Investigation of the movement of a tomato plant during the transition between transport devices

Ivan Mortev
Institute of Soil Science, Agrotechnology and Plant Protection, Sofia – 1331

ABSTRACT :*Mechanized harvesting of tomatoes should be carried out with minimal damage. This is achieved by knowing the processes. The movement of a tomato plant in the period of transition between conveying devices has been studied. Dependencies determining the length of free movement and the rates of fall on the fruit separator are derived, which are essential for determining the kinematic regime and preventing damage to the fruit.*

KEY WORDS: *TOMATO MECHANICAL HARVESTING, TOMATO PLANT MOTION, PARAMETER OF TOMATO PLANT MOTION.*

INTRODUCTION

Tomatoes are a major vegetable crop subject to many research [Arazuri 2007, Zhang 2018, Mitova, 2018, Dimitrov, 2021]. In the case of mechanized harvesting of tomatoes, the plants are pruned from the soil surface and then go through various manipulations [Mortev, 2005]. All these manipulations must be performed with minimal losses and this is obtained with the correct choice of kinematic mode of the working devices. It is very common for them to move from one conveyor to another. In this regard, the aim of the present study is to determine the parameters of movement of a tomato plant during the transition period between the feed conveyor and the fruit separator, during mechanized harvesting.

ESSENCE OF THE STUDY

Previous studies [Mortev, 2008] have shown:

speed change laws

$$\dot{x}_{\Pi} = V_H \cos\alpha;$$

$$\dot{y}_{\Pi} = -gt + V_H \sin\alpha. \qquad 1$$

speed change laws

$$x_{\Pi} = (V_H \cos\alpha)t;$$

$$y_{\Pi} = -g\frac{t^2}{2} + (V_H \sin\alpha)t + H_3. \qquad 2$$

and the equation of motion of the tomato plant

$$y = -g\frac{x^2}{2V_H^2\cos^2\alpha} + x tg\alpha + H_3 \qquad 3$$

Where g is the earth's acceleration;

$\alpha -$ angle of inclination of the conveyor to the horizontal plane;

$H_3 -$ the height from the upper surface of the feed conveyor to the upper surface of the receiving conveyor;

$V_H -$initial speed at which the mass leaves the inclined conveyor and passes to the fruit separator. It is in fact the absolute speed of mass when it is on an inclined conveyor.

Equation (3) is the equation of the parabola. Through it some geometric and kinematic researches can be made. In this case, the length of the flight to the fruit separator is sought. For this purpose, the designations are entered (Fig. 1):

L is the maximum flight length provided that the plant does not meet the fruit-separating chains and continues its movement to the axis of the absolute coordinate system

$L_H -$ the actual flight length of the plant from the feed conveyor to the fruit separator, measured from the point of intersection of the vertical plane at the point of separation of the plant from the feed conveyor and the plane of the fruit separator, to the point of falling of the plant on the fruit separator. In other words, this is the initial position in which the plant falls to be treated.

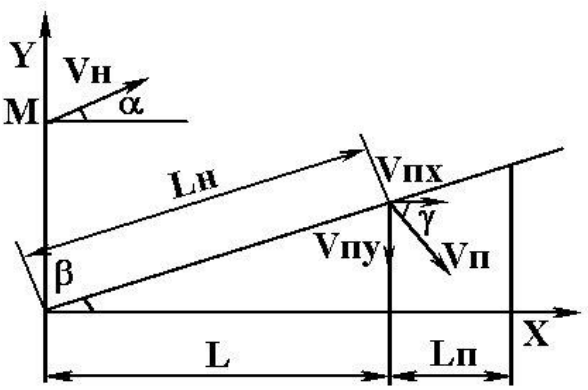

Fig.1. Indications of the flight parameters and the tomato plant from the inclined conveyor to the fruit separator.

The position in which the plant is on the axis of the coordinate system is sought. From this one can mathematically set the conditions:

$$y = 0;\; x = L. \qquad 4$$

Substituting conditions (4) in equation (3) gives:

$$-g\frac{L^2}{2V_H^2\cos^2\alpha} + Ltg\alpha + H_3 = 0 \qquad 5$$

Equation (5) is quadratic [Danchev S., Rashkova I., 1994.] therefore has two roots:

$$L_{1,2} = \frac{-tg\alpha \pm \sqrt{tg^2\alpha - 4\left(-g/2V_H^2\cos^2\alpha\right)H_3}}{2\left(-g/2V_H^2\cos^2\alpha\right)}. \qquad 6$$

After conversion:

$$L_{1,2} = \frac{-tg\alpha \pm \sqrt{tg^2\alpha + 2gH_3/V_H^2\cos^2\alpha}}{g/V_H^2\cos^2\alpha} \qquad 7$$

From equation (7) it is clear that the second root is negative, which makes no practical sense. The positive root of the equation remains:

$$L = \frac{-tg\alpha + \sqrt{tg^2\alpha + 2gH_3/V_H^2\cos^2\alpha}}{g/V_H^2\cos^2\alpha} \qquad 8$$

This is only the imaginary length of the flight that the plant would perform, provided that the fruit separator is not in motion and is not inclined at any angle to the horizontal plane (Fig. 1).

To reflect the adjustments, additional notations are introduced:

$t_{\Pi Y}$ is the conditional time during which the tomato plant is in flight from the feed conveyor to the axis x of the absolute coordinate system;

$t_{\Pi P} -$ the actual time during which the tomato plant is in flight from the feed conveyor to the plane of the fruit separator;

$L_{\Pi} -$ the distance traveled by the separator and the entire machinery during the flight;

$L_y -$ the conditional path traveled by the plant over time $t_{\Pi Y}$.

When the plant is in a state of weightlessness or in other words in the air, the fruit-separating conveyor together with the whole machine moves gradually and follows a path determined by the formula:

$$L_{П} = V_{М} t_{ПУ}. \qquad 9$$

The conditional flight time can be determined by the end conditions in the selected coordinate system:

$$x = L; \; y = 0. \qquad 10$$

Substitute the conditions (10) in the system (2) and obtain:

$$\begin{aligned} &L = (V_{Н} \cos\alpha) t_{ПУ}; \\ &-g\frac{t_{ПУ}^{2}}{2} + (V_{Н} \sin\alpha) t_{ПУ} + H_{3} = 0 \end{aligned} \qquad . \qquad 11$$

It is easier to determine $t_{ПУ}$ by the first equation:

$$t_{ПУ} = \frac{L}{V_{Н} \cos\alpha} \qquad 12$$

After placing (12) in (11) the distance traveled by the machine is determined:

$$L_{П} = \frac{V_{М} L}{V_{Н} \cos\alpha} \qquad 13$$

The total value of the coordinate x will be equal to the conditional path:

$$L_{У} = L + L_{П} \qquad 14$$

Substitute equation (13) in (14) and obtain:

$$L_{У} = L + \frac{V_{М} L}{V_{Н} \cos\alpha}. \qquad 15$$

After conversion of (15) by exporting L outside the brackets is obtained (16)

$$L_{У} = L\left(1 + \frac{V_{М}}{V_{Н} \cos\alpha}\right) \qquad 16$$

From the conditional length of the flight it is necessary to determine the actual. Once the precondition for the movement of the fruit-separating plane has been taken into account, it is necessary to take into account the angle of inclination of the same plane. For this purpose, a trigonometric function will be used (Fig. 1), from which it follows:

$$L_{Н} = \frac{L_{У}}{\cos\beta} \qquad 17$$

Substitute equation (16) in (17) and obtain:

$$L_{Н} = \frac{L}{\cos\beta}\left(1 + \frac{V_{М}}{V_{Н} \cos\alpha}\right) \qquad 18$$

Substitute equation (8) in (18) and obtain the final expression (19) for the length of the fruit separator, which is not used for its intended purpose, as the plant is in flight above it before it is located on the fruit-dividing plane for cultivation.

$$L_{Н} = \frac{-tg\alpha + \sqrt{tg^{2}\alpha + 2gH_{3}/V_{Н}^{2}\cos^{2}\alpha}}{g\cos\beta / V_{Н}^{2}\cos^{2}\alpha}\left(1 + \frac{V_{М}}{V_{Н} \cos\alpha}\right) \qquad 19$$

After conversion, formula (19) takes the form:

$$L_{Н} = \frac{-V_{Н}\sin\alpha + \sqrt{V_{Н}^{2}\sin^{2}\alpha + 2gH_{3}}}{g\cos\beta}(V_{Н}\cos\alpha + V_{М}) \qquad 20$$

The flight length determined by formula (20) provides information on the location of two adjacent conveyors.

Determination of the parameters of movement of tomato plants at the time of falling on the fruit-separating conveyor.

Once the dependencies related to the condition of the tomato plants have been determined before they are processed on the fruit separator, the main operation should be essentially moved on. It could not be said that this moment of fall is the beginning of the detachment of the fruit from the stems due to the fact that even in the field some varieties with a weaker connection between the fruit and the fruit bearing begin to crumble. This depends not only on the variety, but also on many other features related to agricultural techniques and cultivation technology. In addition, fruits can be torn off when the plants are pruned, picked up by the inclined conveyor, and also by the action of other elements of the tomato harvester. But basically the process of fruit separation takes place on the designated node. For this reason, fruiting is considered from the moment the plant falls on it. Dependencies for determining the rates of fall have been derived to be taken into account when determining the kinematic regime of the fruit separator. The aim is to link the kinematic regime with some of the physical and mechanical properties of tomato plants and fruits in order to avoid damage and loss of production.

Determining the rate of fall of the plant on the surface of the fruit separator.

When the plant falls into the plant mass, impulses appear, which are able to tear off some fruits. To determine this speed, the notations are entered:

$V_{XП}$ is the projection along the axis x of the speed of the plant at the time of falling on the fruit separator.

$V_{YП} -$ the projection along the axis y of the speed of the plant at the time of falling on the fruit separator.

$\gamma -$ the angle of absolute velocity of the plant at the time of its fall on the fruit separator relative to the horizontal plane.

It is based on the laws of variation of speed, from the system (1):

From here the horizontal component of the speed is known, but to find the vertical component it takes time to fly $t_{ПР}$. To determine it is based on the final conditions:

$$x = L_{Н}\cos\beta; \qquad y = L_{Н}\sin\beta. \qquad 21$$

Substitute the conditions (21) in the law of motion system (2) and obtain:

$$\begin{aligned} &L_{Н}\cos\beta = (V_{Н}\cos\alpha) t_{ПР}; \\ &t_{ПР} = -g\frac{t_{ПР}^{2}}{2} + (V_{Н}\sin\alpha) t_{ПР} + H_{3}. \end{aligned}$$

22

It would be easier to find $t_{ПР}$ from the first equation:

$$t_{ПР} = \frac{L_{Н}\cos\beta}{V_{Н}\cos\alpha}$$

23

Substitute (23) in (1) the components of the velocities at the moment of fall are obtained:

$$\begin{aligned} &V_{XП} = V_{Н}\cos\alpha; \\ &V_{YП} = -g\frac{L_{Н}\cos\beta}{V_{Н}\cos\alpha} + V_{Н}\sin\alpha. \end{aligned}$$

24

From the components thus obtained, the absolute speed of fall can be found $V_{АП}$:

$$V_{\text{АП}} = \sqrt{V_{\text{ХП}}^2 + V_{\text{УП}}^2} = \sqrt{V_H^2 \cos^2\alpha + \left(-g\,\frac{L_H \cos\beta}{V_H \cos\alpha} + V_H \sin\alpha\right)^2} \qquad 25$$

The absolute speed of fall is an important characteristic that determines the strength of the impact of the elements of the conveyor on the fruit and from there determines the damage to the fruit and the quality of production.

The angle γ between the speed of fall $V_{\text{АП}}$ and the positive direction of the abscissa is determined by a trigonometric function:

$$\gamma = arctg\,\frac{V_{\text{УП}}}{V_{\text{ХП}}} = arctg\,\frac{-g\,\frac{L_H \cos\beta}{V_H \cos\alpha} + V_H \sin\alpha}{V_H \cos\alpha} \qquad 26$$

After bringing under a common denominator and reductions in the trigonometric function is obtained for the angle between the absolute velocity of the plant at the time of its fall on the fruit separator with the horizontal plane (27)

$$\gamma = arctg\left(-gL_H \cos\beta + V_H^2 \sin\alpha \cos\alpha\right) \qquad 27$$

The derived dependences make it possible to establish the characteristics of the movement of tomato plants at the time of submission for fruit separation. The characteristics of the movement can be used to determine the kinematic regimes of the mechanisms in which the damage will be minimized.

CONCLUSIONS

1. In the transition between the feed conveyor and the fruit separator, the tomato plants are in free movement with a flight length determined by formula 20. This provides information on how to place two adjacent conveyors and determine the technological lengths of the conveyors.
2. The absolute speed of fall of the fruit formula 25 is an important characteristic that determines the strength of the impact of the elements of the conveyor on the fruit and from there determines the damage to the fruit and the quality of production.
3. The derived dependencies make it possible to establish the characteristics of the movement of tomato plants at the time of submission for fruit separation.
4. The characteristics of the movement may be used to determine the kinematic regimes of the mechanisms in which damage to the fruit will not occur or will be minimized.

LITERATURE

1. Dimitrov., Em., Petrova, V., 2021. Influence of the irrigation regime on the yield of determinant tomato variety "Nikolina" F1 in Polish production. Proceedings "Ecology and Agrotechnology - Basic Science and Practical Implementation", pp.160-166, ISSN 2683-0663.Bg
2. Mitova, I., Vessela Petrova - Branicheva, Emil Dimitrov, Influence of fertigation on some factors determining the quality of tomatoes variety "Nikolina F1", Soil agrochemistry and ecology, 52, 3/2018 Bg
3. Danchev S., Rashkova I., Handbook of Elementary Mathematics, Sofia 1994. Bg
4. Mortev, IE, Mechanized harvesting of tomatoes, scientific journal of agricultural and forestry science, issue. 2-3, 2005, p114. Bg
5. Mortev, Iv. E., Movement of a tomato plant before submission for fruit separation in a tomato harvester, Agricultural machinery, no. 1, 2008. ISSN: 0037-1718, Sofia, pp. 9-13. Bg
6. Pisarev, A., Mechanical vibrations, Sofia 1985. Bg
7. Pisarev, AM, Paraskov CN, Bachvarov SN, Course in Theoretical Mechanics Part II Dynamics, Sofia 1975. Bg
8. Arazuri, S., C.Jarén, J.I.Arana,J.J.Pérez de Ciriza, Influence of mechanical harvest on the physical properties of processing tomato (Lycopersicon esculentum Mill.) Journal of Food Engineering, Volume 80, Issue 1, May 2007, Pages 190-198
9. Karakolev et al., Tomato picking machine, United States Patent No 4,727,714 Int. Cl. A01D 45/00.
10. Zhang, Baohua, JunZhou, YimengMeng, NaZhang, BaoxingGu, Zhenghong, YanSunusi, IdrisIdris, Comparative study of mechanical damage caused by a two-finger tomato gripper with different robotic grasping patterns for harvesting robots, Biosystems Engineering, Volume 171, July 2018, Pages 245-257