ISSN : 0974 - 7435

Volume 10 Issue 12

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(12), 2014 [6675-6684]

Cam motion simulation and optimization based on matlab /simulink

Caixia Li

Dezhou College, School of Mechancial Engineering, Dezhou 253023, (CHINA)

ABSTRACT

Automobile engine valve mechanism task is to ensure that the valve open or closed within the prescribed time, open or close the action should be quickly. As the camshaft speed increase, the kinematic and dynamic characteristics of the elastic deformation and inertial force on the mechanism of component will influence, causing the valve between the actual displacement, velocity, acceleration and displacement, velocity, acceleration of the name, especially the obvious difference between the actual and nominal acceleration response acceleration, so the elastic dynamic analysis the entire valve mechanism, as an elastic system, the actual output of the dynamic valve with camshaft input response, for cam profile motion / dynamics integrated to provide a theoretical basis. This paper is based on the kinetic theory of mechanical system, the dynamic response analysis of the cam mechanism, including the displacement response, velocity and acceleration response, according to the comparative analysis of results, can explain the harmonic motion law is more obvious in reducing the vibration of high speed cam mechanism effect. Analysis steps as modeling, set up the differential equations of motion and the solution of the differential equations of motion. The differential equations of motion can be obtained by analytical solutions only in some simple cases, in general, can only use the numerical method to solve. In this paper an analytic solution of dynamic response, and are compared with the ideal output response, illustrate the applicability of harmonic motion law is applied to the design of cam mechanism.

KEYWORDS

Cam mechanism; Dynamic analysis; Mechanical vibration; Optimum design of cam profile; Error analysis.

INTRODUCTION

In automatic mechanism in common use, many of the characteristics of cam mechanism is difficult to substitute other institutions, has been widely using in the large range, cam mechanism and the development of this characteristic, become an important branch of modern mechanisms[1]. In the design of cam mechanism, inquiry or select the appropriate cam follower motion law, so as to improve the characteristics of kinematics and dynamics of the entire organization, close and reduce vibration, reduce noise. On the motion law of cam, for many years in many countries of the world, such as Germany and Japan, USA, done a lot of research, has designed dozens of curve[2]. From at present some cam moving curve, method of composition formula on its motion law mainly the following three kinds: one is composed of relatively simple single function, such as sine motion law, motion and cosine law of motion of constant velocity. This curve, the motion characteristics is not very good, generally not suitable for use in high-speed cam mechanisms[3]. Two is composed of a plurality of piecewise function are combined to form, such as modified trapezoid motion law, modified sine law, this type of curve the motion characteristics of ideal. The three law of motion is obtained based on polynomial function.

In the domestic research of high speed cam is begin from seventy later, such as the globe cam, the state planning commission[4]. In 1989 issued a "high speed, high precision of cam mechanism research" research project, the domestic scholars start to design and machining method, motion characteristics of high-speed cam mechanism is studied systematically, the domestic enterprises and institutions of higher learning, research in high speed cam mechanism theory curve design, machining and inspection etc. do a lot of research on the preparation work. Cam mechanism used for light industrial machinery and food industry, packaging industry and tobacco, packaging machinery, along with the market competition is becoming increasingly fierce, the low efficiency of the low speed of packaging machinery has been far from satisfying the needs of the market, packaging machinery, high-speed operation will be the future leader in the packaging industry[5,6].

In foreign countries, its products are mainly in the tobacco industry[7]. In order to adapt to the need of automatic machinery of high performance and efficiency of the cam mechanism, which also along with the improved, both conventional curve cam motion, and has the special law of motion of high speed cam, in some application, various types of products constantly updated, the cam mechanism is also in the updated, current a variety of harmonic cam mechanism used in tobacco machinery, but this kind of cam motion law design, in foreign technology companies have a secret, in the domestic related information and understood, so this kind of design method at present there is no general.

According to the cam contour parameters of various follower work requirement to achieve predetermined motion, this is a difficult point in terms of cam kinematics. In the early days, when the motion law of follower has been selected and do out of lane change chart, do map method to find out all kinds of planar cam profile curve by staff. Cylindrical cam profile although belonging to a space curve, but because of the cylindrical surface can be expanded into a plane, so it can be expanded outline drawing of cylindrical cam with graphic method. But this method has low accuracy, low efficiency, it is difficult to precisely calculate some important parameters such as the pressure angle of cam. For the high speed cam and cam of high precision, coordinate equation must be established, the cam contour curve theory actual contour curve and processing of cutter center track, and can accurately calculate the cam contour curve or the tool trajectory coordinates of each point on the value, has been applied to NC machining.

RELATED THEORY OF CAM MOTION

Cam mechanism dynamics

For the dynamic system research on actual cam mechanism, the analysis steps: establish a differential equation of motion to solve the motion differential equation modeling[8]. Combined with a variety of dynamic factors, modeling is to completely reflect the actual physical model in theoretical research, easy. In response to dynamic analysis draws the mechanism, must be established between the differential equations of input and output, the output solution to the response, an important reference can be used as the vibration and noise of the research institutions[9].

Now the dynamics model of cam mechanism can be simplified as a single degree of freedom vibration model shown in Figure 1, by the vibration theory[10]:

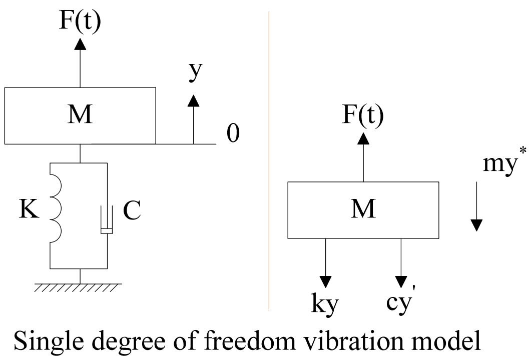


Figure 1: A single degree of freedom vibration model

Harmonic force spring mass system vibration forced vibration:

$$F(t) = F_0 e^{i\omega t} = F_0 \cos(\omega t) + iF_0 \sin(\omega t) \tag{1}$$

F_0 was the amplitude of driving force, w as the excitation frequency of the external force. According to the stress analysis of Figure 1 vibration differential equation:

$$m\ddot{y} + c\dot{y} + ky = F_0 e^{i\omega t} \tag{2}$$

Design: $y = \bar{y} e^{i\omega t}$

y-The complex vibration value of the steady state response;

$\omega_0 = \sqrt{\dfrac{k}{m}}$ -The natural frequency of the system;

$\xi = \dfrac{c}{2\sqrt{km}}$ -Relative damping coefficient.

Into the formula (1) $\bar{y} = H(\omega)F_0$

In the formula:

$$H(\omega) = \frac{1}{k - m\omega^2 + ic\omega} \tag{3}$$

The vibration differential equation of variable for:

$$\ddot{y} + 2\xi\omega_0\dot{y} + \omega_0^2 y = B\omega_0^2 e^{i\omega t} \tag{4}$$

Modal frequency selection

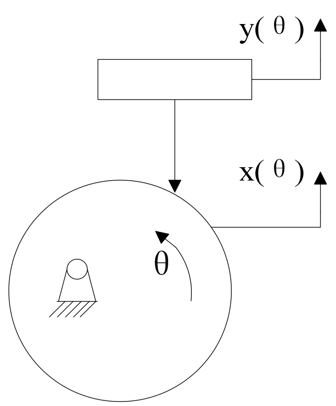
Through the modal view mode, you can decide some modal frequency had a significant effect on mechanism vibration, can make its failure. According to the formula of $n\omega = \omega_0$, is the $n = \dfrac{\omega_0}{\omega}$ to determine the maximum number of harmonics. The number of harmonic components should be less than $n = \frac{\omega_0}{\omega}$, so with cam mechanism limiting harmonics motion curve can avoid resonance mechanism.

Cam for clockwise rotation, the follower oscillating direction is clockwise
Pendulum rod length: l=145.0000mm
Center distance: a=140.0000mm
The initial angle of π=30.0000 degrees:
Roller radius: Rt=16.0000mm
The follower angular displacement: h=10 degrees

THE ESTABLISHMENT OF DYNAMIC MODEL WITH VALVE MECHANISM

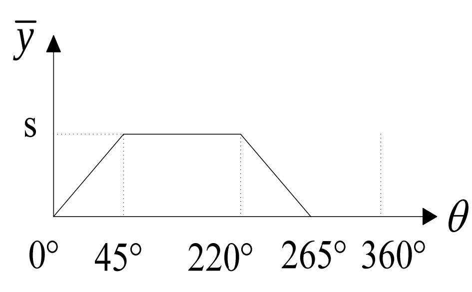
The determination of the actual output of cam mechanism

The kinematics model of the cam as shown in Figure 2, the kinematics model, it does not consider the mechanism of damping, friction and mechanical vibration and impact, so the disc cam mechanism with the actual output y (θ) is equal to the input motion function x (θ)



Kinematics model of cam mechanism

Figure 2 : The kinematics model of the cam



Theory displacement diagram of rise-stop-drop-stop type cam mechanism

Figure 3 : The actual job requirements of Y

Figure 3 shows, in determining the actual job requirements of Y, the traditional method is to use a variety of equation of motion composition to satisfy the phase diagram of the cam, meet after obtaining the actual output motion of cam mechanism. But in 2π for the cycle of fourier transformation on the output motion function, only to the cam mechanism working section has strict requirements, while the non working section only the deviation of the control within the scope of the regulations on the line. Using the finite harmonics superposition represents the actual output cam mechanism:

$$y(\theta) = a_0 + \sum_{n=1}^{k}[a_n \cos(n\theta) + b_n \sin(n\theta)] \tag{5}$$

Under normal circumstances, cease section of the cam mechanism with strict requirements. The formula of a0, an, bn respectively, the partial derivative, and it is equal to zero:

$$\partial \sum_{i=1}^{m}[\int_{\alpha}^{\beta}(y_i(\theta) - \overline{y_i})^2 d\theta] / \partial a_0 = 0$$
$$\partial \sum_{i=1}^{m}[\int_{\alpha}^{\beta}(y_i(\theta) - \overline{y_i})^2 d\theta] / \partial a_n = 0$$
$$\partial \sum_{i=1}^{m}[\int_{\alpha}^{\beta}(y_i(\theta) - \overline{y_i})^2 d\theta] / \partial b_n = 0 \tag{6}$$

In the optimization process, by the theory of phase curve based, with these factors, according to the calculation formula of the cam profile can get the contour curve. Figure 4 is the output motion curve.

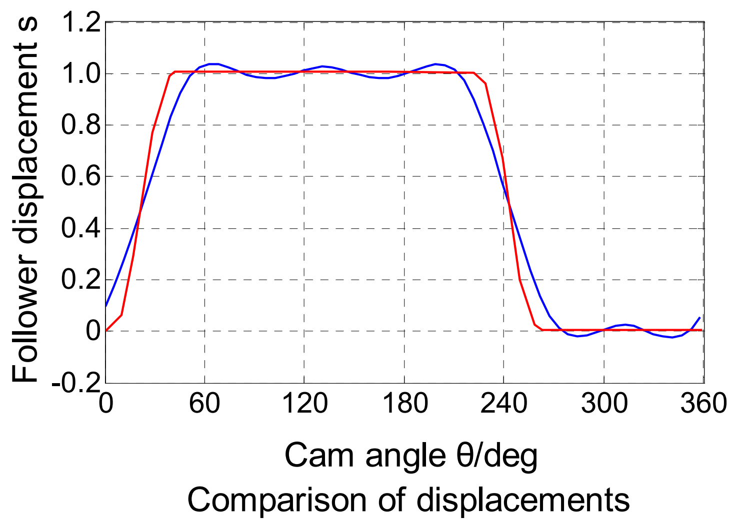


Figure 4 : The output motion curve

Harmonic motion law design example

Design of cam indexing mechanism was called for a formula of phase diagram and embodiment of cam mechanism with modified sine motion law of analogy.

The superposition of harmonic components, the cosine component motion for stay without motion, will produce the flexible impact. Therefore, the dimensionless acceleration can be expressed as the following form:

$$A(T) = \sum_{n=1}^{k}[b_n \sin(2\pi nT)] \tag{7}$$

In it: $0<T<1$

On the integral to:

$$V(T)=\int_0^T A(T)dt=-\sum_{n=1}^{k}[\frac{b_n}{2\pi n}\cos(2\pi nT)]+B \tag{8}$$

$$S(T)=\int_0^T V(T)dt=-\sum_{n=1}^{k}[\frac{b_n}{4\pi^2 n^2}\sin(2\pi nT)]+BT+C \tag{9}$$

Boundary conditions are satisfied:

$$A(0)=A(1)=V(0)=V(1)=S(0)=0,\ S(1)=1 \tag{10}$$

The boundary conditions into the formula:

$$\begin{cases} B=\sum_{n=1}^{k}\frac{b_n}{2\pi n}=1 \\ C=0 \\ V(T)\geq 0 \end{cases} \tag{11}$$

In determining the coefficients of the harmonic component, and law of motion is determined, Figure 5 shows the reference map contrast harmonic motion and modified sine motion law.

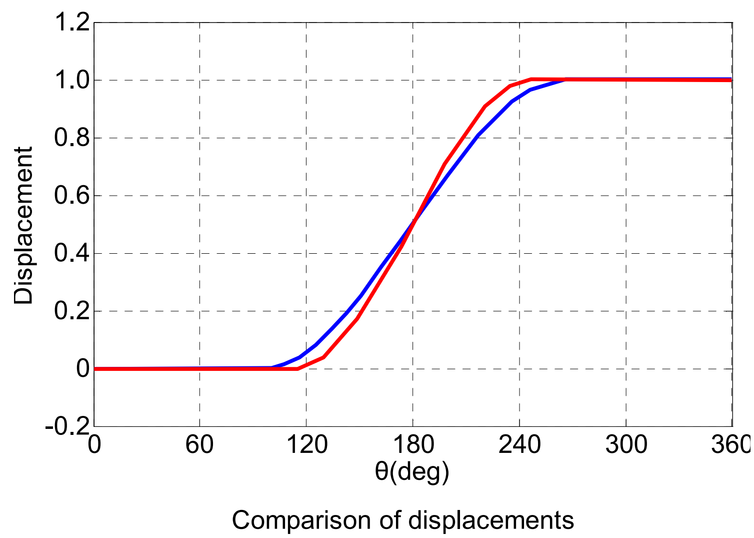


Figure 5 : The reference map contrast harmonic motion and modified sine motion law

Flexibility and modal calculation model

Measured by the pendulum angle displacement curve as shown in Figure 6, the solid measure in order to consider the rigid component of the curve, dotted line measurement for considering flexible body curve, it is obvious in flexible treatment of member, the angular displacement of the swing rod by measuring the increase of 0.1098 degrees.

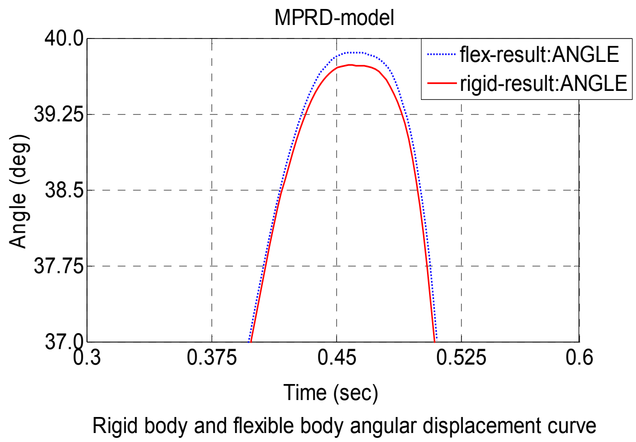


Figure 6 : Measured by the pendulum angle displacement curve

THE EXPERIMENTAL ANALYSIS

The simulation process under Matlab/Simulink

We usually use the finite difference method and other numerical calculation method to solve complex, programming, time-consuming, and is not intuitive, this article using Matlab/Simulink system simulation software to achieve, considering the mathematical model for the movement of h=h (T) for the calculation of piecewise function, to establish the simulation process using M function, can be calculated and judging complex. The whole system needs six integrator, the kinetic equations are solved by the integral of acceleration, velocity and displacement of each element of the x1~x3 are obtained, the modeling steps are as follows.

Start Simulink, rendering the system simulation model

Select the New commands in the File menu, you can enter the Simulink modeling window, according to the system simulation model which will need module, such as integrator, adder, using the mouse to drag the design area, and then connect the organic module (Figure 7), as shown below.

Set the integrator initial conditions

The system is time-varying dynamic process, in order to make the system reaches steady state as soon as possible, reduce the simulation time, avoid the initial conditions of complicated calculation, through clever choice of initial position of mechanisms. In general, the start time of the selection of cam lift as the starting point, the initial displacement and velocity in x1~x3 integrator has the value 0.

The simulation parameter settings of each module

In the simulation, must be based on the specific requirements of the system to correctly choose and set up various simulation parameters, mainly the solver classes and types, the simulation time, oscilloscope parameter setting, output options settings, use the mouse to click the module, can display properties dialog box belongs to this module, parameter and modify or set the response. The Start term in the model window click the drop-down menu, you can start the simulation. In the model output in different position to add Scope module, dynamic curve can watch the time-varying parameters.

Dynamic simulation of the gas distribution mechanism

Under normal circumstances the cam mechanism is simplified as a double degree of freedom dynamics model analysis, we can obtain the approximate results of Engineering satisfactory, but in the case of high-speed operation, often need to be simplified as a multi degree of freedom dynamics model is more accurate, in order to make the analysis results more close to the real situation of cam mechanism operation. With the increase in the number of degrees of freedom, the calculation will greatly increase the workload, so in the establishment of dynamic model, should seize the main and ignore the minor factor, carries on the reasonable choice and to simplify the related parameters. As shown in Figure 8 (a), is an engine cam mechanism system, which is composed of a camshaft, tappet, a rotating arm, valve rod composed of multiple links.

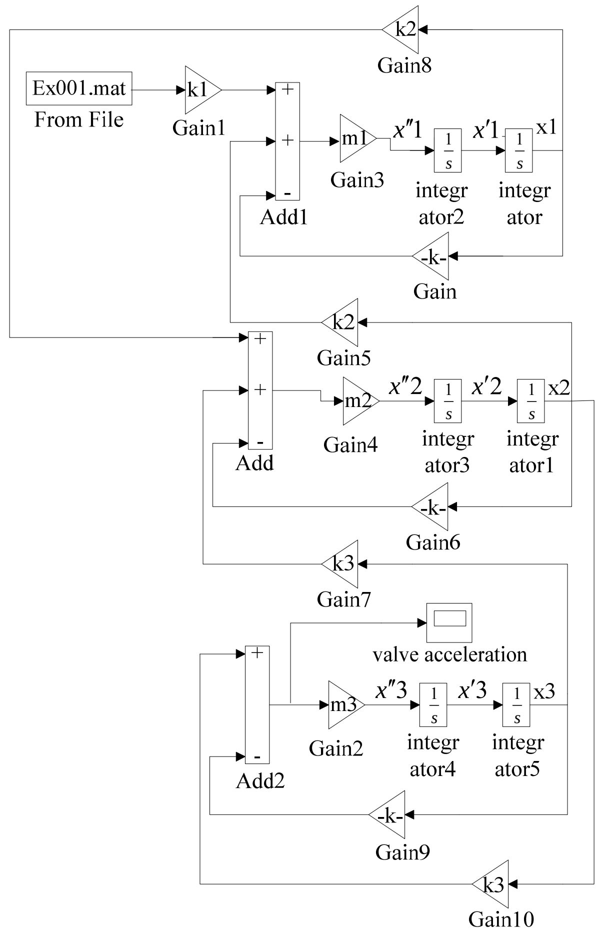


Figure 7 : The mouse to drag the design area

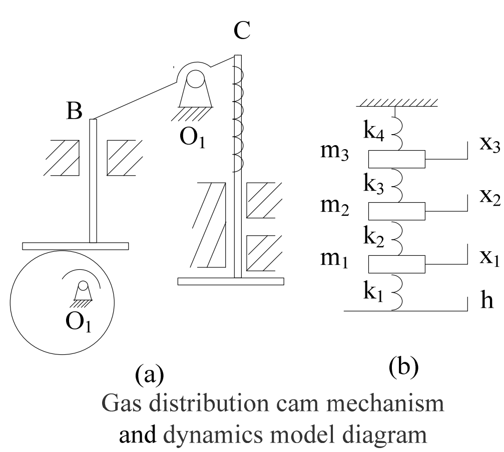


Figure 8 : An engine cam mechanism system

Assuming that the camshaft has larger stiffness, without taking into account its vibration, and the equivalent as concentrated mass, the kinetic model is equivalent to three degree of freedom system with, as shown in Figure 8 (b), where M1 is the equivalent of A point of the concentrated mass, M2 equivalent B point concentrated mass, equivalent m3 C point of the concentrated mass; K1 is a cam push rod and the contact surface of the contact stiffness, K2 tensile tappet stiffness of AB, K3 as the bending stiffness of rotary arm of BC, K4 as the equivalent spring stiffness; the theory of displacement in the H cam follower. The equivalent mass and the equivalent components in the system can be obtained by the stiffness of the knowledge in mechanics of materials, by Lagrange theorem:

$$\left.\begin{aligned} m_1\ddot{x}_1 + k_1(x_1 - h) - k_2(x_2 - x_1) = 0 \\ m_2\ddot{x}_2 + k_2(x_2 - x_1) - k_3(x_3 - x_2) = 0 \\ m_3\ddot{x}_3 + k_3(x_3 - x_2) + k_4 x_3 = 0 \end{aligned}\right\} \tag{12}$$

Simplification of tidy:

$$\left.\begin{aligned} \ddot{x}_1 = [-(k_1 + k_2)x_1 + k_2 x_2 + k_1 h] / m_1 \\ \ddot{x}_2 = [k_2 x_1 - (k_2 + k_3)x_2 + k_3 x_3] / m_2 \\ \ddot{x}_3 = [k_3 x_2 - (k_2 + k_4)x_3] / m_3 \end{aligned}\right\} \tag{13}$$

Now with the exhaust cam mechanism of a engine as an example, the parameter selection system: cam shaft speed 1500r/min, cam profile FB2 type cam, a buffer for 0.2mm, the buffer period of wrap angle, 15 basic section lift of 5.3mm, the basic period of half angle of 60, the equivalent mass of each element is m1=0.25kg, m2=0.18kg, m3=0.21kg, equivalent stiffness k1=k2=k3=4 * 106N m-k4=2.3 * 1, 104N m-1, we use the four order / five order algorithm to calculate. The simulation results, as shown in the figure, the solid line is the acceleration curve of the valve, the dotted line represents the value of design theory, namely the system input signals or cam follower by the change of acceleration, displacement and velocity curves of the valve is not obvious and not shown. Simulation results show that: in the high-speed motion mechanism, considering the elastic deformation of components, the system output response is fluctuation, fluctuation amplitude even more than doubled, which provided the basis for the dynamic design of valve mechanism.

The experimental results and analysis

Design of parts and assembled, and in front of the same settings, again on the mechanism of flexible treatment, based on the dynamic simulation of the processing object. In the graph, the fluctuation of retention curve segment represents a general design through dynamics simulation curve flexibility after the stay period, small fluctuation curve representation through dynamics simulation curve of the improved harmonic cam design. It is clear that the amplitude of vibration, stop segment reduces a lot, in the actual work requirements, but also should strictly control the scope of the maximum deviation, which cannot be greater than the allowable deviation, active member of cam contour cam mechanism designed the, can satisfy the precision of design, at the same time also can meet the need of middle, high speed cam profile. Figure 9 represent the motion deviation map stop segment.

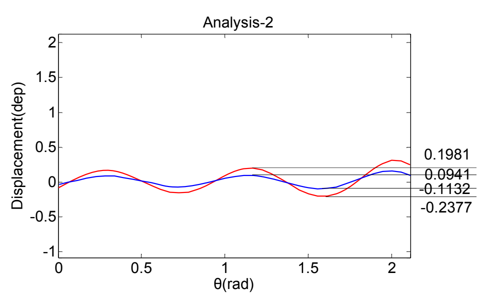


Figure 9 : The motion deviation map stop segment.

CONCLUSION

This paper discusses a suitable mode in high speed cam mechanism, motion law of that design method of harmonic motion rules and corresponding mechanism analysis. The design method based on traditional design, through modal analysis of cam mechanism in traditional design, to observe its vibration mode, determining mechanism of modal frequency, natural frequency of the mechanism to determine the modal frequencies, analysis, effect of vibration on the actuator end. Based on modal analysis, to determine the number of harmonic components, through the definition of displacement, velocity or acceleration harmonic superposition formula as the goal function, according to the law of motion or constraint conditions of the work requirements, by determining the coefficients of the harmonic component of the optimization method, the expression of the final movement are obtained. To set up a dynamic model of system components of the elastic deformation of engine cam mechanism considering the circumstances of high speed, and is used in the Matlab/Simulink solution and simulation, the process is simple, convenient, intuitive, easy to learn, is a kind of simulation method is effective. Output by simulation process can draw the valve response fluctuation, illustrate the analysis of the mechanism dynamics must be at high speed.

REFERENCES

[1] A.Angel, Bayod-Rujula; Future development of the electricity systems with distributed generation[J], Energy, **34(3)**, 377-383 **(2009)**.

[2] Qi Bing l, Yang Xuc-jinl, GongGang-junl; Design and realization of electric Power communication resource management system[J], Relay, **33(16)**, 54-61 **(2005)**.

[3] E.Luder; The network-and system’s theory of electrical communications[J], Umschau inWissensehaft und Teehnik, **74(10)**, 303-306 **(1974)**.

[4] Cai, Jun, Shen, Xucmin, Mark, W.Jon; Downlink resource management for packet transmission in OFDM wireless communication systems[J], IEEE Transactions on Wireless Communications, **4(4)**, 88-1702 **(2005)**.

[5] Lian Zhao, J.W.Mark; Integrated Power control and rate allocation for radio resource management in uplink wideband CDMA systems[C], Proceedings. Sixth IEEE International Symposium on a World of Wireless Mobile and Multimedia Networks, 428-436 **(2005)**.

[6] Man Cheol Kim, Jinkyun Park, Wondea Jung, Hanjeom Kim, Yoon Joong Kim; Development of a standard communication protocol for an emergency situation management in nuclear power plants[J], Annals of Nuclear Energy, **37(6)**, 888-893 **(2010)**.

[7] Chia-HungLien, Hsien-Chung Chen,Ying-Wen Bai, Ming-Bo Lin; Power Monitoring and Control for Electric Home Appliances Based on Power Line Communication[C], Instrumentation and Measurement Technology Conference proccedings, 2-79 **(2008)**.

[8] Xu,Liang, Chen, Tianding, Ren,Zhiguo, Wu,Di; Resource management for uplink OFDM wireless communication system [C]. Global Mobile Congress, 284-288 **(2007)**.

[9] Majid Khodier, Gamcel Saleh; Beamforming and Power control for interference reduction in wireless communications using particle swarm optimization[J], International Journal of Electronics and Communications, **64(6)**, 489-502 **(2010)**.

[10] Aleksandar Radonjie, Vladimir Vujicie; Integer SEC-DED codes for low power communications[J], Information Processing Letters, **110(12-13)**, 518-520 **(2010)**.