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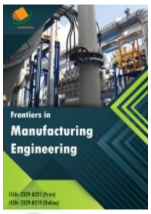

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MODELING AND SIMULATION OF AN AUTOMATIC BALANCE OSCILLATOR MECHANISM BASED ON ANSYS

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ABSTRACT

In order to solve the problem of vibration caused by unbalance dynamic, and optimize certain parameters to improve the balance adjustment device of thermostatic oscillator, this paper introduces a method to simulating the modal of the core components of thermostatic oscillator. By using the finite element software ANSYS Workbench, we obtain the natural frequencies and mode shape maps. And then comparing with the frequencies which balance blocks in different angles, we find that if the machine load remains constant, the change of the center of mass will have little effect on the modal frequency.

KEYWORDS

Modal analysis, ANSYS Workbench, thermostatic oscillator, prototype experiment.

1. INTRODUCTION

Thermostatic oscillator is widely used in industrial fields, for mixing liquids and cultivating bacteria. But its high-speed operation will cause inertia force and then vibration occurred, the vibration emerges the base of thermostatic oscillator.

Based on a study, vibration always happened in rotating machinery, when the vibration frequency is close to the nature frequency of mechanical system, it will generate resonance [1,2]. These vibrations will result in institutional dynamic imbalance, reducing the efficiency and reliability of the machine, shorting the service life of the machine. According to incomplete statistics, mechanical failures caused by vibration account for 70% ~ 80% of total failures [3]. Currently, there is no perfect solution to solve the above problems. Study showed the problems caused by vibration also becomes the biggest obstacle to move the body of scientific knowledge forward [4]. Therefore, the research for dynamic balance technique of the thermostatic oscillator has a significance value on academic and engineering application.

Thermostatic oscillator itself has certain rigidity, it has different frequencies when balancing mass in different angles, if the systems is as same as the natural frequency, resonance makes entire thermostatic oscillator system vibration. ANSYS Workbench software can efficiently solve complex problem, such as structure statics, dynamics, vibration, modal analysis and harmonic response analysis and so on. It is an effective tool for CAE, engineering numerical analysis and simulation.

Modal analysis of multi-body systems is broadly used to study the behavior of dynamic systems. In order to avoid resonance, this paper established the model of thermostatic oscillator and analysis its modal by ANSYS, find its natural frequency. Undoubtedly, it has practical significance for designing thermostatic oscillator.

2. FOUNDATION OF MODAL ANALYSIS THEORY

Modal analysis is an important and useful tool for product design and dynamic testing. Parameters gathered from modal analysis such as natural frequencies, damping ratios and mode shapes are important to achieve desirable properties, and to prevent vibrations or catastrophic failures. These parameters can be obtained from the numerical simulations and experimental analysis. For current work, the fundament of the thermostatic oscillator is fixed. Thus, represented by a set of explicit second order ODEs. In addition, the system is assumed to have generic damping that is not necessarily proportional. According to the dynamic load principle of virtual work, for such a system with finite degree of freedom he set of differential equations is given by,

$$M\phi + C\phi + k\phi = Q \quad (1)$$

Where M is the mass matrix of structural, C is the damping matrix, K is the stiffness matrix, ϕ is the array of the node displacement, Q is the load array of structural. In this paper, taking Q as zero matrix, ignoring the impact of damping system, the definition can be rewritten as:

$$M\phi + K\phi = 0 \quad (2)$$

There is a solution of the linear non-homogeneous recursion equation with constant coefficient, the array of the node displacement is calculated as:

$$\phi = \phi_0 \sin(\omega t + \varphi) \quad (3)$$

Where ω is the natural frequencies of vibration, the unit is HZ; φ is the initial phases of vibration, the unit is "°". Put (3) into (2), which becomes:

$$(K - \omega^2 M)\phi = 0 \quad (4)$$

Equation (4) has a nonzero solution in the condition of the determinant of coefficient is equal to zero, namely:

$$\left| K - \omega^2 M \right| = 0 \quad (5)$$

The above equations in the modal analysis makes the problems of free vibration characteristic (natural frequencies and mode shapes), which can be converted to solve the problems of the matrix eigenvalue and eigenvector. The method will be used to evaluate the individual modal elements.

3. ESTABLISH MODEL OF THE THERMOSTATIC OSCILLATOR

A thermostatic Oscillator model, is chosen to apply the developed methodology. The model consists of the special counterweight mass, namely, the major mass sup-ported by the base support, for the parameters should satisfy the condition of mass balance adjustment. According to a research, it is helpful to introduce flexible bodies into the dynamic model of mechanical system to improve the simulation accuracy [5]. In this article the thermostatic oscillator movement structure assembly of modal analysis is a linear analysis, the whole process is divided into four steps: (1) Build a model; (2) mesh; (3) solve after loading; (4) The result processing.

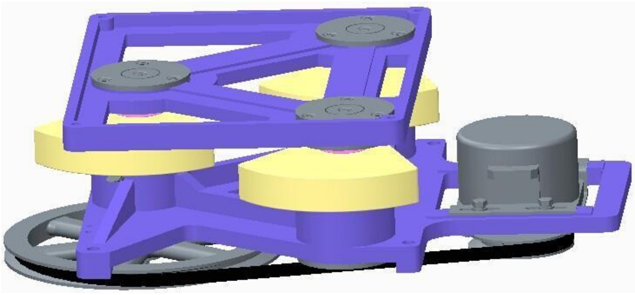
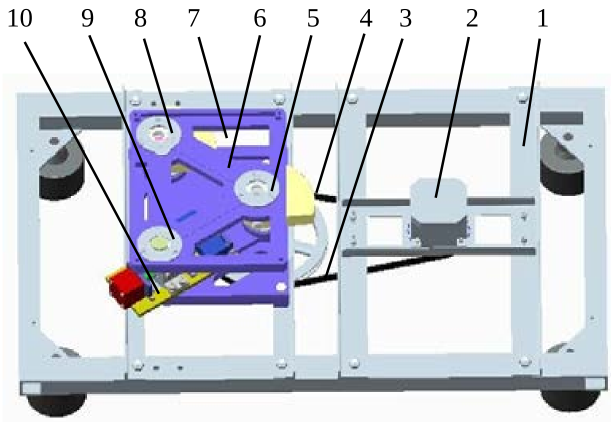


Figure 1: The original structure of thermostatic oscillator.

First of all, the 3d model is established by Cero2.0 software, this paper is based on quality adjusted balance method. Through the motor drive the balance quality, the balancing mass produces equal compensation vector in the opposite direction. This method will not cause damage on the original institutions, so many scholars made in-depth study of the method, such as Van de Vegte, Smalley, Memuth, etc. A group of researchers are trying to design a variety of balancing head [6-13]. The original structure of thermostatic oscillator as shown in Figure 1, this paper improved one of the balance mass as a new dynamic balance control device, the 3d model and physical prototype as shown in Figures 2 and 3.



1-supporting plat; 2-motor 3- belt pulley; 4- balance mass Ⅰ ; 5- drive crankshaft Ⅰ;6- upper cradle; 7- balance mass Ⅱ; 8-driven crankshaft Ⅱ; 9- driven crankshaft Ⅲ;10- The new dynamic balance control device;

Figure 2: The improved structure of thermostatic oscillator.

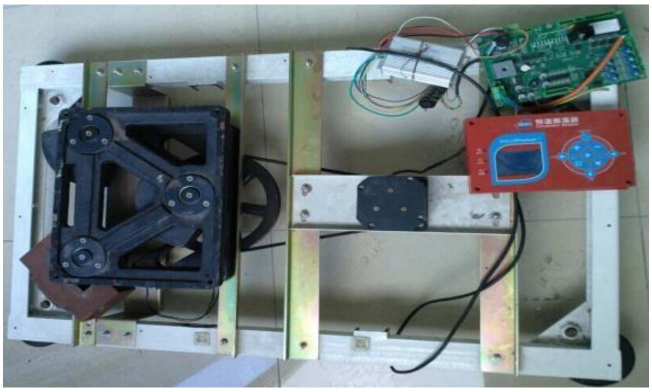
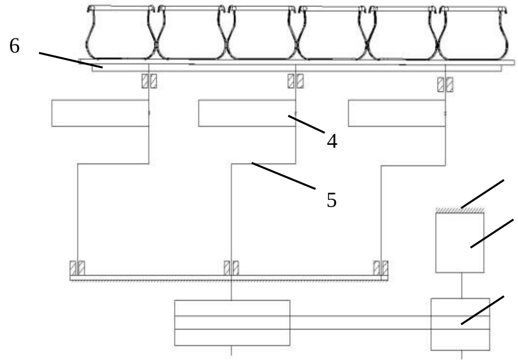


Figure 3: The physical prototype of thermostatic oscillator.

Motor provides the power, to drive the rotation of the pulley and crankshaft, three balance masses are installed on each crankshaft, with the lead of crankshaft, the upper cradle shakes at a certain radius, then the liquid which in the beaker is mixed. The working principle of thermostatic oscillator shown as Figure 4.



1-supporting plat;2-motor; 3- belt pulley; 4-balance mass; 5- drive crankshaft; 6- upper cradle.

Figure 4: The working principle of thermostatic oscillator.

Simplify the parts of bolt holes and bolt of installation structure, converted into STP format, import to workbench, define contact, simplified parts using bonded contact type, then divide the grid load and solving. According to the actual working condition, impose constraints, the bottom of the pedestal are fixed (see Figure 5).The grid as shown in Figure 5.

According to the practical work experience, only a minority of the mechanical structure of the lower modal are easy to be inspired, and not easy to be inspired in higher modal. So, rarely appear when equipment works lower than 10 Hz frequency and higher than 70 Hz frequency phenomenon, so this paper only analyzes the 1-6 order vibration mode of the structural. With the center line of the balance weight to the right of 0°, we get its frequency, it is shown as Table 1,

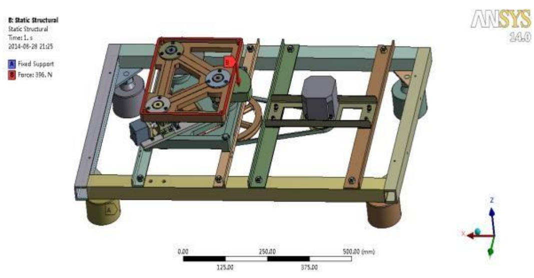


Figure 5: The load and constraint of the crankshaft.

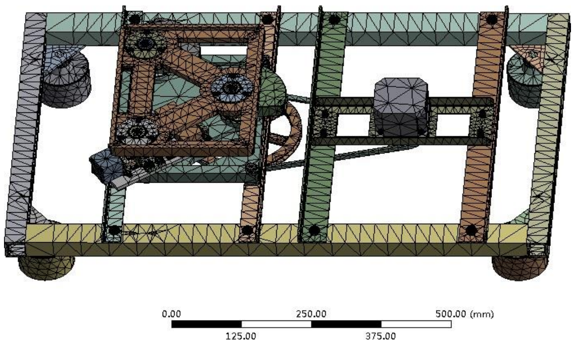


Figure 6: The FEA model of the crankshaft.

Table 1: The tabular data when Balance blocks in 0°.

Mode	Frequency (hz)
1	51.057
2	76.923
3	108.78
4	112.23
5	168.24
6	179.18

When balance blocks in 0°, we get the modal frequency chart (Figures 7-12).

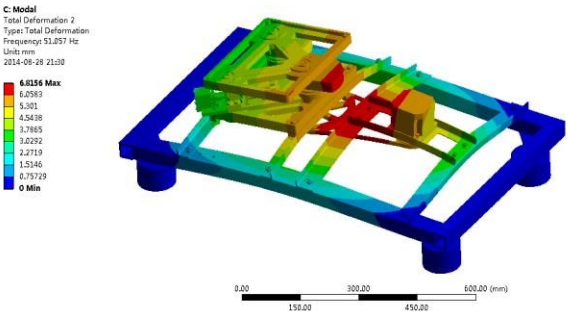


Figure 7: The first order vibration mode of machine.

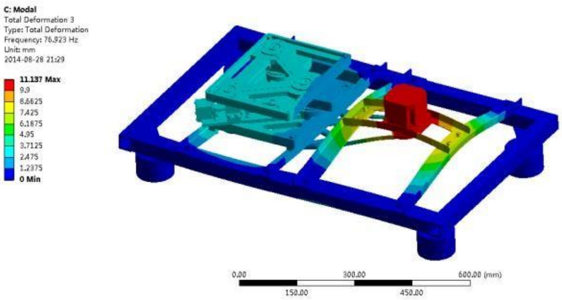


Figure 8: The second order vibration mode of machine.

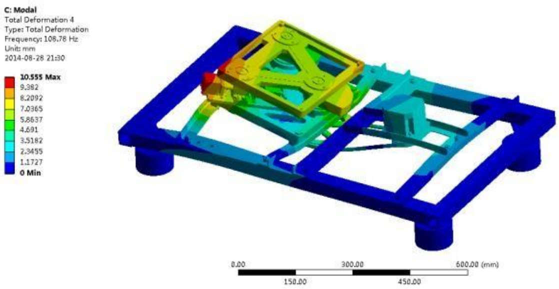


Figure 9: The third order vibration mode of machine.

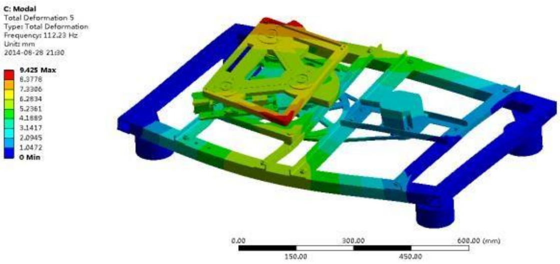


Figure 10: The fourth order vibration mode of machine.

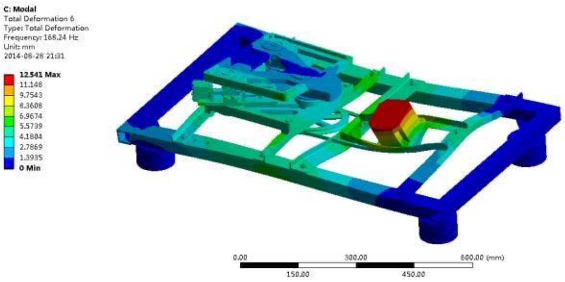


Figure 11: The fifth order vibration mode of machine.

Contrasted the modal frequency of balance blocks in different Angle, we get the Table 2 and the Figure 13. From the chart, It indicate that when the balance blocks of the thermostatic oscillator in different angles, the frequencies of the same number order tend to be similar, the angles has little effect on the frequency variation of the machine.

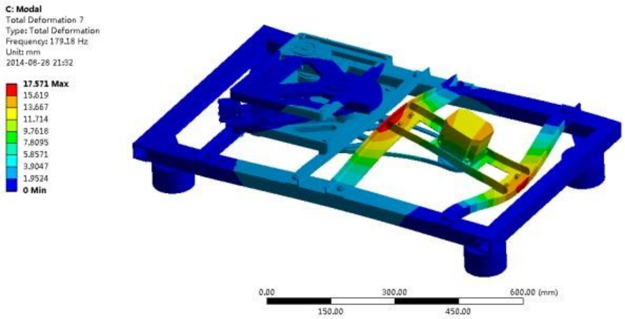


Figure 12: The sixth order vibration mode of machine.

Table 2: The modal frequency of thermostatic oscillator when balance blocks at different angles (HZ).

Mode / Angle	1	2	3	4	5	6
0	51.158	76.902	109.74	112	168.1	178.95
60	51.048	76.924	108.88	112.83	168.81	179.12
120	51.321	76.822	108.65	111.62	168.2	178.86
180	51.343	76.751	107.03	112.42	168.93	179.16
240	51.28	76.777	108.27	112.31	168.43	179.23
300	51.111	76.869	109.19	112	168.34	179.15

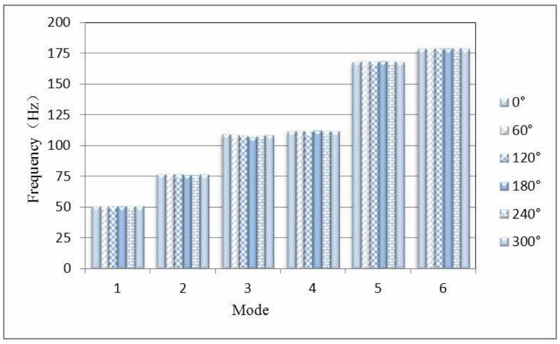


Figure 13: The data comparison of modal frequency when balance blocks at different angles.

Finally, some experiments are made in this paper, to evaluate the effect of the new adjusting device. Change the quality of the load, testing the movement distance of the balance mass. The experimental apparatus is shown in Figure 14. According to the experimental data, we get the contrast figure error rate shown as Figure 15. The chart shows that the new experiment device can meet the design of requirements.

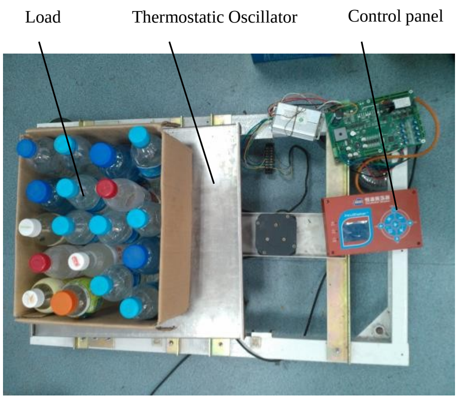


Figure 14: Experimental apparatus.

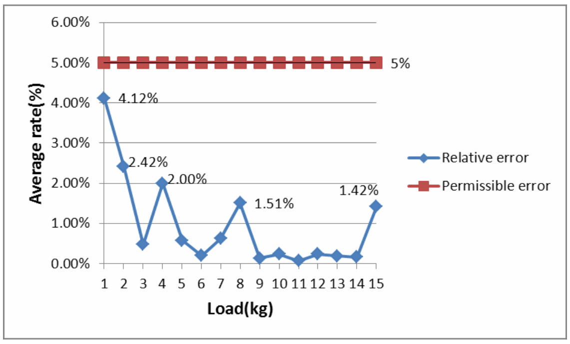


Figure 15: Comparison of experimental results on average error rate and engineering permissable error rate.

4. CONCLUSION

In this paper, ANSYS Workbench is used to analysis the modal of thermostatic oscillator, and we get the inherent frequency and vibration mode. Through the change of the modal analysis we can predict the change of dynamic structure. It will provide the reference for the accurately modal analysis of vibration characteristic the fault diagnosis for vibration and the optimization design of structural dynamic characteristics. The analysis method and consequences on the mechanism of thermostatic oscillator can provide instructions for the development and research on oscillator's mechanism. We can get some results as follows: (1) This paper designed a new automatic balancing device and carries on the analysis, from the results we can indicate that when the balance blocks of the thermostatic oscillator in different angles, the frequencies change little, the changes of the internal coordinates has little effect on the frequency variation of the machine . (2) According to the simulation result, the constraint modal results accord with the actual displacement constraints of thermostatic oscillator. The automatic balancing machine in the first six order some part of the mechanical structure appear deformation, but the bottom bearing does not appear to be out of shape. (3) Experiments indicate that the new thermostatic oscillator can meet the design of requirements and reduce the vibration effectively.

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