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Studying and examining the acceleration and air flow pressure in wheat head stripper

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Abstract

Cereals head stripper combine is a new technology which has developed in last recent years and also is developing. One of major parameters in this combines is the amount of input and output air flow pressure which is effective in the amount of grain and ear losses. The aim of this research is measuring static, dynamic and total pressures in front of head by using from Pitot tube after applying changes (figure) on wheat head stripper which had been designed and made by Nikravesh (S. Mehdi et al., 2009) (figure 1). The maximum and minimum negative static pressure was equal to 8.3 and 1.5 mm gasoline, respectively. Also, the maximum and minimum dynamic pressure was also equal to 5.1 and 1 mm gasoline. Obtained maximum and minimum velocity of air flow in front of head was also equal to 8.264 and 3.659 m/s.

Keywords: head stripper cylinder, Pitot tube, static pressure, dynamic pressure, air flow velocity

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Introduction

The researches on head stripper combines have been conducting and these combines are continually developing (Yuan. J & Lan. Y., 2007). All efforts for minimizing losses after harvest need first to minimizing losses during harvesting.



Figure 1- head stripper of cereals made in Aboureyhan faculty, Tehran University (S. Mehdi et al., 2009)

Cereals head stripper combines are technology which have developed recently and are effective in harvesting rice and wheat. Cereals losses in these combines occur during harvesting operation (product stripping) such as straw and stubble and ear losses. Head stripper combines have been designed for harvesting fine cereal grains such as rice, wheat, corn and other fine cereal grains.

These combines are used widely for small lands (Adisa, 2013). Adia et al., examined cereals combine of rice harvesting in Nigeria and gained the conditions of optimal function for the set. In this research the effect of several parameters combination including cylinder height of stripper from ground, improvement velocity and rotational velocity of stripper cylinder on performance of rice harvesting were examined for reaching to the best performance.

Examination of conducted researches on head stripper combines show that several parameters are effective on appropriate performance of these types of combines (Klinner. WE. et al., 1987). One the most important factors is input and output air pressure from head which is considered in this research.

Many techniques have been used for measuring rate and velocity of air flow mass. Some of these techniques are perforated plates, venturi tubes, pitot tubes, vane anemometer and etc. (Klopfenstein Jr, 1998). Pitot tube is one of tools applied for measuring velocity and pressure of air flow (Munson, 2008).

Pitot tube is a differential anemometer to measure velocity component if air flow be in direction of Pitot tube's tip. The main point in measuring pressure by Pitot tube is that air flow should be in line with entrance of Pitot tube, otherwise the obtained results will have many errors. In fact, Pitot tube works based on fluid kinetic energy (Spelay et al., 2015).

Barker (1922) conducted his pioneer research on low Reynolds numbers by using from Pitot tube. His findings show that Stokes' rule (Schlichting et al., 2000) can be applied for the phenomenon that occurred on tip of Pitot tube in low Reynolds numbers.

Jiang (2003) applied also Pitot tube for measuring air flow pressure in entrance of rice head stripper. He showed that maximum air flow velocity was into finger holes and the minimum one was in the furthest point of stripper's cylinder center.

Although Pitot tube can be used for measuring fluids flow rate, the studies show that there are many Reynolds numbers (low and high) that the errors in them can be due to using from Bernoulli's equation for measuring the rate. This affair is further true especially in low Reynolds numbers in which viscosity effect is not examined in Bernoulli's equation, and enjoys from major importance (Spelay et al., 2015).

Low costs of Pitot tube than other velocity measurement methods and its simplicity in using and installing conditions caused it to be used in wide range of industrial applications (Spelay et al., 2015). If Pitot tube has been designed correctly and density of crossing air from Pitot tube had been known; so, input air velocity from Pitot tube can be computed by standard equation (1) (Miller, 1996).

$$V = 44.72136 . K_{pitot} . \Gamma_{pitot} . \sqrt{\frac{h_{KPa}}{\rho}} \qquad (1)$$

In this equation V is air flow velocity (m/s), K_{pitot} is Pitot tube constant, r_{pitot} is gas density constant, h_{KPa} is total pressure minus static pressure in Kilo Pascal (KP) and ρ is air density in Kilogram on cubic meters (kg/ m^3). Boetcher and Sparrow (2007) examine Pitot tube behavior in low Reynolds numbers by using from numerical simulation. Their results show that where Bernoulli's equation cannot be used, Reynolds number depends on the shape of Pitot tube' tip (Boetcher & Sparrow, 2007).

Zafer & Luecke (2008) examined air flow pressure in a chamber by Pitot tube. The results show that they can acquire to a method for accuracy of model and analyzing self- regulation behavior for high pressures. Then the used model has been developed for mechanic and dynamic systems.

Total relationship between air flow velocity and presser due to movement of crossing air form Pitot tube (total pressure minus static pressure) has been show in equation (1). If a standard Pitot tube has been used, Pitot tube constant (K_{pitot}) is equal to 1. Also, if air flow velocity crossing from Pitot tube limited to subsonic, gas density constant (r_{pitot}) is also considered equal to 1. If the above mentioned conditions are observed, the equation related to point velocity can be simplified and represented as follows:

$$V = 44.72136 . \sqrt{\frac{h_{KPa}}{\rho}} \qquad (2)$$

Sum of static and dynamic pressures are considered as total pressure which is represented in equation (3):

$$p_T = \left(p + \frac{1}{2}\rho v^2\right) \quad (3)$$

Jiang (2003) introduced an equation for computing constant c in which this constant can be acquired by having distance from center of head stripper's cylinder and air flow velocity. According to equation (4), several constants can be acquired for the points that pressure has been measured there.

$$R.V = C \quad (4)$$

In this equation R is distance from center of head stripper cylinder in meter (m), V is air flow velocity in meter on second (m/ s) and c is a constant which is computed by multiplying velocity and distance from center.

Materials and Methods

The quality of using Pitot tube for measuring air flow pressure

The examinations were done after implementing changes on this cereals head stripper made and designed by Nikravesh et al. (S. Mehdi et al., 2009) existing in Aboureyhan faculty of Tehran University (figure 2). By using from Pitot tube and U- shape barometer existing in Aboureyhan faculty of Tehran University, static, dynamic and all air flow in wheat head stripper were computed in its different points.



Figure 2: Conducted pressure examinations on wheat head stripper

All examinations related to pressure measurement were done by rotational velocity of 770 rounds. Also, because of water and alcohol denser as a fluid inside of barometer, it is decided to use from gasoline as a fluid inside of u-shape barometer. So, according to figure 3, different amounts of pressure computed by connecting Pitot tube to u- shape barometer and putting tip of Pitot tube mouth in line with air flow.

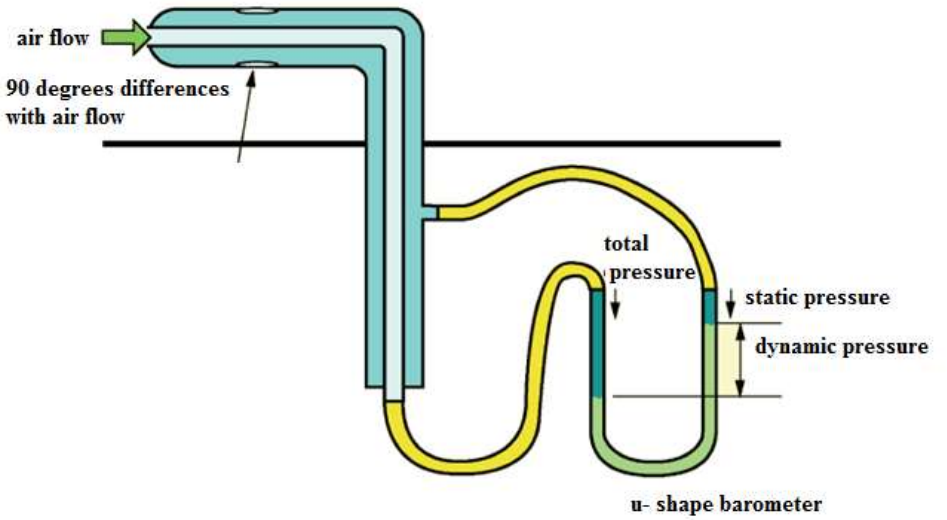


Figure 3: the quality of connecting Pitot tube to u- shape barometer and the quality of establishing tip of Pitot tube against air flow

By pouring given amount of fluid into u- shape scaled barometer and by connecting it to Pitot tube so that barometer put on the ground in balance, total pressure of wheat head stripper was obtained in different points. In following, the quality of acquiring pressure in front of wheat head stripper has been described.

Measuring air flow pressure in front of wheat head stripper

In this stage, this measurement was done for achieving to static and dynamic pressures of air flow in front of head (from finger inside area to cape), according to figures 4 and 5 in different points. So that, these points were in 1 cm- distance with each other. Static and dynamic pressures were obtained in each point and then total pressure was obtained according to equation (4).

This examination was conducted as split plots and in frame of complete random design with two replications and the effect of distance from center of stripper cylinder was examined in 15 levels (290-430 mm) and distance from ground in 3 levels (1 cm lower, in line with and 1 cm upper than horizontal line in line with center of stripper cylinder) on changes of pressure drop in front of head stripper. Also, for simulating farm conditions during wheat harvesting, according to figures 4 and 5, wheat put between scaled board and in front of head and near to fingers.

One important point for doing all examinations of pressure was that u- shape barometer should put in a balance level and also no vibration enter to barometer during examination, otherwise it would be occurred with many errors. SAS 9.0 software was used for doing statistical computations. Also, equation (4) was used for computing constant c in which by putting distance of center of stripper cylinder and air flow velocity in it constant c achieved for each point.



Figure 4: Measuring dynamic pressure in front of wheat head stripper by using from Pitot tube



Figure 5: Measuring static pressure in front of wheat head stripper by using from Pitot tube

Results and discussions

As mentioned before, by using from Pitot tube and U- shape barometer, static and dynamic pressures were examined in different points of set. Then, according to equation (3), total pressure was computed by the sum of static and dynamic pressures. First, the (static and dynamic) pressure of different points between fingers was measured and air flow velocity was acquired by entering dynamic pressure in equation (2). The results related to these examinations have shown in figure 6.

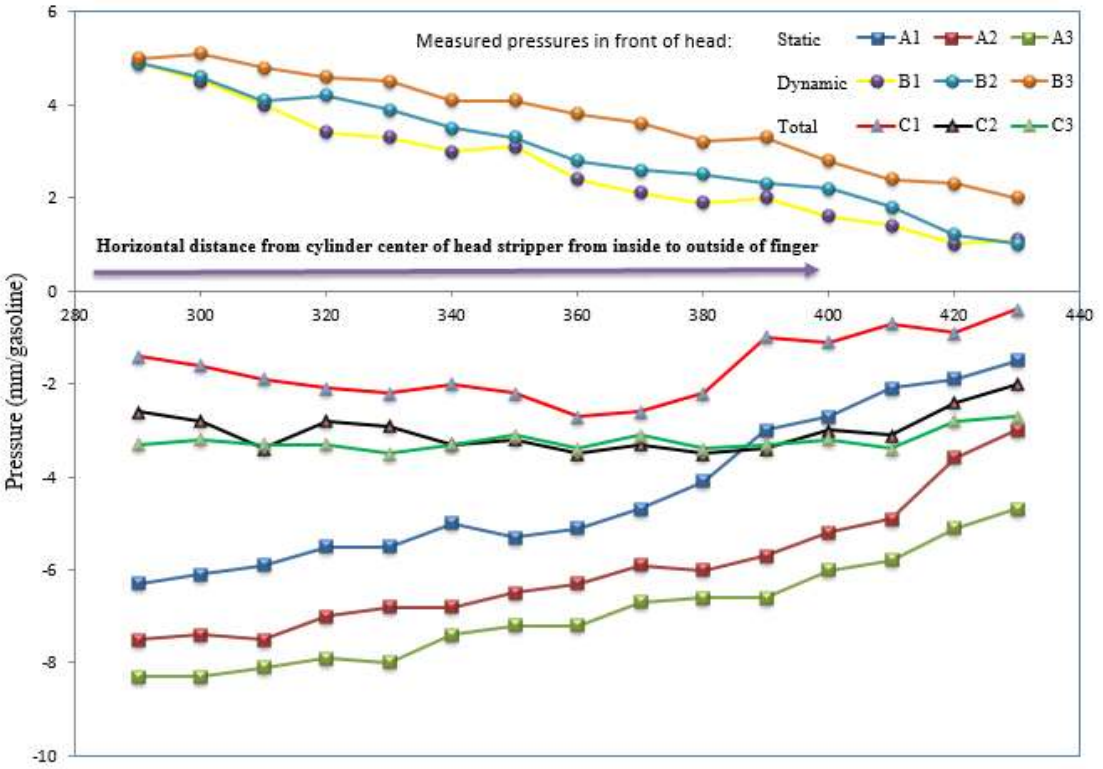


Figure 6: changes on static, dynamic and total pressures in the points located on a balance level from inside of finger area to the cape in front of head

A_1, A_2 and A_3 are related to measured static pressures; B_1, B_2 and B_3 are also related to measured dynamic pressures and C_1, C_2 and C_3 are also related to measured total pressures in finger area to the cape in front of head. 1, 2 and 3 indices are respectively related to one centimeter lower than, in line with and one centimeter higher than horizontal line in line with center of stripper cylinder.

As shown in figure 6, in total status as far as we get away from center of stripper cylinder, dynamic pressure was decreasing and static pressure was increasing. Also, whatever we get near to the center of stripper cylinder, static pressure was decreasing and dynamic pressure was increasing.

Regarding to figure 6, it can be found that total pressure on all 3 statuses did not have similar behavior and were always decreasing and increasing. If static and dynamic pressures were respectively increasing and decreasing by get away from center of stripper cylinder by steady slope. Jiang (2003) resulted that by nearing to center of stripper cylinder air flow velocity was increasing. He, also, resulted that whatever moving form finger holes to outside areas (towards cape) air flow velocity was severely decreasing which are compatible with the results of this experiment (Jiang, 2003).

In first status (A_1, B_1, C_1), maximum and minimum negative static pressure were -6.3 and -1.5 mm gasoline, respectively which the maximum one was related to internal area of finger holes and the minimum one was related to the cape of head stripper. Jiang (2003) also computed maximum and minimum negative static pressure in cape of front of head -10.6 and -3.9 mm water which were a bit compatible with the results of this examination. He also resulted that static pressure by nearing to the center of stripper cylinder was decreasing smoothly which was compatible with the results of this examination.

Maximum and minimum dynamic pressures were also equal to 4.9 and 1 mm gasoline, which respectively were related to the internal and external areas of finger holes. Jiang (2003) also computed maximum and minimum dynamic pressure in cape of front of head 9.55 and 3.82 mm water which were a bit compatible with the results of this examination.

Finally, because static pressure of each point was higher than measured dynamic pressure; so, obtained total pressure in each point was a bit negative. Jiang (2003) reported total pressure in all points "negative" and only in one point which is related to external areas of finger holes "positive". Maximum and minimum negative total pressure was equal to -2.7 and -0.4 mm gasoline that both of them were in external area of finger holes.

In first status (A_2, B_2, C_2), maximum and minimum negative static pressure were equal to -7.5 and -3 mm gasoline, respectively which the maximum one was related to internal and external areas. In fact this amount in two sides becomes equal between two areas. Also, the minimum negative static pressure was belonged to external area of finger holes which located in furthest point than center of stripper cylinder.

Maximum and minimum dynamic pressures were also equal to 4.9 and 1 mm gasoline, which the maximum one was related to the internal areas of finger holes; and the minimum one was related to the external areas of finger holes in furthest point of the center of stripper cylinder. Maximum and minimum negative total pressure was respectively equal to -3.5 and -2 mm gasoline that both of them located on the external areas of finger holes. Here the results achieved by Jiang (2003) and mentioned above were confirmed.

In first status (A_3, B_3, C_3), maximum and minimum negative static pressure were equal to -8.3 and -4.7mm gasoline, respectively which the maximum one was related to internal and the border between external and internal areas. And, the minimum negative static pressure was belonged to external area of finger holes which located in furthest point than center of stripper cylinder

After acquiring the results related to pressure, it is necessary to see that whether considered parameters have significant effect on measured pressures or not. Here the effect of variables "distance from the center of stripper cylinder" and "vertical distance with crossing horizontal line from the center of stripper cylinder on static and dynamic pressures" have been examined in which the results related to variances analysis of the mentioned variables have been shown in table 1.

Table 1: results of variance analysis related to the effect of distance from the center of stripper cylinder and vertical distance with crossing horizontal line from the center of cylinder

Changes resource	Freedom degree	Squares average	
		Static pressure	Dynamic pressure
vertical distance with crossing horizontal line from the center of stripper cylinder (a)	2	52.72**	8.76**
Distance from the center of stripper cylinder (b)	14	11.16**	7.73**
ab	28	0.26**	0.09**

** Significant difference in 1% level, * significant difference in 5% level, and ns lack of significant difference between different levels

The findings resulted from variance analysis for measured static and dynamic pressures in front of head show that the amounts of independent variables of vertical distance with crossing horizontal line from the center of stripper cylinder and distance from the center of stripper cylinder were significant on pressure drop in internal area of head with a confidence coefficient of 99%.

Examining the effects of means related to static and dynamic pressures for vertical distance with crossing horizontal line from the center of stripper cylinder between two "one centimeter lower than and in line with crossing horizontal line of the center of stripper cylinder" show that the significant difference was in 1% level. Maximum static pressure in 1 cm lower than crossing horizontal line from the center of stripper cylinder was averagely -4.31 mm gasoline and the minimum one for 1 cm lower than crossing horizontal line from the center of stripper cylinder was averagely -6.93 mm gasoline.

Maximum amount of dynamic pressure in 1 cm upper than crossing horizontal line from the center of stripper cylinder was averagely 3.7 mm gasoline and the minimum one for 1 cm lower than crossing horizontal line from the center of stripper cylinder was averagely 2.65 mm gasoline.

Examining the effects of means related to static and dynamic pressures for distance from the center of stripper cylinder between two levels of 420 and 430 mm show that the significant difference was in 1% level. Maximum static pressure in 430 mm distance from the center of stripper cylinder was averagely -3.07 mm gasoline and the minimum one for 290 mm distance from the center of stripper cylinder was averagely -7.37 mm gasoline. Maximum dynamic pressure in 290 mm distance from the center of stripper cylinder was averagely 4.93 mm gasoline and the minimum one for 430 mm distance from the center of stripper cylinder was averagely 1.37 mm gasoline.

Examining the counter effects of variables "vertical distance with crossing horizontal line from the center of stripper cylinder and distance from the center of stripper cylinder on measured static and dynamic pressures" show that the significant difference was in 1% level. Maximum static pressure in 1 cm lower than crossing horizontal line from the center of stripper cylinder with 430 mm distance from the center of stripper cylinder was averagely -1.5 mm gasoline and the minimum one in 1 cm upper than crossing horizontal line from the center of stripper cylinder with 290 and 300 mm distance from the center of stripper cylinder was averagely -8.3 mm gasoline.

Maximum dynamic pressure in 1 cm upper than crossing horizontal line from the center of stripper cylinder with 300 mm distance from the center of stripper cylinder was averagely 5.1 mm gasoline and the minimum one in aligned and 1 cm lower than crossing horizontal line from the center of stripper cylinder with 420 and 430 mm distance from the center of stripper cylinder was averagely 1 mm gasoline.

To determine the relationship between the measured features (static pressure and dynamic pressure) correlation coefficient (R) was used for computing them. The results show that there is higher correlation between static and dynamic pressures which its amount was equal to -0.898. This correlation was incomplete and reverse. Means that, by increasing static pressure dynamic pressure was decreasing relatively and vice versa. Also, the obtained number shows the used amount for predicting has nearly 72% common variance with predicting performance. Also, the relationship between two items has been significant in 1% level.

For achieving to one model between parameters and considered features of this research, regression analysis was used. Regarding to the results related to regression analysis it can be found that both different factors, vertical distance with crossing horizontal line from the center of stripper cylinder and Distance from the center of stripper cylinder, play a significant role in determining explaining coefficient (R^2) of static and dynamic pressures.

The results derived from regression analysis show that by increasing height from ground (vertical distance with crossing horizontal line from the center of stripper cylinder), static pressure was decreasing (DF=1, F=31.69, P=0.1119, R^2=0.9694) and dynamic pressure was increasing (DF=1, F=40.33, P=0.0994, R^2=0.9758). By increasing height from ground, static pressure from -5 to -6 mm gasoline with -1.3 slope was decreasing and dynamic pressure from 3 to 3.5 mm gasoline with 0.55 slope was increasing. Means that static pressure has been changed with further slope than dynamic pressure.

Also, the results derived from regression analysis show that by increasing distance from the center of stripper cylinder, static pressure was increasing (df=1, F=218.98, P=0.0001, R^2=0.944) and dynamic pressure was decreasing (df=1, F=1952.39, P=0.0001, R^2=0.9934). By increasing distance from the center of stripper cylinder, static pressure from -6 to -5 mm gasoline with 0.0298 slope was increasing and dynamic pressure from 3.5 to 3 mm gasoline with -0.0251 slope was decreasing. Means that static pressure has been changed with further slope than dynamic pressure.

Here, the results due to dynamic pressure (B_1, B_2, B_3) in front of head by putting in equation (2) can compute air flow velocity for different points which by putting in equation (4) the constant c can be attained for different points.

At first, the results related to 1 cm lower than crossing horizontal line from the center of stripper cylinder have been considered. The results show that by increasing distance from the center of stripper cylinder the air flow velocity and dynamic pressure were decreasing. Jiang (2003) also resulted that by getting away from the center of stripper cylinder the air flow velocity and dynamic pressure were decreasing which are compatible with the results of this research. Also, but replacing the distance from the center of stripper cylinder and air flow velocity in equation (4) the amount of constant c was decreasing gradually.

Maximum and minimum of constant c were respectively equal to 2.349 and 1.537. the average of constant c was equal to 2.031. Jiang (2003) computed this constant equal to 2.796. he, also, attained only one constant which was located at internal area of finger holes (the space between finger holes) (Jiang, 2003). In this experiment dynamic pressure was measured in different points of the front of the head in which each one had a constant c. The constant c measured by Jiang (2003) was 1.38 times more than that for this experiment. The reason for this furthering can be due to further rotational velocity of stripper cylinder.

In this section the results related to the points on horizontal line aligned with the center of stripper cylinder have been considered. Here like the previous one for each point with dynamic pressure, the constant c can be computed by putting in equation (4). the average of constant c was equal to 2.175. Maximum and minimum constant c was respectively equal to 2.400 and 1.573. The amount attained by Jiang (2003) was equal to 1.29 times more that attained constant in this experiment. For this reason that dynamic pressure was measured in different points in this experiment, while Jiang measured it in one point and only in internal areas of finger holes which its amount in internal area was more than external one because of higher air flow velocity and lower distance from the center of stripper cylinder (Jiang, 2003). In this experiment, different constant c were computed in external points (from the tip of finger hole to the cape) and finally one constant c was reported by averaging all figures.

At last, the results related to 1 cm upper than crossing horizontal line from the center of stripper cylinder have been considered. Here, the results show that by getting away from the center of stripper cylinder the air flow velocity and dynamic pressure were decreasing. In this experiment, different constant c was computed in different points which its average was 2.471. The number that Jiang (2003) attained was 1.13 times higher than the average of attained constant in this experiment. Maximum and minimum constant c was respectively equal to 2.593 and 2.225. Jiang (2003) resulted that by getting away from the center of stripper cylinder the air flow velocity and dynamic pressure were decreasing which are compatible with the results of this research.

Klopfenstein Jr (1998) attained air flow velocity 3.69, 5.84 and 8.02 m/ s for 0.008, 0.02 and 0.38 Kilo Pascal pressures which are compatible with the results of this research. Also, Tado (2014) attained air flow velocity 650, 750, 850 and 950 rounds in rotational velocities which are in limitation of 6 to 13 m/ s that are compatible with the current research's results.

According to the results it can be found that whatever the distance from ground was increasing and getting near to the cape the velocity of air flow was decreased. This can be due to this fact that the flow in points near to the cape has less velocity than the points away from cape because of attrition between wall and air.

Conclusion

Regarding to the resulted findings for static, dynamic and total pressures it can be found that maximum and minimum negative static pressures were respectively -8.3 and -1.5 mm gasoline. Maximum and minimum dynamic pressures were respectively 5.1 and 1 mm gasoline. And finally maximum and minimum total pressures were respectively -3.5 and -0.4 mm gasoline.

The results of this experiment show that there are different constants because of different distances from the center of stripper cylinder and different velocities of air flow for head stripper, while Jiang (2003) reported only one constant for one point in internal area of finger holes. Also, regarding to the results in can be found that maximum constant c was related to B_2 which is equal to 2.593 and minimum constant was related to B_1 equal to 1.537. Regarding to the results of this research it can be found that whatever distance from ground were increasing and getting near to the cape, the air flow velocity would be increasing.

Also, whatever distance from the center of stripper cylinder getting away the velocity of air flow was decreasing. Maximum and minimum air flow velocity measured in this experiment were respectively equal to 8.264 and 3.659 m/ s. the maximum one was related to internal finger holes areas and the minimum one was related to external finger holes areas.

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