able to ensure that all of corn from the primary belt during the transfer process, the belt speed is not lower than 1.426 m/s.

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