

**KINEMATIC OF THE SAUSAGE-FEEDER WITH CRANK MECHANISM****ĐỘNG HỌC CỦA MÁY CẤP XÚC XÍCH SỬ DỤNG  
TRỤC KHUYU THANH TRUYỀN****Nguyen Hong Ngan***Ho Chi Minh City University of Technology, VNU – HCM, Việt nam*

Received 10/10/2016, Peer reviewed 20/10/2016, Accepted for publication 10/11/2016

**ABSTRACT**

*The sausage feeder takes an important role in automatic packaging systems. This paper presents the theoretical calculation, kinematic characteristics of an automatic 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. Velocity of crank and connecting rod is performed by differentiating the position in terms of following crank angle and connecting rod angle respectively. The acceleration equation is derived from the velocity in the same principle. Based on the kinematics, equations of the crank mechanism motion, components are formulated for each moving link and platform then, all motion parameters of each component about its crank angle are readily derived and the interaction of the sausage with mechanism was built. Furthermore, the 2D models are provided by using 2D Auto CAD software to visualize the system and mathematical algorithm solved by using software MATLAB-SIMULINK.*

**Keywords:** *kinematics; cranks mechanism; sausage feeder; automatic packaging system; vibration mechanism.*

**TÓM TẮT**

*Máy cấp xúc xích có vai trò quan trọng trong dây chuyền đóng gói tự động. Bài báo trình bày các tính toán lý thuyết, đặc điểm động học của một máy cấp xúc xích tự động sử dụng kỹ thuật rung động và cơ cấu tay quay con trượt. Động học của cơ cấu tay quay con trượt được thực hiện bằng phương pháp lặp vector và quy tắc cosin để mô tả vị trí của cơ cấu. Vận tốc của tay quay và thanh truyền được xác định bằng đạo hàm vị trí theo góc quay của trục khuỷu và thanh truyền tương ứng. Phương trình gia tốc cũng xác định nhờ đạo hàm các vận tốc theo cùng một nguyên tắc. Dựa trên các phương trình động học của chuyển động, các thành phần cơ cấu tay quay con trượt, các thông số chuyển động của mỗi thành phần theo góc quay, sự tương tác xúc xích với cơ cấu đã được xây dựng. Các mô hình 2D đã được cung cấp bằng cách sử dụng các phần mềm 2D Auto CAD, các thuật toán toán học được giải quyết bằng cách sử dụng phần mềm MATLAB - SIMULINK.*

**Từ khóa:** *động học; tay quay con trượt; máy cấp xúc xích; hệ thống đóng gói tự động; cơ cấu rung.*

**1. INTRODUCTION**

Sausage processing packaging has been automated in most companies. However,

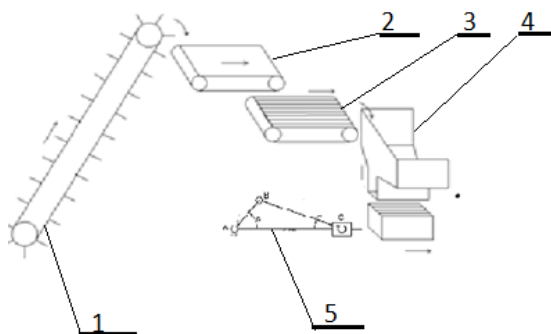
sausage feeding for packaging machines is still done mostly by hand. The automated machine is very costly. This paper presents the theoretical calculation, kinematic and

dynamic characteristics of an automatic sausage feeder using vibration technique and crank mechanism.

## 2. AUTOMATIC SAUSAGE FEEDER.

Sausage feeder system in the chain (Fig.1) is operating as follows:

Workers poured sausages into the hopper on the lifting conveyor 1, conveyor lift sausages to intermediate conveyor 2, intermediate conveyor move sausages down distribution conveyor 3, sausages through distribution conveyor line, go to the hopper 4. From the hopper, sausages fall down to vibration feeder 5, the crank mechanism behind the feeder push sausage on the feeder to packaging conveyor.



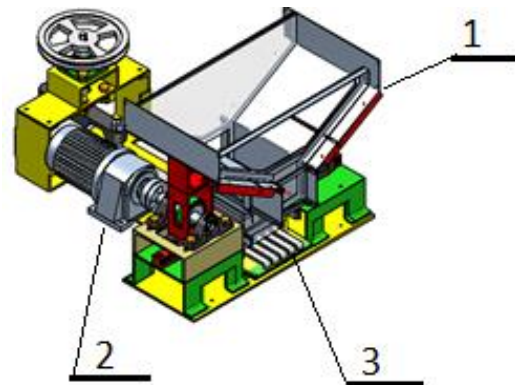
**Figure 1.** Sausages feeder system in the chain: 1- conveyor; 2- intermediate conveyor; 3- distribution conveyor; 4- hopper; 5- vibration feeder

## 3. AUTOMATIC SAUSAGE FEEDER WITH CRANK MECHANISM

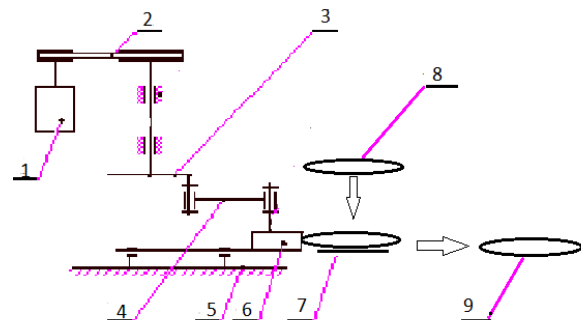
Vibrate automatic sausage feeder (figure 2) is the most important part in the system and principal diagram of the crank mechanism with sausage is shown in Figure 3. It includes hopper containing sausages, hopper vibration mechanism and slider crank mechanism.

Crank mechanism comprises of piston, connecting rod and crankshaft. In formulation of the crank mechanism such as: piston kinematics and connecting rod

kinematics of a sausage feeder, the given parameters are stated in table 1.



**Figure 2.** Vibrate automatic sausage feeder: 1- sausage-hoppers; 2- vibrate mechanism; 3- sliding crank



**Figure 3.** Principal diagram of the crank mechanism with sausage: 1- engine; 2- transmission belt; 3- crankshaft; 4- Connecting rod; 5- slider; 6- piston; 7- sausage on the top piston; 8- sausage go in to piston; 9- sausage leave from the piston.

**Table 1.** Parameter of feeder with sliding 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
Weight of a Sausage piece	g	35

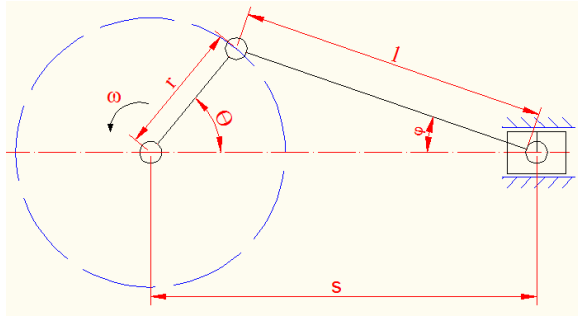


Figure 4. Slider crankshaft structure

## 4. KINEMATIC ANALYSIS OF THE SLIDER MECHANISM.

### 4.1 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 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 maybe complicated or simplified depend on: first, revolution; second, twice of revolution, and negligible fourth order.

A distance from crankshaft center to piston pin in fig. 4 is formulated by expression: The piston position (is a distance from crankshaft center to piston pin) in fig. 4 can be formulated as:

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

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

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

The piston position as follows

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

In there (figure 4):

l- a connectingrod length;

θ- crankshaft angle;

r- a crank length;

ω- angle crankshaft acceleration.

### 4.1.2 Piston Velocity

Piston 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  $\theta = \omega t$

$$v = \frac{ds}{d\theta} - \text{piston velocity.}$$

To express the velocity with respect to time

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

We have

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

### 4.1.3. Piston Acceleration.

Piston acceleration is the upward acceleration from crankshaft center along to cylinder bore center and can be calculated as:

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

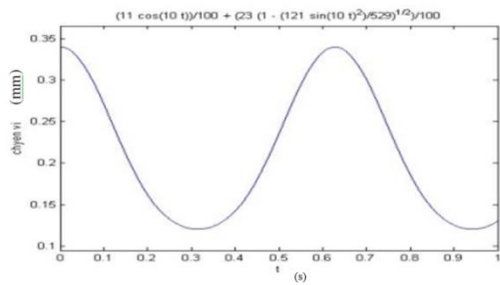
Then

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

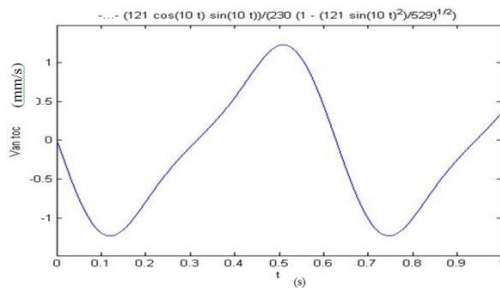
Table2. The feeding results with crank mechanism

r =110 mm; l=230 mm		
Crankshaftangle	ω=10	Ω = 12
Acceleration	rad/s.	rad/s
Max Piston Velocity	1250	1500
	mm/s	mm/s
Piston Accelerationin forward	8000	1200
	mm/s <sup>2</sup>	mm/s <sup>2</sup>
Piston Accelerationin return	1600	24000
	mm/s <sup>2</sup>	mm/s <sup>2</sup>

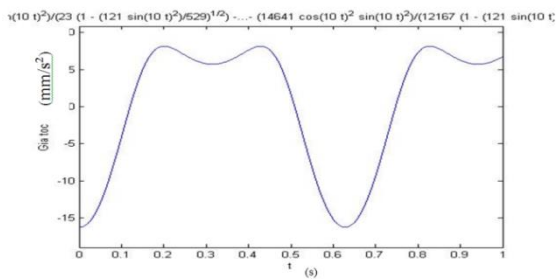
The purpose of the structure is to provide sufficient quantities of sausages. The speeds level is adjusted by the servo motor speed sync with speed packing. The feeding is done by a crankshaft mechanism. Chart principle diagram of the structure calculation pushing presented in Fig.5 and Fig.6. The received results are presented in the Table 2.



*Piston Position.*



*Piston Velocity*



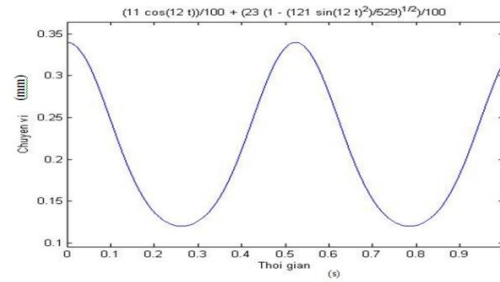
*Piston Acceleration*

**Figure 5.** Displacement, velocity and acceleration of the piston in frequency  $\omega = 10 \text{ rad / sec}$

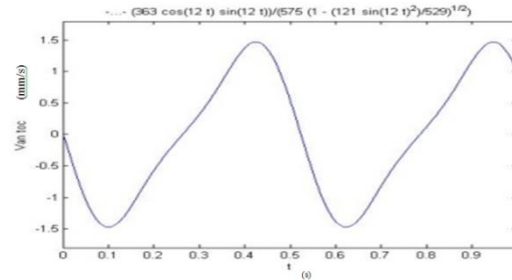
#### 4.2. Kinematic Modeling of Connecting Rod Motion.

The connecting rod is a major link inside of a engine. It connects the piston with

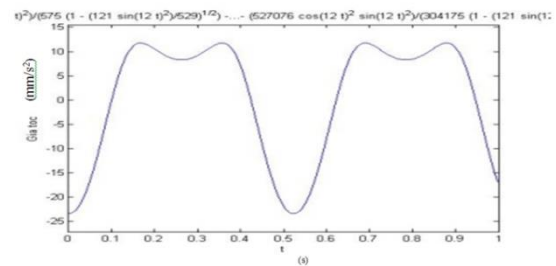
the crankshaft, transfers power from piston to crankshaft and sending it to the transmission. Connecting rod is one component of the crank mechanism. It is crucial to formulate the kinematics of connecting rod.



*Piston Position.*



*Piston Velocity*



*Piston Acceleration*

**Figure 6.** The displacement, velocity and acceleration of the piston in frequency  $\omega = 12 \text{ rad / sec}$

#### 4.2.1. Instantaneous Velocity of the Connecting Rod

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

Where:  $v_{con}$  – instantaneous velocity of connecting rod. Differentiate equation (2)

according to angle theta. Differentiate equation (2) with respect to angle theta

$$\frac{d\phi}{d\theta} = \lambda \frac{\cos \theta}{\cos \phi}, \cos \phi \approx 1 \tag{8}$$

$$v_{con} = \omega \lambda \cos \theta \tag{9}$$

**4.2.2. Instantaneous Acceleration of the Connecting Rod**

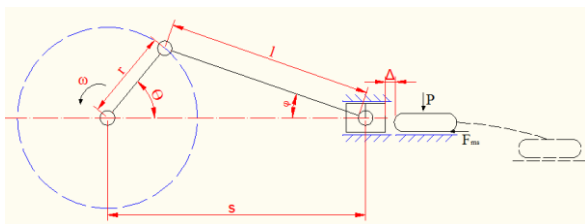
$$a_{con} = \frac{dv_{con}}{dt} = \frac{dv_{con}}{d\theta} \frac{d\theta}{dt}$$

Differentiating equation 9 according to angle theta

$$a_{con} = -\omega^2 \lambda \sin \theta \tag{10}$$

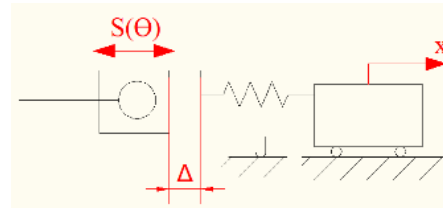
**5. KINEMATIC ANALYSIS OF THE SLIDER-CRANK MECHANISM AND SAUSAGE**

**5.1 Kinematics Modeling of Sausage motion.**



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

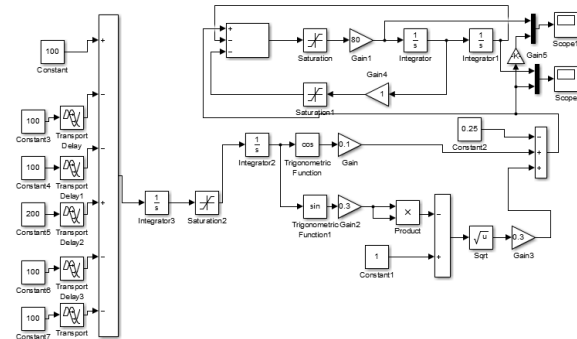
The relationship between the position of the crankshaft, connecting rod structure and sausage is shown in Figure 7. First, piston doesn't touch to sausage; next, top piston compresses sausage in elastic limit, then pushes sausage up to the sausage packaging. The forces on the sausage include: a weight of sausage above (P) and a friction force with platform (Fms) The impact model Model of the impact of the piston on sausages is presented in Figure 8. From equation (3), building on the mat chart lab simulation, can be determined kinematic parameters of the crankshaft systems - sausage.



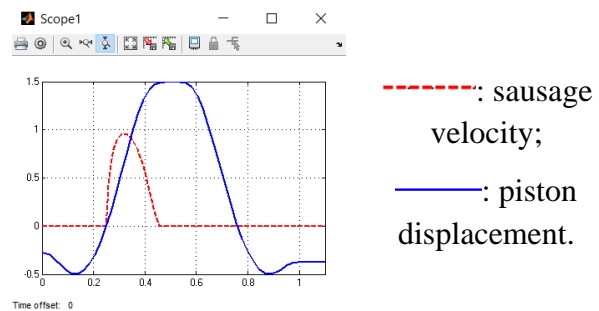
*Figure 8. Impact model of the piston on sausages*

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

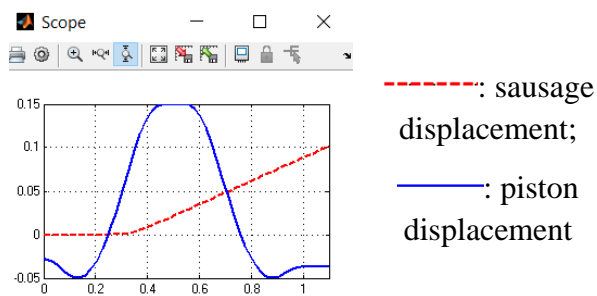
Based on the impact model of the piston on sausage (Figure 8), Matlab - Simulink diagram was built to determine the kinetic parameters of the piston and sausages in Fig.9. From then, determine the relationship parameters between of a rotation, distance of piston and original given sausages. Figure 10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



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



*Figure 10. Graphs relationships of piston displacement - sausage velocity*



**Figure 11.** Graphs relationships of piston displacement - sausage displacement

## 6. RESULT AND DISCUSSION

The conclusions of are drawn as follows:

1. The modelling methodology for kinematics of crank mechanism has been derived systematically by considering the geometric configuration of the crank mechanism of the automatic 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 kinematic system of sausage feeder from the crank to the sausage, identify the impact of the crankshaft speed, the relative sausages position, sausage speed during of the working piston.

## 7. CONCLUSION

According to computational and experimental results, it could be seen that the automatic sausage feeder chain was operating in sync with automatic packaging machines. Frequency pushing of the feeder always adjusted in line with the frequency of packaging machines. Moreover, working frequency of crankshaft follows packaging speed. The parameters of sausage feeder were calculated to ensure the consistent with sausage packaging requirements.

## REFERENCES

- [1] Zinovjav, V.A., (1992) Mechanisms and Machine Theory. Moscow, - 384p. (in Russian)
- [2] Krewer, (1995) "Conveyor arrangement for a sausage packaging machine", Bulletin 1998/18.
- [3] Righelle, (1992) "Machine for the separation of one continuous sausage into individual sausages", Bulletin 92/38.
- [4] Michaud, Presseau, Drolet, (1994) "Sausage link handling and packaging machine", Bulletin 91/46.
- [5] Zinovjav, V. A. (1992) Mechanisms and Machine Theory. Moscow,- 384p. (in Russian).
- [6] Sumskii, S.N. (1980) "Calculation of Cinematic and Dynamic Properties of Flat Lever" Mechanisms. Moscow, 310 p. (in Russian).
- [7] Paulauskas, L. (2002) "Theoretical basics of automated packaging machine package closing modules. Balttexmasch 2002, Kaliningrad, p.115-118.
- [8] Paulauskas, L. (2002) "Calculation of packing automatic machines with rotation slide-block.", Int. Scientific Practical Conf. "New trends in quality food production". Jelgava, Latvia, p.196-202.
- [9] Henry, J., Topolsky, J., and Abramczuk, M., (2015), "Crankshaft Durability Prediction – A New 3D Approach," SAE Technical Paper No. 920087, Society of Automotive Engineers. Mechanics, Materials Science & Engineering, October 2015 – ISSN 2412-5954

- [10] Anusha B and Reddy C. VijayaBhaskar, (2013) Modeling and Analysis of Two Wheeler Connecting Rod by Using Ansys, Journal of Mechanical and Civil Engineering, Vol.6, Page 83-87, May. - Jun.
- [11] Norton R.L., (2012) Kinematics and Dynamics of Machinery, Tata McGraw Hill Education (P) Ltd., New Delhi.

**Corresponding Author:**

Nguyen Hong Ngan

Ho Chi Minh City University of Technology, VNU – HCM, Việt nam

Email: [nhngan@hcmut.edu.vn](mailto:nhngan@hcmut.edu.vn), [ngan.ng.h@gmail.com](mailto:ngan.ng.h@gmail.com)