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Kinematic Analysis of the Slider-Crank Mechanism in Automated Vibration Sausage Feeder

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Abstract: The sausage feeder takes an important role in automated packaging systems. This paper presents the theoretical calculation, kinematic and dynamic characteristics of an automated sausage feeder using vibration technique and crank mechanism. The kinematics formulation of the crank mechanism is done using vector loop method and cosine rule are applied to describe the position of the mechanisms. Following the velocity of crank and connecting rod is performed by differentiating the position in terms of the crank angle and connecting rod angle respectively. The acceleration equation with brief form is derived from the velocity in the same principle. Based on the kinematics, the equations of motion of crank mechanism components are formulated for each moving link and platform then, all motion parameters of each component about its crank angle are readily derived. Furthermore the 2D model is provided by using 2D Auto CAD software in order to visualize the system and mathematical algorithm solved by using software MATLAB. The forces of sausage acting on the crank mechanism and system kinematic of sausage feeder from the crank to the sausage are also determined based on the angles of the crank and connecting rod. The feeder has been fabricated, installed in the real production line.

Keywords: *Kinematics, Cranks Mechanism, Sausage Feeder, Automated Packaging System, Vibration Mechanism*

Introduction:

In the sausage processing enterprises, sausage processing packaging has been automated in most companies, but issuance of sausage on packaging machines is still done mostly by hand, by automated equipment costs the entire system of foreign chains is very high, and requires extensive grounds. At companies in Vietnam for granting sausage packaging machine to perform manually. This paper presents the theoretical calculation, kinematic and dynamic characteristics of an automated sausage feeder using vibration technique and crank mechanism. The feeder is the one important component of automation sausage feeder chain.

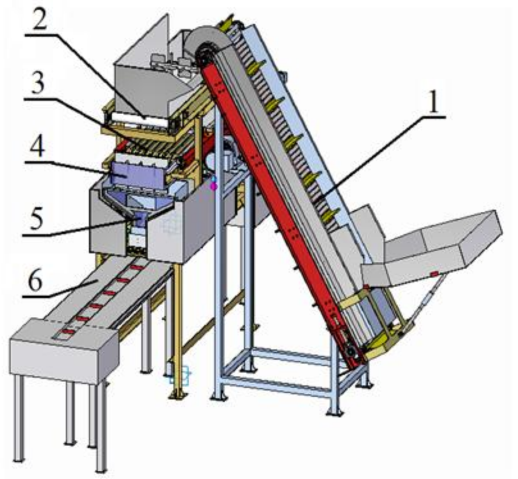


Figure 1: Structural 3D of automation sausage feeder chain.

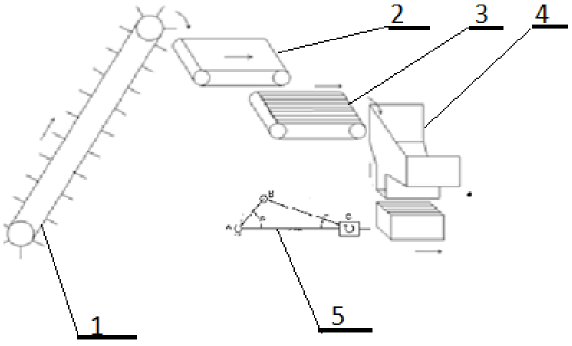


Figure 2: Sausages movement in the chain.

Automation sausage feeder chain:

Automation sausage feeder chain is made as shown in fig 1, and sausages movement shown in fig 2.

Chain structure includes the following major components: Lifting conveyor 1; Intermediate feed conveyor 2; Distribution conveyor 3; Inspired hopper 4; Vibration sausage feeder 5 (including crankshaft mechanism and vibration hopper); Packaging conveyor 6.

Chain is operating as follows:

Workers poured sausages into the hopper of the lifting conveyor 1, conveyor lift sausage to intermediate conveyor 2, intermediate conveyor move sausage down distribution conveyor 3, sausages through distribution conveyor line, go to the hopper 4. From the hopper, sausages fall to the vibration feeder, the crank mechanism behind the feeder push sausage on the feeder to packaging conveyor 6.

Automated sausage feeder with crank mechanism: Vibration automated sausage feeder is a most important part in the system. Structure shown in Figure 3. It includes hopper containing sausages, hopper vibration mechanism and slider crank mechanism.

Need to understand the characteristics and dynamics kinetics of the automated sausage feeder with crank mechanism to achieve the optimal parameters.

Crank mechanism comprises of piston, connecting rod and crank shaft. In formulation of the crank mechanism such as piston kinematics and connecting rod kinematics of already existing sausage feeder need parameters, the given parameters are stated in table 1

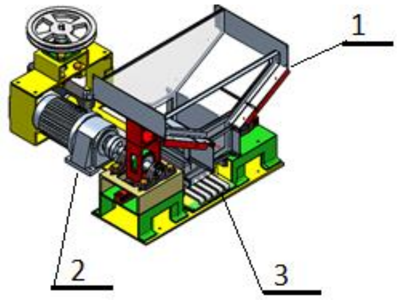


Figure 3. Vibration automated sausage feeder:1- hopper containing sausages; 2- vibration mechanism; 3- slider crank mechanism.

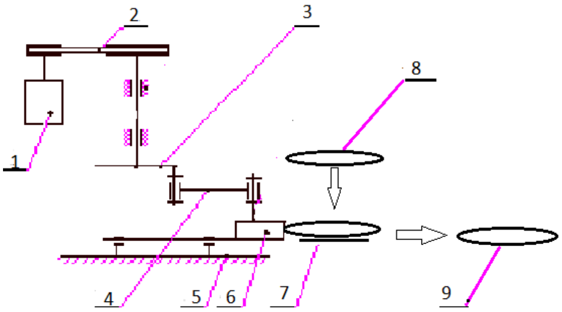


Figure 4. Diagram principle of crank mechanism with sausage: 1- engine: 2: transmission belt; 3- crankshaft; 4-rod; 5- slider; 6-piston of crank mechanism; 7-sausage on the top piston; 8 – sausage go to piston; 9 - sausage leave the piston.

Table1. Parameter of feeder with slider crank mechanism

Parameters	Unit	Values
Connecting rod length	mm	300
Crank radius	mm	100
Piston diameter	mm	20
Stroke	mm	200
Speed of Crank	rpm	140
Sausage weight on feeder	kg	5

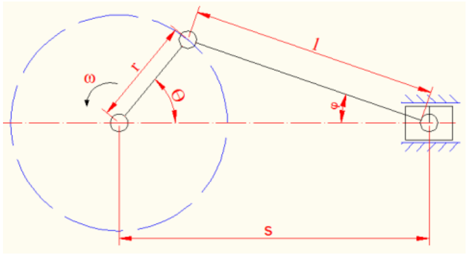


Figure 5. Slider crankshaft structure

Kinematic analysis of the slider- mechanism:

Kinematic Modeling of Piston Motion:

Piston is one of the main parts in the system and its purpose is to transfer force from engine to the crankshaft via a connecting rod.

4.1.1. Piston Pin Position.

The displacement of the piston with respect to crank angle can be derived from simple trigonometry. This can then be differentiated to yield velocity and acceleration of the piston. The expressions obtained tend to be very complicated and can be simplified into the expression containing only first order (once per revolution), second order (twice per revolution), and a negligible fourth order.

The piston pin position is the position from crank center to the piston pin center in fig. 5 and can be formulated from cosine rule of the trigonometry

$$s = l\cos\phi + r\sin\theta \qquad (1)$$

$$l\sin\phi = r\sin\theta$$

$$\sin\phi = \frac{r\sin\theta}{l}, let\ \frac{r}{l} = \lambda, therefore \qquad (2)$$

The piston position as follows

$$s = r\cos\theta + l\sqrt{1-\lambda^2\sin^2\theta} \qquad (3)$$

4.1.2 Piston Pin Velocity.

Piston pin velocity is the upward velocity from crank center along cylinder bore center and can be calculated as the first derivative of equation 3 with respect to angle theta $\theta = \omega t$

$v = \frac{ds}{d\theta}$ – piston pin velocity.

To express the velocity with respect to time

$$v = \frac{ds}{d\theta}\omega$$

We have

$$v = -r\omega\sin(\omega t) - \frac{2l\lambda^2\omega\sin(\omega t)\cos(\omega t)}{\sqrt{1-\lambda^2\sin^2(\omega t)}} \qquad (4)$$

4.1.3. Piston Pin Acceleration:

Piston pin acceleration is the upward acceleration from crank center along cylinder bore center and can be calculated as the second derivative of equation 3 with respect to angle theta.

To express the acceleration with respect to time can be express as

$$a = \frac{d^2 s}{d\theta^2}\omega^2 \qquad (5)$$

Then

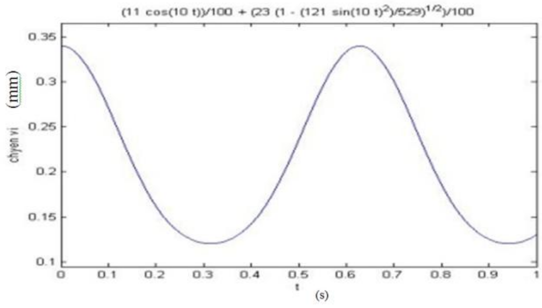
$$a = -r\omega^2\cos(\omega t) - \frac{r^2(\omega^2\sin^2(\omega t) - \cos^2(\omega t))}{\sqrt{1-\lambda^2\sin^2(\omega t)}} - \frac{l(\lambda^2)^2\sin^2(2\omega t)}{4\sqrt{1-\lambda^2\sin^2(\omega t)}} \qquad (6)$$

Survey process of restructuring activities pushed sausages level.

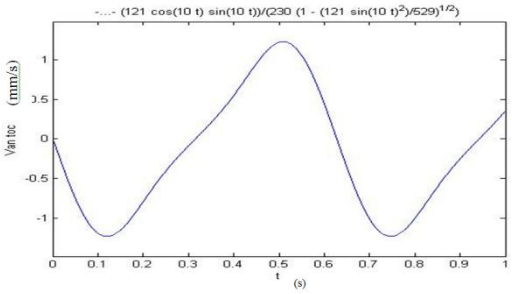
The purpose of the structure is pushed sausage levels are sure to provide sufficient quantities of sausages and is part of the conveyor belt to automatic packaging machine, the speed level is adjusted by the servo motor speed sync with speed packing. The feeding is done by structural push rod to the crankshaft. Chart principle diagram of the structure calculation pushing presented in figure 4, and figure 5. The results received are presented in the table below.

r=110 mm; l=230 mm		
Crank rotation	ω=10 rad/s.	ω= 12 rad/s
Max Piston Pin Velocity	1250mm/s	1500 mm/s
Piston Pin Acceleration in forward	8000 mm/s^2	1200 mm/ s^2
Piston Pin Acceleration in return	1600 mm/ s^2	24000 mm/ s^2

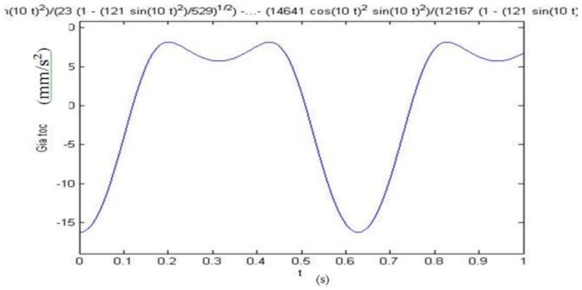
Piston kinematic



Piston Pin Position.

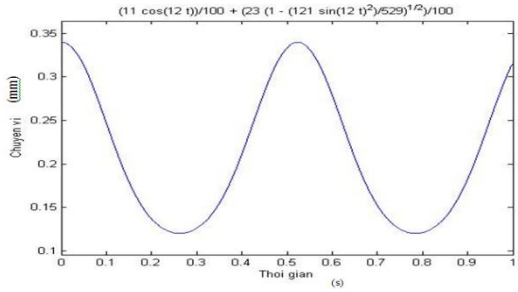


Piston Pin Velocity

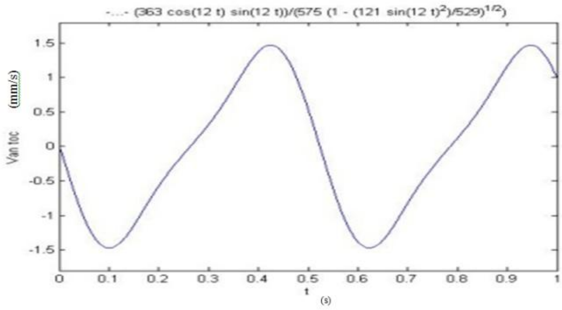


Piston Pin Acceleration

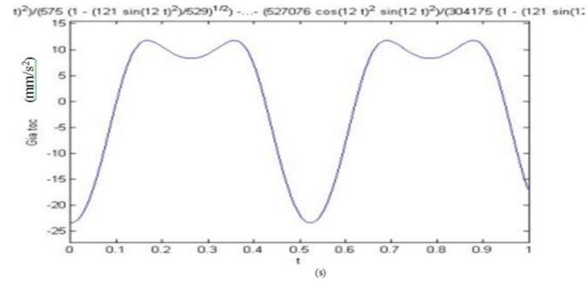
Figure 5. displacement, velocity and acceleration of the piston when the frequency ω = 10 rad / sec



Piston Pin Position.



Piston Pin Velocity



Piston Pin Acceleration

Figure 6. The displacement, velocity and acceleration of the piston when the frequency ω = 12 rad / sec

Kinematics Modeling of Connecting Rod Motion:

The connecting rod is a major link inside of a engine. It connects the piston to the crankshaft and is responsible for transferring power from the piston to the crankshaft and sending it to the transmission. Connecting rod as one component of the crank mechanism it is crucial to formulate the kinematics of connecting rod

4.2.1. Instantaneous Velocity Connecting Rod

$$v_{con} = \frac{d\phi}{dt} = \frac{d\phi}{d\theta}\frac{d\theta}{dt} \qquad (7)$$

where v_{con} – instantaneous velocity of connecting rod. Differentiate equation (2) with respect to angle theta

$$\frac{d\phi}{d\theta} = \lambda\frac{\cos\theta}{\cos\phi}, \cos\phi \approx 1, \qquad (8)$$

$$v_{con} = \omega\lambda\cos\theta \qquad (9)$$

4.2.2. Instantaneous Acceleration. Connecting Rod

$$a_{con} = \frac{dv_{con}}{dt} = \frac{dv_{con}}{d\theta}\frac{d\theta}{dt},$$

Differentiating equation 9 with respect to time

$$a_{con} = -\omega^2\lambda\sin\theta \qquad (10)$$

Kinematic analysis of the slider-crank mechanism and sausage:

Kinematics Modeling of Sausage motion

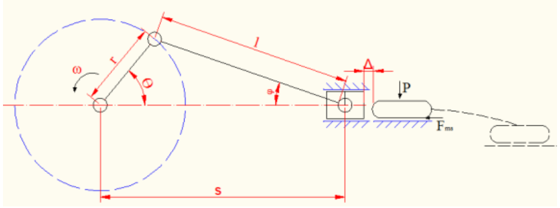


Figure 7. The relationship between the structural position of the crankshaft connecting rod and sausage

The relationship between the position of the crankshaft connecting rod structure and sausage is shown in Figure 7. At the back of the piston, the top piston will leave from the sausage, the forward, at first piston not touching to sausages, the next the piston will compressed sausage in elastic limit, then push sausage up to the sausage packaging. The forces on the sausage are the weight of sausage above (P) and the friction with platform (Fms). Model of the impact of the piston on sausages is presented in Figure 8. From equation (3), building on the mat chart lab simulation, kinematic parameters of crankshaft systems - sausage will be determined.

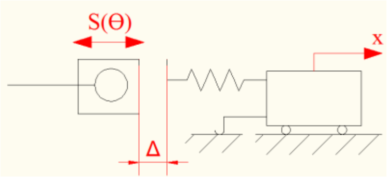


Figure 8. Model of the impact of the piston on sausages

5.2 Kinematic parameters of the slider-crank mechanism and sausage:

Based on the model of the impact of the piston into the sausage (Figure 8), matlab - simulink diagram was built to determine the kinetic parameters of the piston and sausages in Figure 9. From then determine the relationship between the parameters of a rotation with the distance between the piston and the original given sausages. Figure 10 is a graph of relationships piston displacement - velocity sausage, and figure 11 is a graph relationships piston displacement-displacement sausag

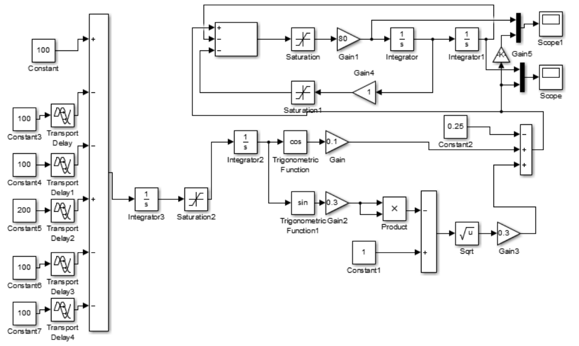
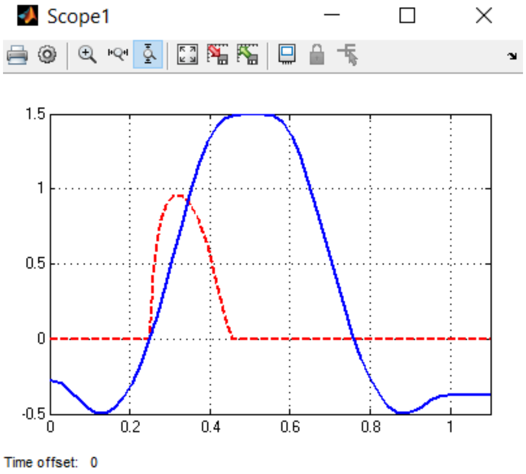


Figure 9. matlab - simulink diagram to determine the kinetic parameters of the piston and sausages.



╌╌╌: sausage velocity;

─── piston displacement.

Figure 10. Graph relationships piston displacement - sausage velocity

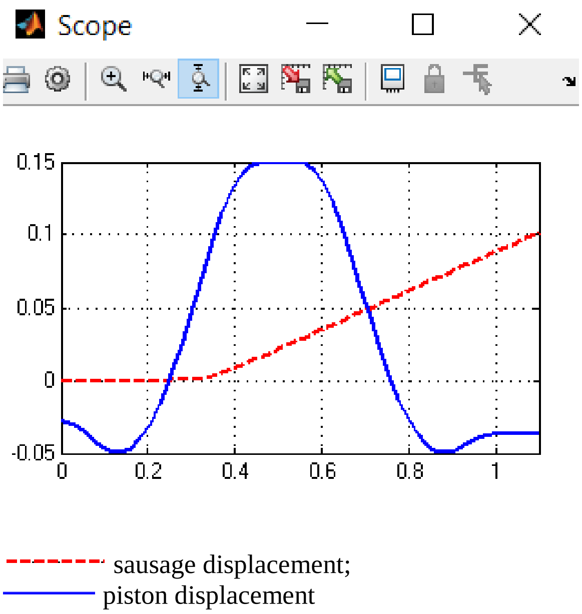


Figure 11 graphs relationships piston displacement - sausage displacement

Results and Discussion:

The conclusions are drawn as follows:

1. The modeling methodology for kinematics of crank mechanism has been derived systematically by considering the geometric configuration of the crank mechanism of the automated feeder system. The forces of the sausage applied to the crank mechanism also properly analysed

2. Through consideration of the crank mechanism the position, velocity and acceleration is properly formulated.

3. From the chart matlab - simulink we can survey system kinematic of sausage feeder from the crank to the sausage, identify the impact of the crankshaft speed, the relative position of sausages, speed of sausage during the working piston.

Conclusion:

Through computational and experimental shows automation sausage feeder chain were operating in sync with automatic packaging machines, frequency pushing of the feeder always adjusted in line with the frequency packaging machines, working frequency of crankshaft follow packaging speed. The parameters of sausage feeder calculated to ensure the consistent with sausage packaging requirements

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