International Journal of Multimedia and Ubiquitous Engineering
Vol.11, No.7 (2016), pp.253-260
http://dx.doi.org/10.14257/ijmue.2016.11.7.25

Research and Analysis on the Experimental Simulation System of Mechanical Transmission

Guanfei Yin and Dongfang Song

Henan polytechnic, Henan, China
Corresponding E-mail:256572885@qq.com

Abstract

Since mechanical processing and transmission system is an important part of the mechanical processing link, compared with the working system, the transmission system not only needs to transmit greater power, it also requires higher efficiency and longer life, which also needs better abilities in the following aspects: variable - speed, adjusting speed, differential speed, so as to change the rotation direction of outputting shaft as well as the reverse transmission power and so on. In this paper, it takes the general form of the step chain driving system for mechanical processing as the starting point, combined with the interpretation of the single degree of freedom dynamic analysis equation, as well as the analysis on the virtual prototype model of the mechanical processing step chain driving system, realizing the simulation of the dynamic characteristics of the mechanical processing transmission system.

Keywords*: mechanical processing driving system; Simulation system; Dynamic analysis*

1. Introduction

With the development of market economy in China, it has promoted the rapid development of mechanical processing and other industries, therefore, the market demand for the products is growing. However it is lack of the theory analysis and research on this kind of mechanical system, so the performance of this kind of mechanical product is difficult to meet the market demands. And the foreign countries in this regard can be clearly stronger than that in china. Taking the full automatic cutting machine as an example, the cutting speed of the developed country can be as high as 10000 to 12000 times per hour, while the domestic similar products generally can reach to 6000 to 8000 times per hour, not only the production efficiency is low, but also the positioning accuracy is low, the noise is large under the high speed working condition. The results of this research of this paper can be used to guide the design of mechanical products in printing, packaging, mechanical packaging and so on. This series of advanced transmission mechanical designs can have great practical value in improving the design level of the mechanical products, reducing the noise and improving the accuracy of the positioning as well as the production efficiency.

2. The General Form of the Step Chain Drive of the Mechanical Processing Transmission System

Step chain transmission system as the implementation of automatic machinery can commonly be used in the implementation of mechanical transportation or moving goods. Taking the cutting machine step system as an example, in order to make the researching

ISSN: 1975-0080 IJMUE

questions have the general character, it can neglect the rail shape of the transmission chain, the number of the chain and the number of the different main and driven chains. [1] The drive wheel is usually driven by the indexing cam mechanism of movement which can be known as the degree of movement. The output shaft of the indexing mechanism is fixedly connected with the driving sprocket that can drive the chain to realize the intermittent movement. The driven chain wheel is usually attached to a spring that can support the device, which can play the role of guiding and supporting the chain. [2] Between the chain of spacing, there is fixed on the title of the paper tooth row. Its working principle can be shown as follows: the tooth row can stop working from the position A title paper conveying to the expected position B after the positioning, this time corresponding to the other device which can complete the paper molding process, when the process is completed, the chain can repeat the above steps to go on with the intermittent movement. Because the chain is at the high speed working condition, the dynamic characteristics are different from the constant speed, the inertia force is the main working load, the step speed and the position precision of the stepping chain transmission system are the main factors that can affect the efficiency of mechanical processing and the quality of the products [3].

3. Dynamic Analysis Equation of Single Degree of Freedom

In order to get the basic characteristics of cam mechanism, now it can study the model of cam mechanism with single degree of freedom which can be shown in Figure 1 Among them, m is the quality of the output end, which is the sum of the equivalent mass of the cam mechanism as well as the transmission system. While k is the spring constant of the transmission system; is the viscous dragging coefficient of the transmission system. Moreover, the inherent friction and clearance of the system can be neglected.

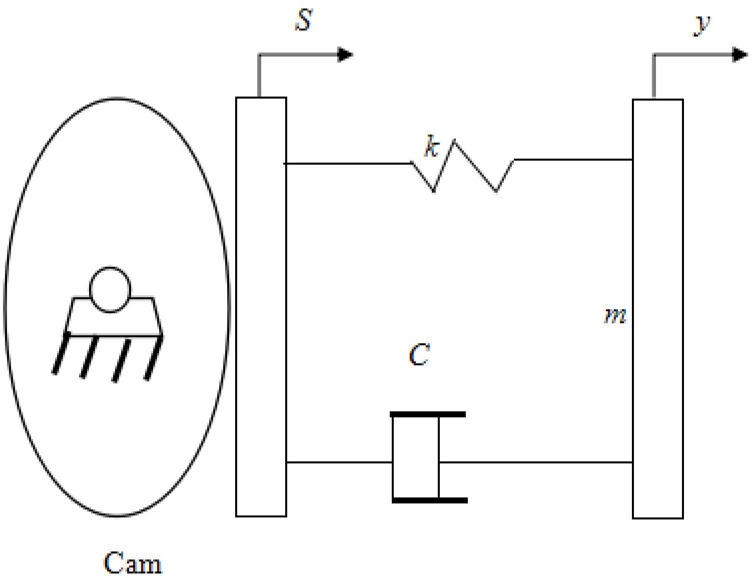

Figure 1. Model of Cam with Single Degree of Freedom

Based on the model with single degree of freedom model, the vibration equation of the cam can be established as follows:

$$m\ddot{y}+c\dot{y}+ky=ks+c\dot{c}$$

Among the formula, *m, c, k*------------ mass, damping and stiffness of the system

y、$\dot{y}$、$\ddot{y}$ ----------the response of the system, as well as the corresponding derivative number

s 、 $\dot{s}$ 、 $\ddot{s}$ -----------the displacement of the theory of motion, velocity and acceleration.

4. Simulation Study on Step Chain of mechanical Processing

4.1. Dynamic Theory of Dynamic Multi Body System

Objects are made up of large quantities of components in the project system. When it goes with the optimal design and behavior analysis, it can be divided into two categories: one type can be known as the structure, their features are in the component under normal conditions there is no relative motion; the other is called institutions, its characteristics are running in the system there is relative motion between the parts in the process. These Mechanical models of complex systems for multiple widget can be connected through a pair, which can be called as the multi body system. If the objects in the system can make rigid body hypothesis, such systems can be called as rigid multi body system; if we consider the deformation of the object in the system, namely, the body can make a flexible body hypothesis, then it can be called as flexible multi body system.[4]

Dynamics of multi body system can adopt computer to solve the complicated problem of the mechanical system. It will use computer to finish the tasks such as: setting up models, writing motion differential equations, solving and some other work, which can have obvious advantages in analyzing large-scale complicated three-dimensional mechanical systems. The research on the dynamics of multi body system can be including two aspects: the method of setting up models as well as numerical algorithm. Modeling refers that it can be based on the need of practical engineering problems, the problems can be abstracted into multi rigid body, flexible body or rigid flexible coupling multi body system, and then the related physical quantities of the system can be analyzed and described, and the dynamic equations of multi body system can be derived from the relevant mathematical, mechanical theory and method. The dynamic equations of multi body systems are generally nonlinear ordinary differential equations (ODE) or differential algebraic equations (DAE), generally speaking, it is the numerical solution that is obtained by computer numerical simulation, which can get the features of dynamics of multi body system through analyzing the value of numerical analysis.[5]

4.2. Model of Two Dimensional Rigid Bodies

In the system, it can set up a global coordinate system *xoy*, which can be shown in Figure1. Each rigid body can have movement in the coordinate system, and the siamese coordinate system $x_i'o_i'y_i'$ can be set up on each rigid body respectively, the movement of the siamese coordinate system can decide the movement of movement if each component. Figure 2 is the schematic diagram of the model of single rigid body in the moving plane.

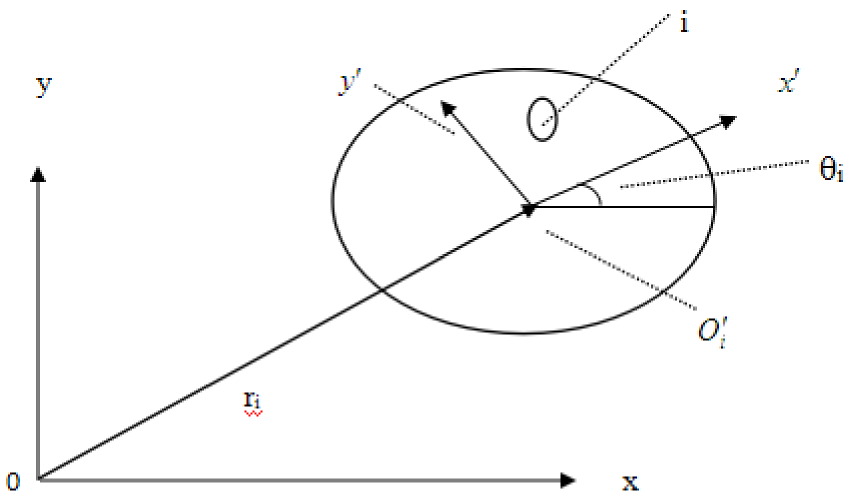

Figure 2. Model of Single Rigid Body

4.3. Model of 3D Rigid Body

The generalized coordinates of the three-dimensional system are more complicated than those of the two-dimensional system, which makes the problem larger in scale. In the system, a global coordinate system *oxyz* can be set up, as for the arbitrary rigid body member i, the original point o_i' of siamese coordinate system $o_i'x_i'y_i'z_i'$ can be fixed at the center of the rigid body center. At this time, Siamese coordinate system can also be known as the center-of-mass frame, which can be shown in Figure3.

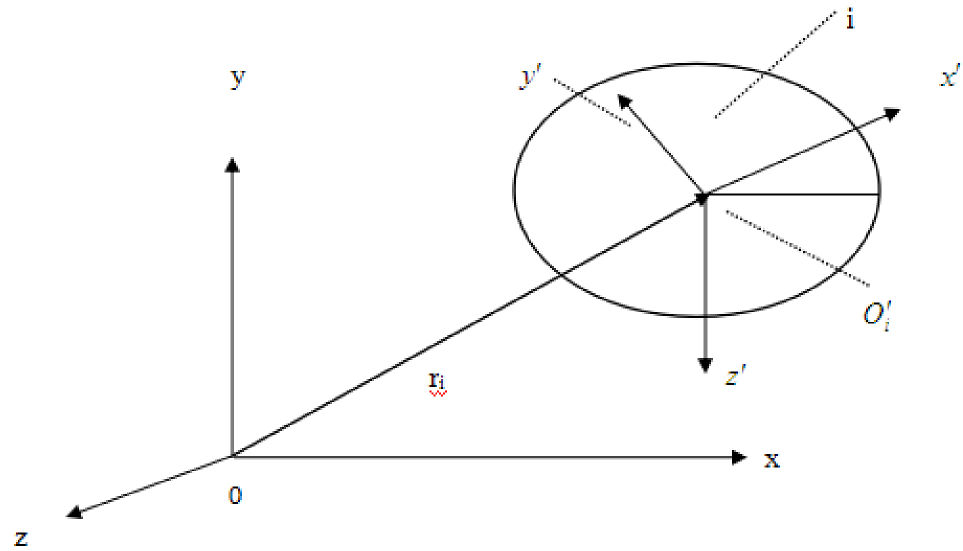

Figure 3. Model of Single Rigid Body

4.4. Virtual Prototyping Model of Mechanical Processing Step Chain Transmission System

The main structure of the step chain system are as follows: pin shaft, roller, sleeve, chains, sprockets and other parts. If can set up the corresponding solid model with link system structure. In this paper, in order to reduce the number of the rigid body of virtual prototype model effectively, saving time, without affecting the chain drive on the basis of dynamic properties, the roller and sleeve can be regarded as a whole, which can form a part of the inner link. Then it can build internal and external links on the basis of this entity. As for the modeling of the link, it can adopt gear drawing method with three circular-arc plus one straight line, so as to ensure the full shape of the tooth profile of chain wheels.

According to the design parameters of the prototype, it can set up the coordinate system, the fixed and driven sprocket chain, according to the total number of the assembled chain, it can organize the chain which should be paralleled to the assembly of the indexing cam; it can add the additional equivalent mass concentration for transferring the goods or heavy; the tension spring can be arranged on the driven shaft. According to the actual working condition of this kind of system, the loose side is on the lower side, and the tight side is on the upper side, the guide can be arranged both on the loose side and the tight side. In this model, selecting 4 links as the equivalent mass evenly, so as to simulate the quality of the actual cutting machine. Introducing the entity model in Pro/E environment in the ADAMS environment through public files interface. In order to ensure that the model can be effectively introduced into the ADAMS environment, the setting unit in Pro/E should be: mm, kg, second.

4.5. Modeling of State Transition Function

The positions of mechanical logistic tanker and obstacles are defined through 2D grid map. The state set S is used to describe the positions of mechanical logistic tanker and obstacles. At any moment, the state of each grid might be one of the following four types: being occupied by the mechanical logistic tanker, being occupied by the obstacle, being blank and terminal.

Definition 1 Suppose the environment is divided into N grids. The state set of mechanical logistic tanker path planning is defined as:

$$s_i = \begin{cases} s\_r & (grid\ is\ robot) \\ s\_o & (grid\ is\ obstacle) \\ s\_b & (grid\ is\ blank) \\ s\_t & (grid\ is\ terminal) \end{cases} \quad (1 \le i \le N) \tag{1}$$

Where, i is the number of grid where the mechanical logistic tanker is located, $S = \{s_1, s_2, \ldots s_N\}$

Definition 2 Suppose the mechanical logistic tanker can move at four directions in the environment. The executable action set for the mechanical logistic tanker that is described by the action A is as below:

$$A = \{East, South, West, North\} \tag{2}$$

The state transition function $T(s,a,s')$ means the probability of reaching the state s' by executing the action a in the state s. That is, $T(s,a,s') = P(s'|s,a)$. When the mechanical logistic tanker executes a certain action, the expected effect might not be fully achieved, and there is a failure probability to some extent. In a practical environment, it can be obtained from statistical data. In a simulation environment, suppose the probability for the mechanical logistic tanker to successfully execute the action is δ, and the probability for the mechanical logistic tanker to fail to execute the action, move toward the opposite direction or remain still is $1-\delta$.

4.6. Modeling of Observation Function

Use the observation set Z to indicate mechanical logistic tanker's cognition for the environment. That is the result for detecting the positions of mechanical logistic tanker and obstacles by the sensor. Suppose the detection state for mechanical logistic tanker for the grids includes being occupied by the mechanical logistic tanker, being occupied by the obstacle, being blank, terminal and unknown state. In particular, the unknown state means the undetected grids.

Definition 3 Suppose the environment is divided into N grids. The observation set of mechanical logistic tanker for the environment is defined as:

$$z_i = \begin{cases} z\_r & \text{the detected grid is robot} \\ z\_o & \text{the detected grid is obstacle} \\ z\_b & \text{the detected grid is blank} \\ z\_t & \text{the detected grid is terminal} \\ z\_u & \text{the detected grid is unknown} \end{cases} \quad (1 \le i \le N) \tag{3}$$

Where, i is the number of grid where the mechanical logistic tanker is located, $Z = \{z_1, z_2, \ldots z_N\}$

Being influenced by such factors as sensor precision and environmental noise, there might be errors between the grid state detected by the mechanical logistic tanker and the actual state. Such errors can be expressed by the observation function $O(s', a, z)$. $O(s', a, z) = P(z \mid s', a)$. In a simulation environment, suppose the probability for the mechanical logistic tanker to successfully detect the grid state is μ , and the probability for detection failure is $1-\mu$. To simplify the model complexity, the grid state is uniformly set as $z-u$ when the detection fails.

4.7. Modeling of Reward Function

To prevent path planning from getting into local optimum, immediate $R(s,a)$ and cumulative reward $V_\pi(s)$ for path/action need to be concerned. $R(s,a)$ means immediate reward obtained from executing the action a in the state s . For a certain state s , the state after mechanical logistic tanker movement includes collision, being in blank grid and arriving at terminal. Set the reward obtained from mechanical logistic tanker movement in blank grid as a negative incentive, which can prevent the mechanical logistic tanker from wandering in the blank grid. Therefore, set the immediate rewards for reaching these three states as -100, -1 and 100.

To achieve the global optimum of path planning, obtain the shortest path by maximizing the cumulative reward. The cumulative reward $V_a(s)$ is obtained through Bellman equation:

$$V_t(s) = R(s,a) + \gamma \sum_{s' \in S} T(s,a,s') V_{t-1}(s') \tag{4}$$

Due to the uncertainty of mobile mechanical logistic tanker for the environment observation, the environment for the mechanical logistic tanker is not always confirmed to be a certain state s but there are multiple states distributed in form of probability. Therefore, the belief state space B is introduced to indicate the probability distribution for the states observed by the mechanical logistic tanker in the practical environment state. The belief B at t is described by Formula (5) and calculated by Formula (6).

$$b_t = P(s_t \mid a_t, z_t, a_{t-1}, z_{t-1}, a_{t-2}, z_{t-2}, \ldots, a_0, z_0, s_0) \tag{5}$$

$$\begin{aligned} b'(s') &= P(s' \mid z, a, b) \\ &= \frac{O(s', a, z) \sum_{s \in S} T(s, a, s') b(s)}{P(z, a, b)} \end{aligned} \tag{6}$$

The functions based on belief state and cumulative reward can be rewritten by Formula (7) as:

$$V_t^*(b) = \max_a [\sum_{s \in S} b(s) R(s,a) + \gamma \sum_{z \in Z} P(z \mid b, a) V_{t-1}^*(b)] \tag{7}$$

It can be seen that the process of getting maximal strategy is an iteration process of obtaining the maximum function. The iteration ending condition is shown in Formula (8):

$$\left\| V_t(b') - V_{t-1}(b) \right\| < \frac{\xi(1-\gamma)}{2\gamma} \tag{8}$$

The strategy of mobile mechanical logistic tanker's POMDP model decision is to map the state to the action. That is $\pi(s) \to a$. To obtain the globally optimal solution, the optimal strategy π^* is the action to reach the maximal expected value for discount cumulative reward and can be solved by Formula (9).

$$\pi_V^*(b') = \arg\max_a [\sum_{s \in S} b(s)R(s,a) + \gamma \sum_{z \in Z} P(z \mid b,a) V_{t-1}^*(b)] \tag{9}$$

5. Simulation Study on the Dynamic Characteristics of Mechanical Processing Transmission System

5.1. The Force of the Roller on the Indexing Plate

The parallel indexing cam mechanism is a kind of complex conjugate cam mechanism, in one moving period, each cam should promote a number of rollers, each roller has a corresponding cam contour curve, which can finish a certain kind of movement like finishing relay race. Therefore, each cam contour curve should be composed of several sections of simple cam contour curve. At the same time, as the conjugate cam, the cam 's meshing movement must have certain degree of coincidence (the ratio between more than two rollers simultaneously drive the driven wheel to rotate the angle and the roller along the driven plate angle) in order to realize the lock. Taking the virtual prototype model as an example, it can be based on the modified sine wave (MS) motion, it can go on with the simulation calculation under the condition that the stiffness of spring is110N/mm, the pre-tightening force is 0N, and inputting shaft speed of the cam is 200r/min.

5.2. Effects of Stiffness and Preload on the Dynamic Characteristics of Mechanical Processing Transmission System

In engineering, the driven wheel of the step chain transmission system is generally accompanied by a spring support device, which can play a supporting role for the chain. In the virtual prototype, a linear spring is arranged along the longitudinal direction, and the spring is established between the frame and the slide. The virtual rotation pair is established between the driven sprocket and the slider, therefore, the chain wheels can rotate around the axis of freely, which also can move longitudinally at the same time.

6. Conclusion

At present, the analysis on the stress of the chain usually stays at the theoretical stage, in this paper, through the virtual prototype simulation, it can be obtain the chain hinge force variation law when the chain step is in motion. In one step movement cycle, the greatest tension of the chain appears at the edge of the acceleration section, and the tension of the chain tends to be zero at the lower part, compared with the changing situation of the tight side, the situation of the loose side is quite different, since the greatest tension of the chain appears at the edge of decreasing section and the tension of the chain is smaller at the loose side of the acceleration section, it can be increased near the cross point, which is caused by the inertia of the system. When the chain is in the step motion, the chain force changes are closely related with the movement of the cam, when it adopts MCV motion, the change of the chain tension is the biggest, the value of tension amplitude is also the largest, from the above tension test results it can find out the hinge force between segments are the dynamic load changes periodically in the step movement, which can be more prone to get fatigue failure. Therefore, under the same condition, based on the analysis on the tension of the step chain in the movement, it is better to adopt step motion law with the maximum acceleration is smaller as much as possible.

References

[1] I. Troedsson and L. Vedmar, "A Method to Determine the Static Load Distribution in a Chain Drive", ASME J, Mech. Des., vol. 121, **(1999)**, pp. 402-408.

[2] I. Troedsson and L. Vedmar, "A Dynamic Analysis of the Oscillations in a Chain Drive", Journal of Mechanical Design, vol. 123, **(2001)**, pp. 395-401.

[3] H. Zheng, Y. Y. Wang and G. R. Liu, "Efficient Modeling and Prediction of Meshing Noise from Chain Drives", Journal of Sound and Vibration, vol. 245, **(2001)**, pp. 133-50.

[4] H. Zheng, Y. Y. Wang and K. P. Quek, "Investigation of Meshing Noise of Roller Chain Drives for Motorcycles", Noise Control Engineering Journal, vol. 50, **(2002)**, pp. 5-11.

[5] H. Zheng, Y. Y. Wang and K. Quek, "A Refined Numerical Simulation on Dynamic Behavior of Roller Chain Drives", Shock and Vibration, vol. 11, **(2004)**, pp. 573-84.

[6] M. A. A., "The Dynamics of a Harmonic Potential Field-Guided food logistic tanker in a Cluttered Environment", Indu. Ele. IEEE Tran. on, vol. 56, no. 2, **(2009)**, pp. 488-496.

[7] M. L. Littman, "A tutorial on partially observable Markov decision processes", Journal of Math. Psy., vol. 53, no. 3, **(2009)**, pp. 119-125.

[8] S. Ross, J. P. Pineau and S. Paquet, "Online Planning Algorithms for POMDPs", Journal of Arti. Int. Res., vol. 32, no. 2, **(2008)**, pp. 663-704.

Authors

Guanfei Yin, assisted professor, Research direction: Mechanical design; Car Design.

