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Research Article

Theoretical Research on Performance of the Corn Length Grading System

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Abstract: In order to solve the fresh corn grading problem in the corn deep processing enterprise, in this study, the grading system that the corn length was grading index has been proposed. Instead of the method of artificial classification, through the grading system the people have been liberated from heavy manual labor. And, through the theoretical research on the performance of the corn length grading system, the theoretical grading rate has been determined and can reach 11900/h; through analyzing the nozzle purging corn, the best purging position has been determined and was centroid of the corn. When the corn roots was in the former, the nozzle purging effect was best; The impact factors of measuring accuracy in grading system have been analyzed; the amount of compressed air purging corn has been determined and need 5.15 m^3/h.

Keywords: Corn, grading system, grading rate, grading purging, performance

INTRODUCTION

Corn is one of important agricultural products in our country and is an important raw material of food products and food processing and corn yield in jilin province is first on the list of the national corn. The industry chain of corn from planting, processing and circulation has become very mature and increasingly brought to the attention of the government, enterprises and research institutions. Through the research of market and enterprise, the deep processing products whose raw material is fresh corn are very popular with the market and the market prospect is very good. Zhang *et al*. (2005) and Yang and Li (1997) discussed that the processing and development of fresh corn also conducted in-depth research. Brian *et al*. (1966) have designed grading and sorting device for thin skin vegetables or fruits; Klukis (1984) have designed automatic corn sorting and inspection system; Demars and Ruhter (1994) have researched device for feeding corn. And at present in fresh corn grain processing enterprises, the corn grading was based on artificial separation method. This kind of grading method was strong subjectivity, low production efficiency and affect the accuracy of grading; and abroad the cost of grading equipment is too high and there is no domestic molding equipment of corn automatic classification.

In order to solve the problem of the fresh corn classification, in this study, the grading system that the corn length was grading index has been proposed. Instead of the method of artificial classification, through the grading system the people have been liberated from heavy manual labor. And the performance of the grading system have been researched theoretically through the following such as the grading rate, the best method of grading purging, the precision of measurement of corn length and gas consumption of the grading system.

MATERIALS AND METHODS

The grading rate: Classification rate refers to that when the corn was graded work based on corn length in the grading system, per unit time in meeting the requirements of the classification indexes of maize corn number, unit is: a/hour. The grading rate is an important indicator of quality evaluation rating system, related to that the automatic grading system in the actual production can replace artificial classification work and whether to effectively improve the production efficiency and production capacity. In this section, the corn grading rate has been theoretically calculated (Zhang, 2002). Through the theoretical calculation, the maximum grading rate of the grading system has been derived.

According to the grading principle of grading system, the grading rate of corn length automatic grading system was available:

$$V = \frac{3600 \times v_0}{L_x + L_{n(n-1)}} \quad (1)$$

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Table 1: Theoretical grading rate of the grading system in different speed of conveyor belt

Speed of conveyor belt (m/s)	The minimum distance between the adjacent corns, (mm)	The minimum distance between the nozzle (mm)	The minimum value of length of conveyor belt (mm)	The maximum classification rate in the theory (a/h)
0.7	6.80	35.0	195	9333
1.0	14.0	42.0	216	10588
1.3	21.2	49.2	238	11359
1.6	28.4	56.4	260	11900
1.9	35.6	63.6	281	12302
2.2	42.8	70.8	303	12611
2.5	50.0	78.0	324	12857
2.8	57.2	85.2	346	13056

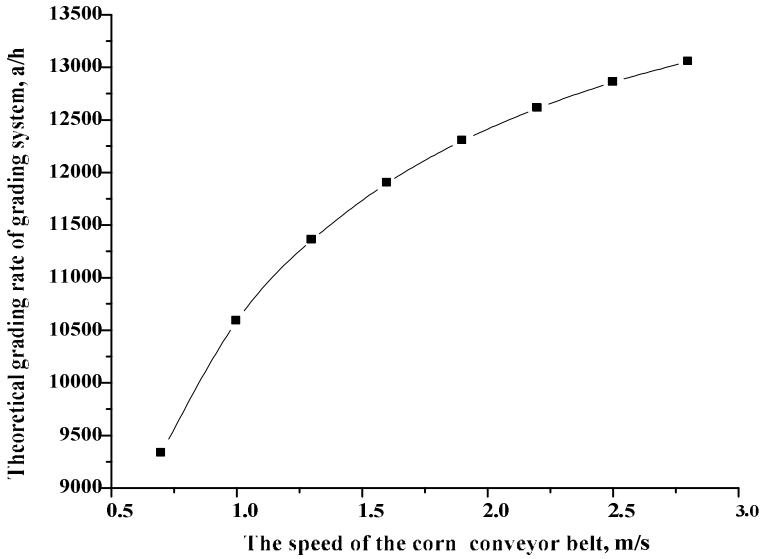

Fig. 1: Theoretical grading rate of the grading system with the speed of the corn conveyor belt

v_0 = Speed of the corn conveyor belt, m/s
L_x = Length of the ear of corn, m
$L_{(n\text{-}1)n}$ = Distance between two consecutive corn grain on the conveying belt, m

The type 1 has show that he main factors influencing the classification rate were The speed of the corn grain conveyor belt v_0, the distance between two consecutive corn grain on the conveying belt $L_{n(n-1)}$ and The length of the ear of corn L_x. Because the speed of corn grain conveyor belt can be regulated by the motor and the length of the corn was a constant value, so the key factor influencing the grading system was the distance between the consecutive corn $L_{n(n-1)}$. Here on the basis of test model, the $L_{n(n-1)}$ minimum has been analyzed and determined.

Assuming that four nozzles were set up in the grading system, the distance was 90 cm between corn measurement unit and the first nozzle, the length of the corn has been calculated according to 20 cm. According to the analysis of the above, the speed of corn conveyor belt was changing and the theoretical grading rate of the grading system as shown in Table 1. Data in the table were maximum or minimum value under the theory condition. It has reference significance to research and development production prototype of the grading system.

According to the theory of calculation data in the Table 1, the theory of maximum grading rate curve of grading system can be obtained when the speed of the corn conveyor belt changed, as shown in Fig. 1.

In the Fig. 1, it has show that with the speed of corn conveyor belt was improved, the grading rate of the grading system was also improved. But, when the speed of conveyor belt was about 1.6 m/sand increasing, the increasing amplitude of the grading rate of the grading system was decreasing. This was mainly due that when the conveyor belt speed was the large, it will result that the running in corn conveyor belt was not stable and affect the accuracy of grading system. So, the speed of conveyor belt should not be more than 1.6 m/s. According to the data in Table 1, under the condition, the grading rate of grading system can reach 11900 a/hour.

Grading purging: Grading systems were to corn of different lengths grading. This action was performed by the nozzle group of corn purging. Purging execution ways directly affected effect of the grading system. In

this study, Purging process, the position of the nozzle purging force on corn has been analyzed in theory, the best position of nozzle purging corn has been gotten; the theoretical moment of nozzle purging corn has been given.

Precision of length measurement: The precision of length measurement refers to the grading system measured by the measuring unit of corn length value and the corn degree of close to actual length value. The precision of that measurement unit of corn length value is higher and the closer the actual length value. The precision of length measuring that reflection of the grading system performance is one of an important symbol. Theoretically illustrates the use of the two groups of correlation type optical fiber sensor can measure the length of the corn, measuring the length of the calculation formula was:

$$L_x = \frac{a \times (t_2 - t_1)}{t_3 - t_1} \quad (2)$$

L_x = Length of the corn C1 C2 under test, m
a = Distance between the sensor A and the sensor B, m
t_1 = Time from Corn endpoint C1 walked to the sensor A, s
t_2 = Time from Corn endpoint C2 walked to the sensor A, s
t_3 = Moment from Corn endpoint C1 walked to the sensor B, s

Grading gas consumption: The power of the nozzle purging corn was the compressed air. In this section, the amount of compressed air what need to consume in the grading system of corn (Li, 2007; Anderson, 2005).

When the nozzle was purging corn, the volume flow of compressed air through the nozzle mouth for:

$$q_m = v \times A \quad (3)$$

v = Speed of the compressed air at the nozzle exit, m/s
A = Cross section area of the nozzle exit, m^2

RESULTS AND DISCUSSION

Purging location: When the nozzle was purging corn, purging different position will affect the corn grading effect. So, the purging different position of corn should been analyzed in the theory (Liu and Wu, 2007). According to the shape of the corn, the corn has been reduced to a frustum of a cone of geometry. The shape heart of corn wasn't on the axis of the center of corn, but it was the partial root side in the center of the axis. Assuming that the distance from the root of corn to the centroid O was a, the distance from the tip of corn to the centroid O was b, the distance from centroid O to the lower part of corn and the upper part of corn was r. The profile simplified geometric model of corn was shown in Fig. 2.

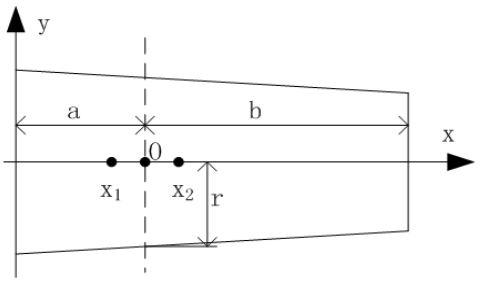

Fig. 2: Profile simplified geometric model of the corn

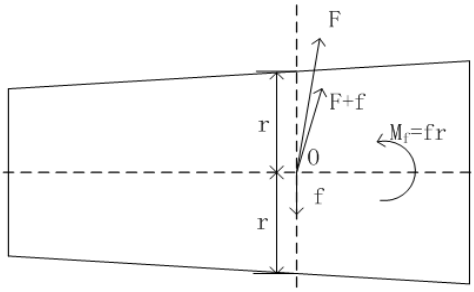

Fig. 3: Force diagram of the corn tip in the former

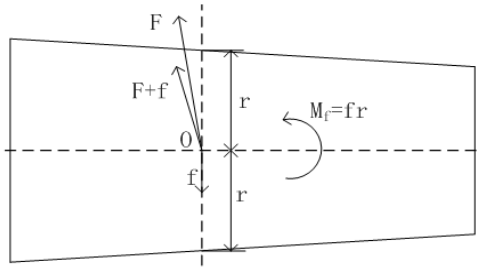

Fig. 4: Force diagram of the corn roots in the former

The best location that the nozzle was purging corn: When the nozzle was purging corn to grade, the flat nozzle mouth section axis has been required to be parallel and in a horizontal plane to the axis of the corn. Assuming that the average force that the nozzle to the corn was F. When the nozzle to the average force F was purging corn to leave conveyor belt, the corn was the effect of conveyor belt friction f. Because the corn was moving uniformly in the level on the conveyor belt and on the vertical direction gravity of corn and the upward force of conveyor belt were balance, so only considering the effect of the average force of the nozzle and the friction of conveyor belt of corn. In this study, through the comparison of the force to the tip of the ear of corn in the former and the root in the former, the best purging location has been determined. The force was shown in Fig. 3 and 4.

By the known Fig. 3 and 4, when the nozzle was purging corn, their force were same and the corn were subject to the average force of the nozzle and the friction of conveyor belt, the difference was the direction of the resultant force. Figure 3 has shown that when the tip of the corn was in the former, the direction of resultant force was backward; it would have the effect of slowing down the movement of corn; the corn wasn't smoothly into the grading exports. Figure 4 has shown that when the corn root was in the former, the direction of the resultant force was forward; it would have the effect of acceleration, the corn can be smoothly into the grading exports.

Thus it was concluded that it was good that the corn root was in the former for grading. So in the use of this grading system for corn grading, the corn roots should be in the former.

The location and time of the Nozzle purging in Corn dynamic: The purging process of the nozzle to corn grain was in motion on the conveyor belt. So, the purging process was dynamic. Based on the above analysis, it has been shown that when the nozzle was purging corn, the average force of the nozzle was in the corn centroid that was the best location. So, when the corn was moving, the position of the nozzle purging corn should be moved forward.

The nozzle jet sectoral flow velocity distribution was shown in Fig. 5. Nozzle mouth above corn axis said that the position of the mouth nozzle purging corn was above the x axis. Nozzle mouth below corn axis said that the position of the mouth nozzle purging corn was below the x axis. When purging corn, the compressed air was fan formation, the velocity distribution of air in injection sector was formed.

Figure 5 has shown that at the center line of the spray sector, the air velocity was highest; on the edge of the fan, the airflow velocity was zero.

So, sector in injection, purging force of corn was big in near the center line of the spray sector.

In this study, they have been also analyzed that the nozzle mouth in corn ear axis above, below and on the same axis, corns were in the position of nozzle jet area, as shown in Fig. 6 to 8.

In the Fig. 6, it has been shown that the average force of the jet stream function of on the top of the corn Fu was greater than the average force F_d at the bottom. So the corn yield around its own axis rotate or trend, visual observation for the counterclockwise direction before.

Figure 7, the average force of the jet stream function at the bottom of the corn F_d was greater than the average force at the top F_u. So the corn yield around its own axis rotates or trend, for clockwise direction before the visual observation.

In the Fig. 8, it has been shown that the average force of the jet stream function at the bottom of the corn F_d was equal to the average force at above of corn F_u. So, the corn not generate the rotation or trend of rotation, because the force at above and below were equal.

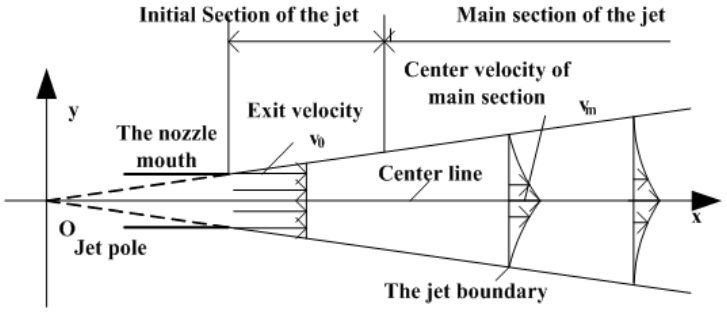

Fig. 5: Nozzle jet sectoral flow velocity distribution

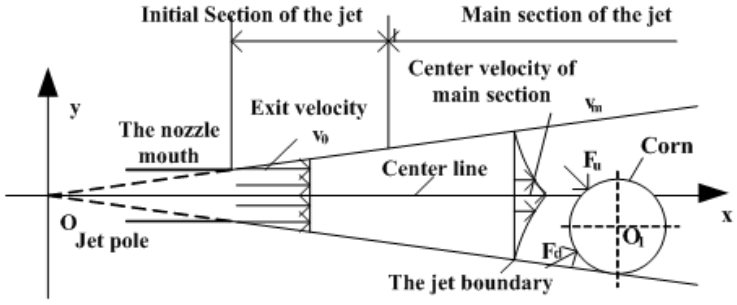

Fig. 6: Nozzle mouth located above the corn axis

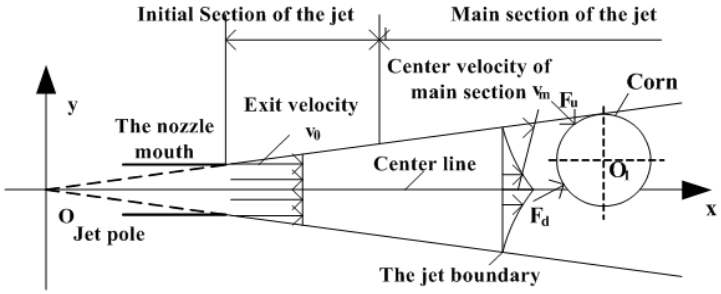

Fig. 7: Nozzle mouth located below the corn axis

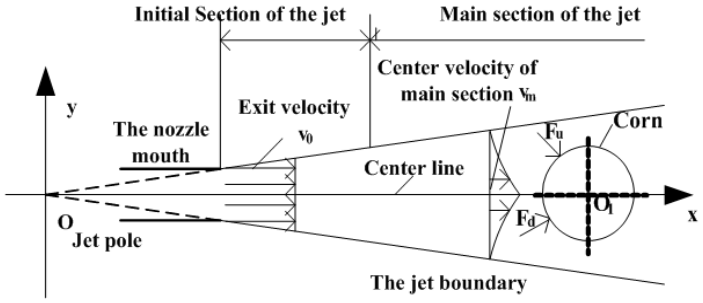

Fig. 8: Nozzle mouth and corn axis at the same level

To sum up, when corn ear was purging left the conveyor belt, would be affected by friction force f couple of M_f direction is counterclockwise, the Fu of couple of M_{fu} direction was counterclockwise, F_d of couple of M_{fd} direction was clockwise, nozzle purging corn, should make the nozzle down to the bottom of the mouth in the corn ear axis. For corn ear when the two different stress testing found that the two kinds of stress state of corn into the classification of different stability level of the mouth, when the axis of the jet fan was located in the stability of the lower part of corn axis than when the axis of the jet fan was located in the stability of corn axis above.

Analysis of length measuring precision: From the type 2, the parameters of accuracy of corn length Lx were t_1, t_2, t_3 and a. According to the Eq. (2), the factors influencing precision of corn length have been analyzed.

The distance parameter a: A was the line distance between the sensor A and sensor B, was to determine the numerical values. So, the light from sensor A and B were required to maintain parallel and the direction was vertical by the speed of the corn. Otherwise the real distance of sensor and sensor B will be greater than the theoretical calculation of the distance A. the length of the corn calculated was smaller than real length.

Parameter of time t: The sensors recorded time t_2 and got a time t_2-t_1, recorded time t3 and got a time t_3-t_1. Thus the speed of the corn on the conveying belt can be calculated and eventually got length data of the corn. So it was the key to the timely and effectively record of the three time data to get the accurate length of the corn.

Corn to keep still as opposed to the conveyor belt: When the corn was into the measuring unit area, the corn should be relatively static with the conveyor belt so as to ensure the measuring the speed of calculation and real tape speed of conveyor belt to be same. And when the corn in measuring unit was relatively moving with the conveyor belt, it would affect that the sensor recorded the time t_1, t_2 and t_3 of the corn going.

Grading gas consumption: According to the previous results have show that the speed of compressed air at nozzle exit v = 114 m/s, cross section area of the nozzle exit $A = 16\times\pi(0.5\times10^{-3})\ 2 = 12.56\times10^{-6}$ m^2. So, when the nozzle was purging corn, the volume flow of compressed air through the mouth of the nozzle was 1.43×10^{-3} m^3/s.

Due to the compressed air will exist the problems in the grading system such as pipe joint leakage, pipeline itself and etc. Therefore, under the condition of the grading system grading, the maximum consumption number of compressed air per hour for:

$$Q_{max} = 3600\times qm \quad (4)$$

By type 4, the maximum consumption number of compressed air per hour for grading system: Q_{max} = 5.15 m^3 /h.

CONCLUSION

In this study, the grading rate of grading system for the length corn has been calculated. For the corn that nozzle purging has been analyzed, according to the shape characteristics of corn, the corn has been reduced to state of a frustum of a cone of geometry to analyze the force, thus the best purging centroid position has been obtained in the corn. And when the corn roots were in the former, the result was best in the nozzle purging corn. According the structure of the grading test prototype, the time and location of corn what the nozzle was purging corn has been given. Measurement accuracy of grading system and the compressed air volume scavenging corn have been calculated, the main factors influencing the accuracy of measurement and the maximum consumption number of compressed air have been obtained respectively.

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