Virtual Prototype Design of a Novel Centrifuge and Its Simulation Analysis

Haobo Wang[1], Jintong Han[2], Shuo Han[1], Hui Li[1]*

1.School of Mechanical Engineering and Automation, Northeastern University, Shenyang, China 110819
2. Northeast Yucai Foreign Language School, Shenyang, China 110179

Abstract: In order to solve the problems of light-weight design of a centrifuge, a novel type of centrifuge is designed and its dynamic characteristics are studied. Firstly, a novel structural design is proposed and its three-dimensional model is established based on SolidWorks software. Then, based on ADAMS simulation platform, a virtual prototype of the centrifuge is built up, and the dynamic simulation analysis of the whole centrifuge is carried out. The simulation results show that the designed centrifuge has good dynamic stability, and the acceleration response amplitude of key parts increases as the rotating speed and unbalance increases. Based on the simulation results, the design structure and parameters needs to be further optimized and improved in order to reduce the vibration of the centrifuge operation and improve its stability, and this can provide guide for the design and research of related products.

Keywords: Centrifuge; Virtual prototype; Dynamic simulation

1 Introduction

Centrifuge is a machine that uses centrifugal force to separate components in liquid and solid particles or mixture of liquid and liquid. Since the advent of centrifuge, it has experienced changes of low speed and overspeed. Its progress is mainly reflected in two aspects, centrifugal equipment and centrifugal technology which are complementary.

Moreno - Barragan [1] uses 3D finite element model to realize the accurate diagnosis of several vibration faults of aeroengine. The elastic support structure is closely related to the vibration of rotor system and even the whole machine, and its unique relative independence has become a widespread concern of scholars at home and abroad. San Xiaogang[2] investigated the lightweight design of large base using results of topology optimization of continuum structure.The theory of continuum topology optimization is

*Corresponding author (lh200300206@qq.com)

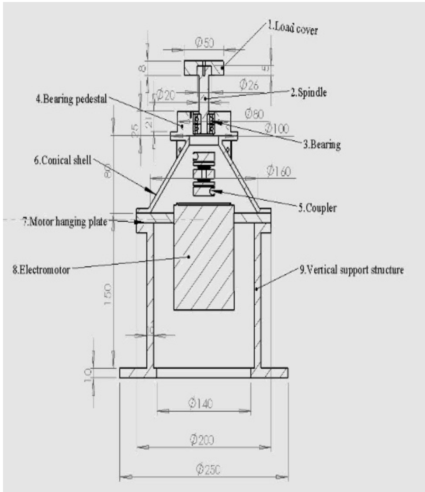
 ISSN 2572-4975 (Print), 2572-4991 (Online)

introduced,and mathematical model of topology optimization is established.Then make topology optimization design to the base of a large theodolite and obtain its optimal material distribution. Results of finite element analysis to the truss base show that, comparing to the traditional cast structure, the lightweight base can lose 357.4kg and lightweight ration is 27.8% without changing the static displacement.Wang Yuegang et al.[3] established a virtual prototype model of the composite system of centrifuge and shaking table in ADAMS virtual prototype software platform.Then, the system is considered as a rigid flexible coupling system, the dynamics simulation analysis of the system is done. At the same time, the effect on the output properties of the system caused by the angular velocity of centrifuge facility and frequency of vibration shaker is studied. It provides a theoretic basis for the design of the centrifuge facility-vibration shaker system.Based on the workbench, Cheng Xiaoyong [4] established a three-dimensional solid model of the support, which consists of the pedestal, gearbox, support plate and bearing pedestal. The stiffness of the support under different grid division and bearing loading mode was discussed.In literature[5],the belt drive system of the centrifuge as the core component for variable gravity experiment in space station is analyzed by multibody system dynamics, and the virtual prototype is built by the belt discretization. The curves of displacement,velocity,acceleration,tension,contact are obtained by simulation.Qiu Qingzhang et al.[6] established the vibration model of the tripod centrifuge.The characteristics of the generalized coordinates changing with time are obtained by numerical simulation. The dynamic characteristics are analyzed and the correctness of the dynamic model is verified.The centrifuges in our study can complete the conventional solid-liquid separation, liquid-liquid separation and other work, but due to the application of the centrifuges in the space capsule, there are strict requirements on their quality and size.

In order to provide enough centripetal acceleration, the rotating speed of the centrifuge must be increased without increasing the size of the rotating mechanism. Under the condition of large load and high rotating speed, the vibration and its transmission law are studied, and the vibration reduction scheme is designed. Because of its relatively complex structure, stress and material, it is difficult to use the traditional analytical method and solution, so in order to reduce the cost and time, we will use the design virtual prototype for this centrifuge to carry out simulation analysis.

2 Structural design

A new type of centrifuge structure is designed, and the topology of the main parts is optimized to realize the lightweight design. The main parts include load plate, shaft, bearing, bearing house, coupling, conical shell, motor hanging plate, motor and vertical support. The motor drives the load plate to rotate through the main shaft, forming the rotor part of the centrifuge. The bearing pedestal, plate and vertical support structure complete the stator part. The main shaft and the bearing pedestal are connected by two angular contact ball bearings, and its detailed structure is as shown in Fig.1. Then, the 3D model of centrifuge is established by SolidWorks software, as shown in Fig.2.



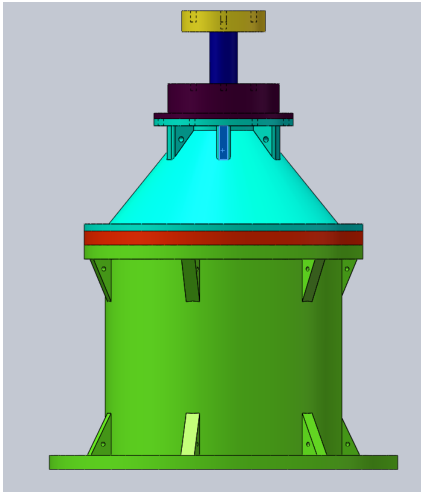


Fig.1 Diagram of a new lightweight centrifuge **Fig.2** The 3D model of centrifuge

The 3D solid model is imported into Adams. Then add fixed joint between the model and ground. Thirdly, add rotating joint between the spindle and the model. Finally, the multi-rigid model is generated after adding constraints, as shown in Fig.3.

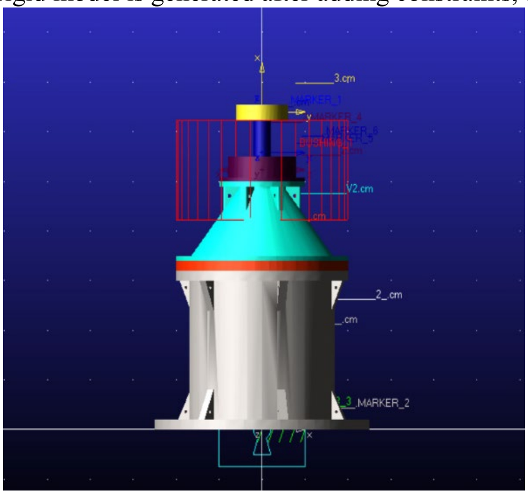


Fig.3 The model of Centrifuge in ADAMS

3 Simulation analysis

Simulate the centrifuge, simplify the model, apply the fixed pair on the load plate and the main shaft, and apply the spring support on the main shaft by Adams. The time-domain and frequency-domain graphs are obtained by changing the speed and unbalance of the measuring points 1 and 2 on the main shaft and load plate respectively.

 ISSN 2572-4975 (Print), 2572-4991 (Online)

3.1 Vibration response of different speeds with 500g.mm unbalance

500g.mm unbalance force is exerted on load plate, and the rotating speed is adjusted by Frequency converter, to 12000r/min, 9000r/min, and 6000r/min. And acceleration response amplitude of measuring point 1 and point 2 are both obtained. Layout of measuring points is as shown in Fig.4.And the different results are shown from Fig.5 to Fig.10.

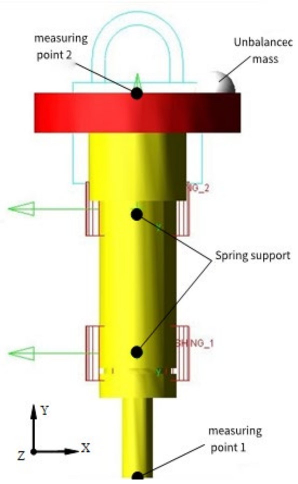
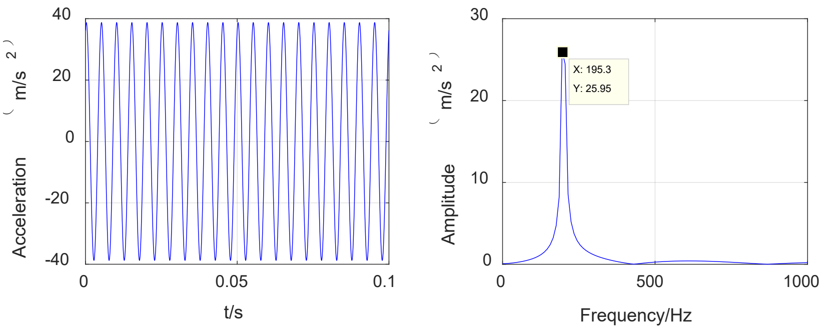


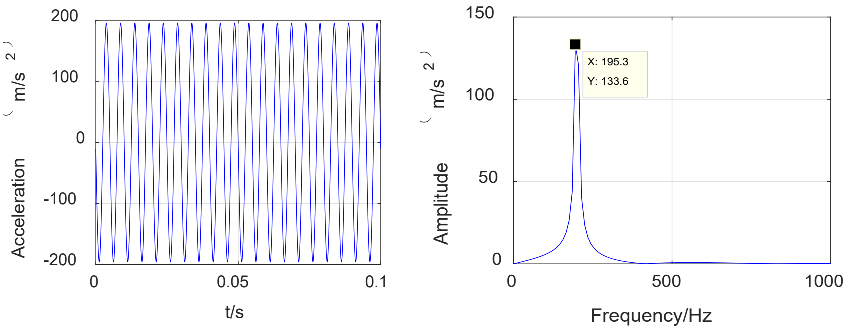
Fig. 4 Layout of measuring points

(1) working condition：12000r/min



(a) Time domain chart (b) phase chart

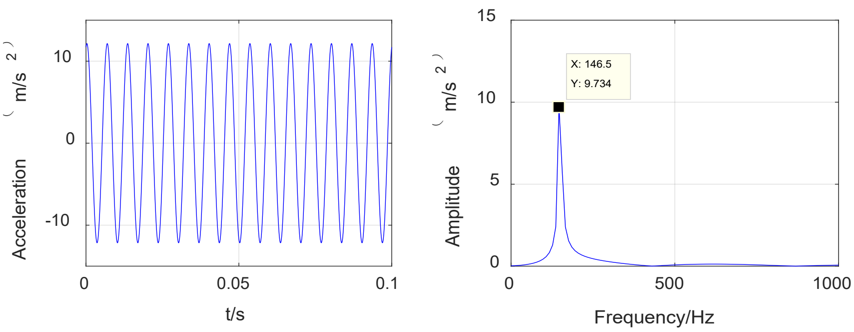
Fig.5 Acceleration response amplitude of measuring point1 in X-direction



(a) Time domain chart (b) phase chart

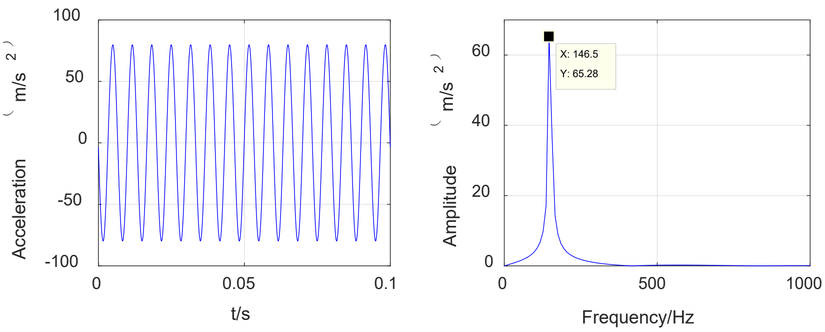
Fig.6 Acceleration response amplitude of measuring point2 in X-direction

(2) working condition：9000r/min



(a) Time domain chart (b) phase chart

Fig.7 Acceleration response amplitude of measuring point1 in X-direction

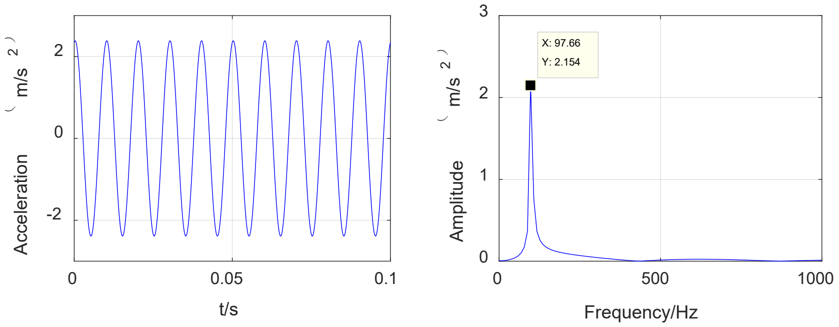


(a) Time domain chart (b) phase chart

Fig.8 Acceleration response amplitude of measuring point2 in X-direction

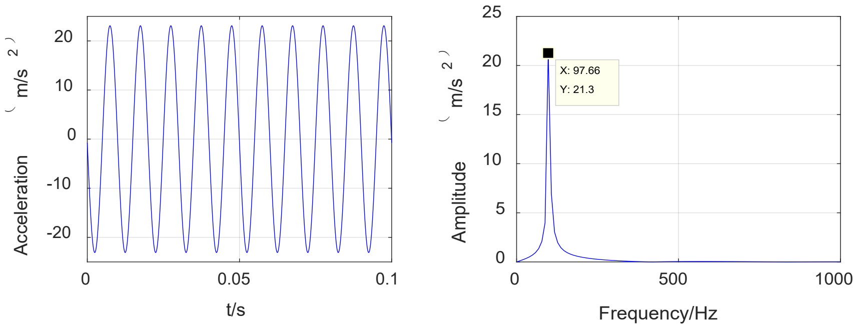
(3) working condition：6000r/min

 ISSN 2572-4975 (Print), 2572-4991 (Online)



(a) Time domain chart (b) phase chart

Fig.9 Acceleration response amplitude of measuring point1 in X-direction



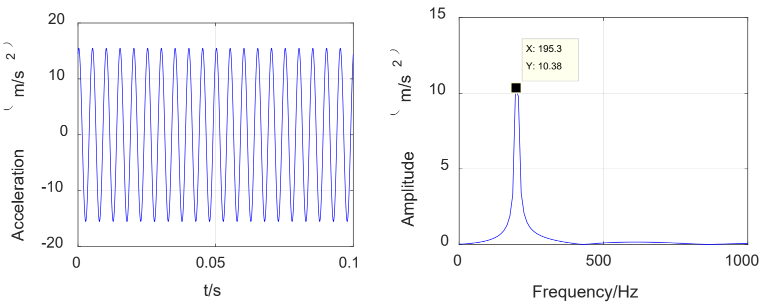
(a) Time domain chart (b) phase chart

Fig.10 Acceleration response amplitude of measuring point2 in X-direction

3.2 Vibration response of different speeds with 200g.mm unbalance

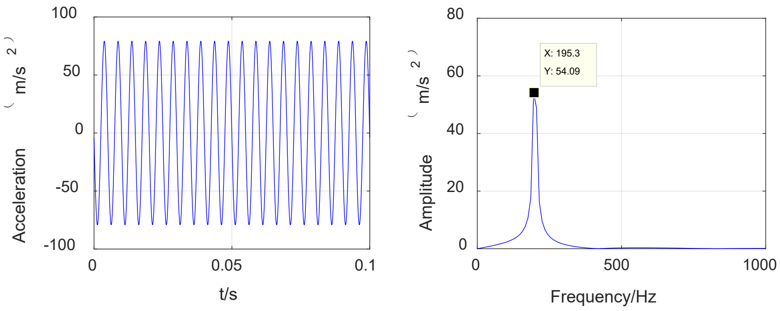
200g.mm unbalance force is exerted on load plate, and the rotating speed is adjusted by Frequency converter, to 12000r/min, 9000r/min, and 6000r/min. Acceleration response the amplitudes of measuring point1-2 are both obtained. And the different results are shown from Fig.11 to Fig.16.

(1) working condition：12000r/min



(a) Time domain chart (b) phase chart

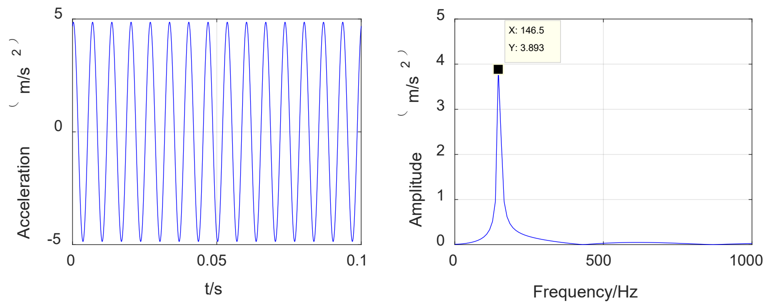
Fig.11 Acceleration response amplitude of measuring point1 in X-direction



(a) Time domain chart (b) phase chart

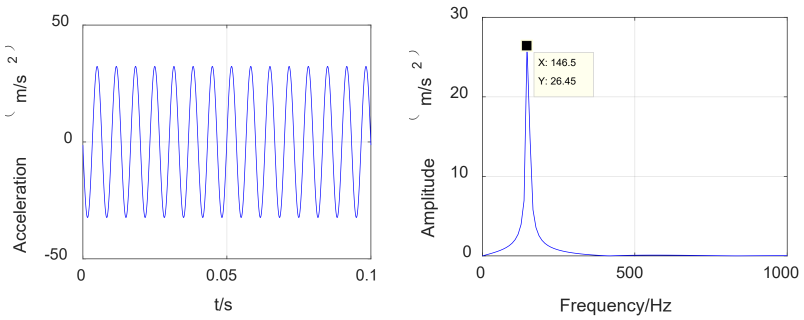
Fig.12 Acceleration response amplitude of measuring point2 in X-direction

(2) working condition：9000r/min



(a) Time domain chart (b) phase chart

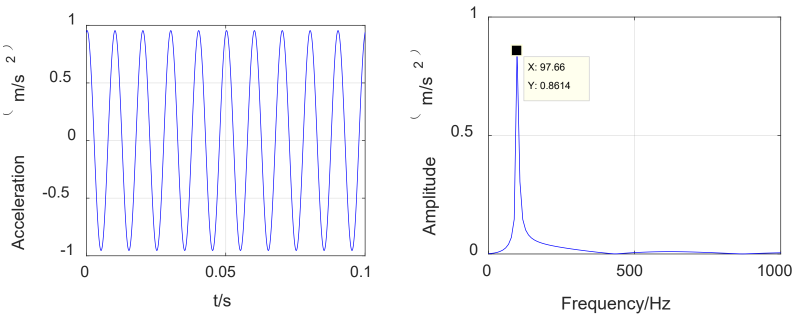
Fig.13 Acceleration response amplitude of measuring point1 in X-direction



(a) Time domain chart (b) phase chart

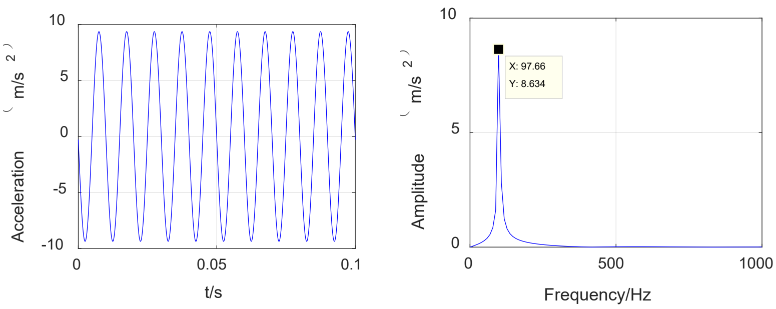
Fig.14 Acceleration response amplitude of measuring point2 in X-direction

(3) working condition：6000r/min



(a) Time domain chart (b) phase chart

Fig.15 Acceleration response amplitude of measuring point1 in X-direction



(a) Time domain chart (b) phase chart

Fig.16 Acceleration response amplitude of measuring point2 in X-direction

3.3 Vibration response of different speeds with 200g.mm unbalance

Both of acceleration response amplitude of measuring points 1 and measuring points 2 in X-direction are curved as Fig.17-Fig.18. As can be seen, the acceleration response amplitude of key parts increases as the rotating speed and unbalance increases. The vibration of the end of the shaft is larger than that of load plate.

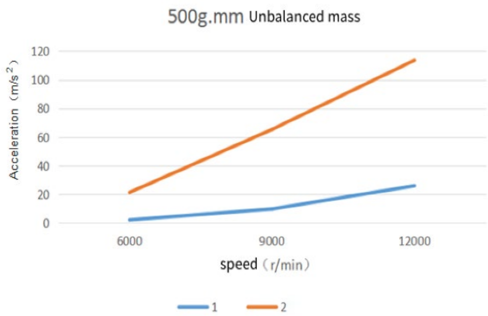


Fig.17 Acceleration response amplitude of measuring points1-2 with 500g.mm unbalance

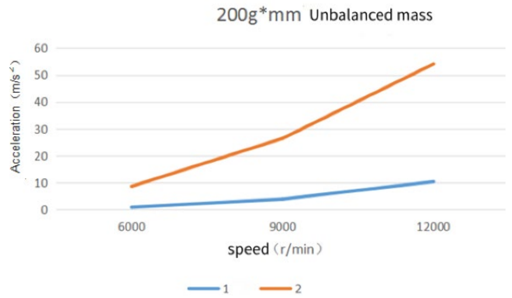


Fig.18 Acceleration response amplitude of measuring points1-2 with 200g.mm unbalance

4 Conclusion

In this experiment, SolidWorks was used to establish a new lightweight centrifuge model, and then ADAMS simulation system was used to simulate the model. The vibration response law of the centrifuge under different rotating speeds and different imbalances was studied, that is, with the increase of rotating speed, the vibration of the centrifuge increased; the larger the unbalance, the greater the vibration of the centrifuge. Therefore, it is necessary to optimize the structure of the centrifuge to further reduce the vibration level of the centrifuge.

References

1. Moreno-Barragan J A, Investigations into engine transient response due to internal and external dynamic excitations , ***6th IFToMM Conference on Rotor Dynamics,*** 2002, 171.
2. San X G, Wang Y, Xue Y, Based on the continuum topology optimization of the large base lightweight design, ***Journal of Changchun University of Science and Technology,*** 2012,35(3):4-7.
3. Wang Y G, Zuo Z Y, et al, Kinematics and dynamics simulation analysis of centrifuge facility-vibration shaker system based on ADAMS, ***Journal of Machine Design,*** 2013,30(7):33-37.
4. Cheng X Y, Chen G, Li C G, et al, Rotor support simulation design and equivalent stiffness computation for aero-engine, ***Aeronautical Computing Technique,*** 2012, 42(6):9-12.
5. Li T F, Liu B S, Xue J, Wang K, Multibody dynamics analysis for the belt drive system of the centrifuge in space station, ***Journal of Mechanical Transmission,***2016,40(10):143-147.
6. Qiu Z H, Chen W W, An W, Wu X Q,Vibration model of three-foot centrifuge, ***Light Industry Machinery,***2014,32(6):17-20.