Design of a Vehicle-mounted Seismic Simulation Platform

2020, Vol.1 No.6
© Art & Design Research 2020
DOI: 10.37420/j.adr.2020.030
https://masonpublish.org

Yang Dai*
Chongqing Liandong Human Resources Co., Ltd., Chongqing, China
*Corresponding author, e-mail: snesx@msn.com

Abstract

Considering that there are a variety of earthquake science popularization vehicles, earthquake simulation experience platforms, and earthquake science popularization teaching equipment currently on the market, this article combines the characteristics of mobile publicity vehicles and earthquake simulation experience platforms to design a brand new car as a carrier, earthquake knowledge experience platform to achieve the purpose of enhancing the effectiveness of earthquake science propaganda.

Keywords

Earthquake experience; Vehicle-mounted platform; Popularization of earthquake science

Introduction

Earthquake is a natural disaster that can only be prevented to reduce casualties. Since the Wenchuan earthquake, China has set up the "5.12 Earthquake Prevention and Mitigation Day", which requires the whole society to organize various kinds of popular science and publicity activities for earthquake prevention and disaster reduction, so that people can experience the scene of earthquake disasters in advance, enhance the awareness of earthquake prevention and self-relief capacity, and minimize the disaster losses. In view of the current situation of earthquake and secondary disaster simulation experience equipment in China, a vehicle mounted earthquake experience platform is designed to make up for the limited coverage capacity and high operating cost of the exhibition hall.

The Key Technical Requirements of the Vehicle-mounted Seismic Platform

The earthquake experience car sets up an earthquake experience room based on the real home

environment. There are tables, chairs, gas stoves, cabinets, ceiling lights, collapsed beams in the room. When an earthquake occurs, the platform will vibrate, causing roof collapse, beam falling, circuit short, gas leakage. The experiencer needs to complete actions such as avoiding, cutting off the switch, closing the valve, and extinguishing the fire. The seismic simulation platform is the key to all links.

At present, the driving of seismic simulation platform mainly includes electric push rod type and hydraulic servo-controlled type. We consider the advantages of hydraulic servo-controlled type with large thrust, large displacement and long life at low frequency, so this project chooses hydraulic servo-controlled method to design the earthquake simulation platform. According to the previous analysis, the key technical requirements that need to be implemented are as follows:

① Through PC, seismic platform, communication network and other equipment, we simulate the three stages of seismic wave when an earthquake occurs. According to the sequence of occurrence time, the seismic waves generated by earthquakes are generally divided into three stages: P wave, S wave and L wave. The amplitude of P wave is smaller and the frequency is higher (> 3Hz), and the upper and lower vibrations are the main ones. The amplitude of S wave is larger and the frequency is lower (< 3Hz), which is mainly left-right shaking. L wave is generally considered as the superposition of P wave and S wave, which is the most destructive. The time and interval of these three stages should be calculated and designed according to the real seismic data and theoretical knowledge. When people are experiencing vibration, we must popularize the basic knowledge about earthquake and tell the experiencer to show the real state.

② Magnitude simulation and magnitude display. According to the amplitude and frequency of the seismic station, we designed five earthquake magnitudes: from 4 to 8, and the magnitude is selected by the operator. At the same time, we set the front of the body can display the current magnitude of the LED home screen. The seismic simulation platform will also realize the vibration of six degrees of freedom in three directions, up and down, left and right, front and back. Moreover, the vibration direction can be superimposed, and multiple directions can vibrate at the same time.

Model Selection of Vehicle-borne Seismic Platform

The earthquake simulation platform is used for on-board earthquake experience, and the size of the carriage body is 6500×2420×2500 (mm). Because other equipment will be placed, the effective use space of the platform is 4170×2000×2020 (mm). The main loads are people (experiencers) and the furniture in the room. The number of people to experience is set to 5, and the average weight of each person is 80kg, plus the total load-bearing load of the furniture will not exceed 1000kg. In addition, under comprehensive consideration, we have reserved 50% of the space.

Table 1. Design specifications of earthquake simulation platform

Parameter	Indicator
Platform size	3120×1517×600m
Rated load	1000kg
Maximum displacement	±50mm
Motion frequency	0 ~ 10Hz
Maximum acceleration	1g
Vibration direction	XYZ triaxial compound

Because XYZ hydraulic cylinders are designed on different vibration platforms, the pressure on the platforms is also different. On the premise of ignoring external leakage, fluid compressibility and friction, in order to ensure that the seismic simulation platform can meet the target of 3,000kg rated load and 1g maximum acceleration, the thrust output of the hydraulic cylinder must be greater than the resistance received:

Friction:

$$F_f = \mu \times F_n = \mu mg$$

Inertia:

$$F_m = m \times a$$

Output thrust:

$$F_1 = p_1 \times A_1 \times \beta$$

Output tension:

$$F_2 = p_2 \times A_2$$

Pressure area of push side piston (cm^2):

$$A_1 = \pi D^2/4$$

Pressure area on pull side piston (cm^2):

$$A_2 = \pi(D^2 - d^2)/4$$

In the above formula, μ is the friction coefficient of the transmission mechanism, generally =0.16; g is the acceleration due to gravity, g=9.8m/s^2; is the mass of the moving parts, the weight of the platform is 1t plus the maximum load of 1,000kg, which is =2,000kg; movement acceleration a=g=9.8m/s^2; A is the hydraulic cylinder area, is the hydraulic pump output pressure, load factor =80%, D40-L100 ball head cylinder inner diameter D=40mm, piston rod diameter d= 25mm.

Therefore, on the X and Y axes, there are:

$$p_1 = \frac{F_1}{A_1\beta} = \frac{F_m + F_f}{A_1} = \frac{ma + \mu mg}{\beta \pi D^2/4} = \frac{2000 \times 9.8 + 0.16 \times 2000 \times 9.8}{0.8 \times 3.14 \times 4^2/4} = \frac{2262.74kgf}{cm^2} = 230.89Mpa$$

$$p_2 = \frac{F_1}{A_2\beta} = \frac{F_m + F_f}{A_2\beta} = \frac{ma + \mu mg}{\beta\pi(D^2 - d^2)/4} = \frac{2000 \times 9.8 + 0.16 \times 2000 \times 9.8}{0.8 \times 3.14 \times (4^2 - 2.5^2)/4}$$
$$= 3713.21 kgf/cm^2 = 378.90 Mpa$$

On the Z axe, there are:

$$p_1 = \frac{F_1}{A_1\beta} = \frac{F_m + F_f}{A_1} = \frac{ma + mg}{\beta\pi D^2/4} = \frac{2000 \times 9.8 + 2000 \times 9.8}{0.8 \times 3.14 \times 4^2/4} = 3901.27 kgf/cm^2$$
$$= 398.09 \text{Mpa}$$

$$p_2 = \frac{F_1}{A_2\beta} = \frac{F_m + F_f}{A_2\beta} = \frac{ma + mg}{\beta\pi(D^2 - d^2)/4} = \frac{2000 \times 9.8 + 2000 \times 9.8}{0.8 \times 3.14 \times (4^2 - 2.5^2)/4}$$
$$= 6402.09 kgf/cm^2 = 653.27 Mpa$$

According to calculations, in order to ensure that the platform can support a weight of 1,000kg, we need to select a motor with a voltage of 220V, a power of 0.7KW, a gear pump displacement of 2.5m/r, and a working pressure of 10MPa. The components of the hydraulic platform are selected from the fastest running device in China (the cylinder running speed is 500mm/s, the solenoid valve is 300 times per minute), and the surface is laminated with laminate flooring.

Design of the Motion Mechanism of the Vehicle-mounted Seismic Platform

At present, according to the classification of driving energy, the common seismic simulation platform has hydraulic, electric and pneumatic three kinds. Each of the three actuators has its own characteristics. Pneumatic actuators are powered by a gas source, which is cheaper than electric ones. And because the medium air viscosity is small, its long-distance transmission loss is small, the structure is simple and easy to maintain. However, the main disadvantages of the pneumatic mechanism are poor precision, slow response, poor anti-deviation capability. This is because if automatic control is needed, it must add solenoid valve, and solenoid valve sensitivity will directly affect the pneumatic valve. In addition, the gas is highly compressible, so it takes time to fill the cylinder and empty it, but it cannot return to the preset position in time after the gas source is cut off.

The advantages of the second electric actuator are strong anti-deviation ability, constant output torque, high sensitivity, and high control accuracy. But its structure is complex and easy to break down. And if the electric adjustment is too frequent, it will easily cause the motor to overheat and increase the wear of the reduction gear. In addition, the speed control time of the motor is long, and the response from the regulator output signal is relatively slow.

The third kind of hydraulic actuator has a large thrust and can easily bear the weight of the equipment on the platform. Moreover, it is small in size, light in weight, small inertial force, stable in operation, fast in response, and precise control. Therefore, it can realize the conversion of fast linear reciprocating motion without changing the rotation direction of the motor, which is very suitable for simulating seismic waves. In addition, the hydraulic pump and the hydraulic motor are connected by oil pipes, which is not only suitable for the vehicle-mounted environment with a small space, but also this oil liquid can make the movement surfaces of the components self-lubricate and reduce wear. However, this kind of hydraulic pressure is expensive, the system is complicated, and there are problems such as oil leakage. All things considered, we choose hydraulic mechanism to build an earthquake simulation platform for the vehicle environment.

The platform vibration mechanism is superimposed by three independent motion axes of X, Y, and Z to achieve six degrees of freedom. As the three axes need to operate independently and do not affect each other, our design uses three-layer steel structure mobile platforms. And the power mechanism is mainly composed of hydraulic cylinders, proportional servo valves, consoles and computer control systems. Z1~3# are 3 hydraulic cylinders in the Z-axis direction, X4# is a hydraulic cylinder that controls the X-axis direction, and Y5# is a hydraulic cylinder in the Y-axis direction, a total of 5 hydraulic cylinders. Each cylinder is individually controlled by a proportional valve.

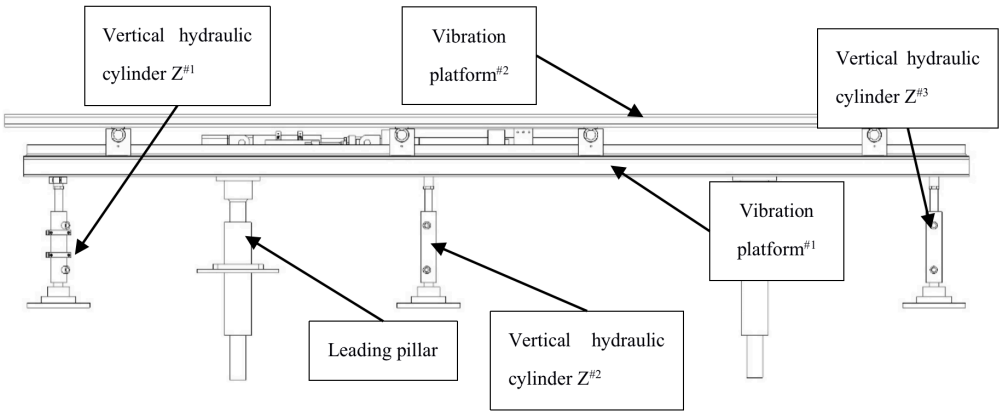


Figure 1. Structure diagram of seismic simulation platform (a)

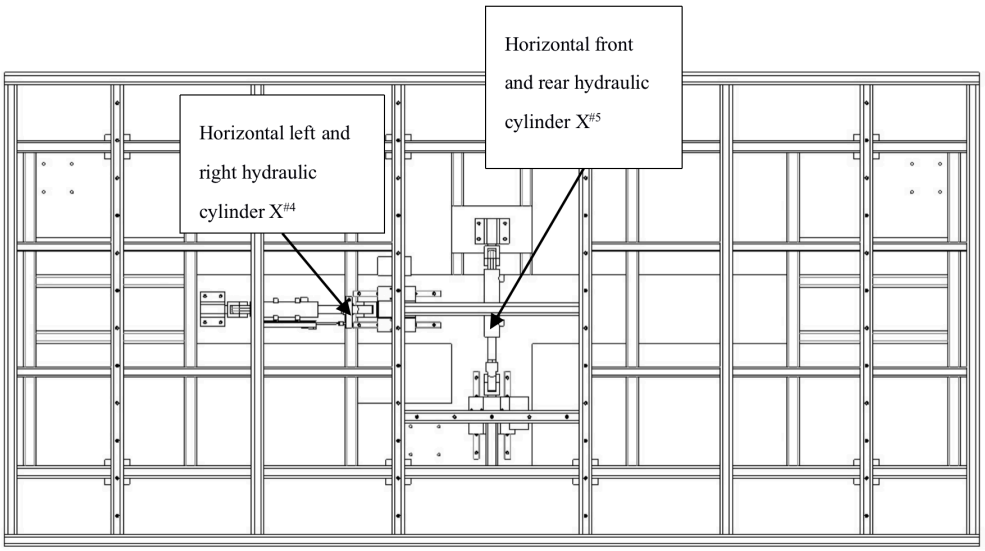


Figure 2. Structure diagram of seismic simulation platform (b)

The hardware structure of the hydraulic platform is shown in Figure 1 and Figure 2: Z#1, Z#2, Z#3, X#4, Y#5. The five hydraulic cylinders control the speed of the platform through a balance valve, making it more stable during the descending process. Considering the platform needs to have several degrees of freedom of vibration, so we choose the D40-L100 ball-head cylinder, so that the hydraulic cylinder can be in a certain space within the cone angle of arbitrary swing. The big degree of freedom of the ball-head cylinder ensures enough rotation angle, which can fully transfer the output force corresponding to the three directions of XYZ and reduce the friction force.

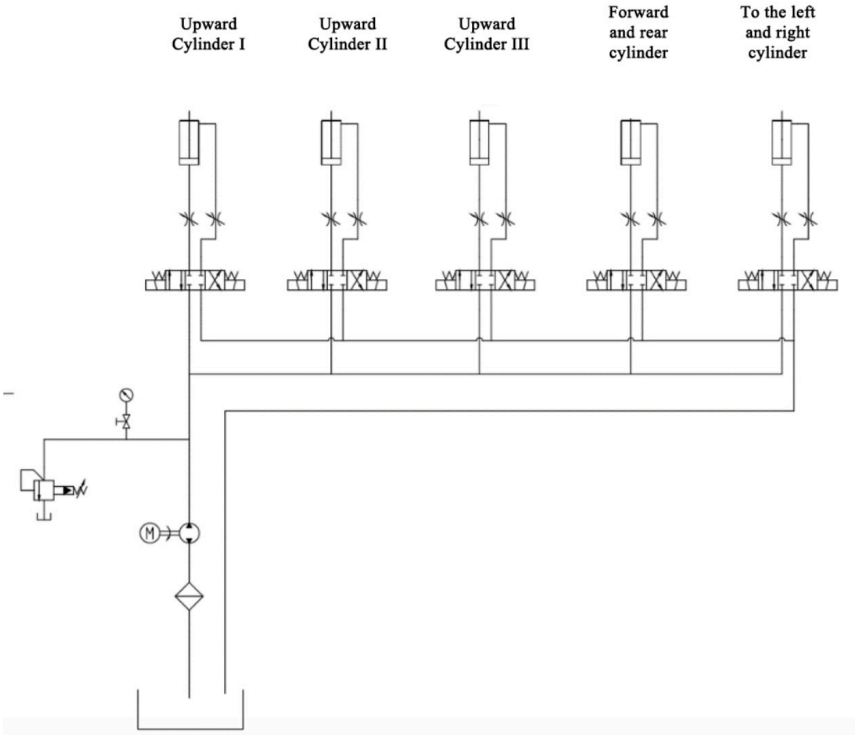


Figure 3. Schematic diagram of hydraulic system

The design index of each hydraulic cylinder is 0~10Hz, -50.0mm~+50.0mm. Since there is movement time for the reciprocating displacement of the hydraulic platform, if the frequency is set too high, the amplitude will be too small and the seismic effect cannot be reflected. Therefore, in order to highlight the vibration effect, the actual reserve, the frequency set at 0-5 Hz (adjustable) , each degree of freedom maximum displacement ± 45 mm (adjustable) . The seismic simulation platform can realize six-degree-of-freedom motion by adjusting the running speed of oil cylinder and shaking around three support points. Based on the above analysis, the structure of the control system of the final seismic simulation platform is as follows:

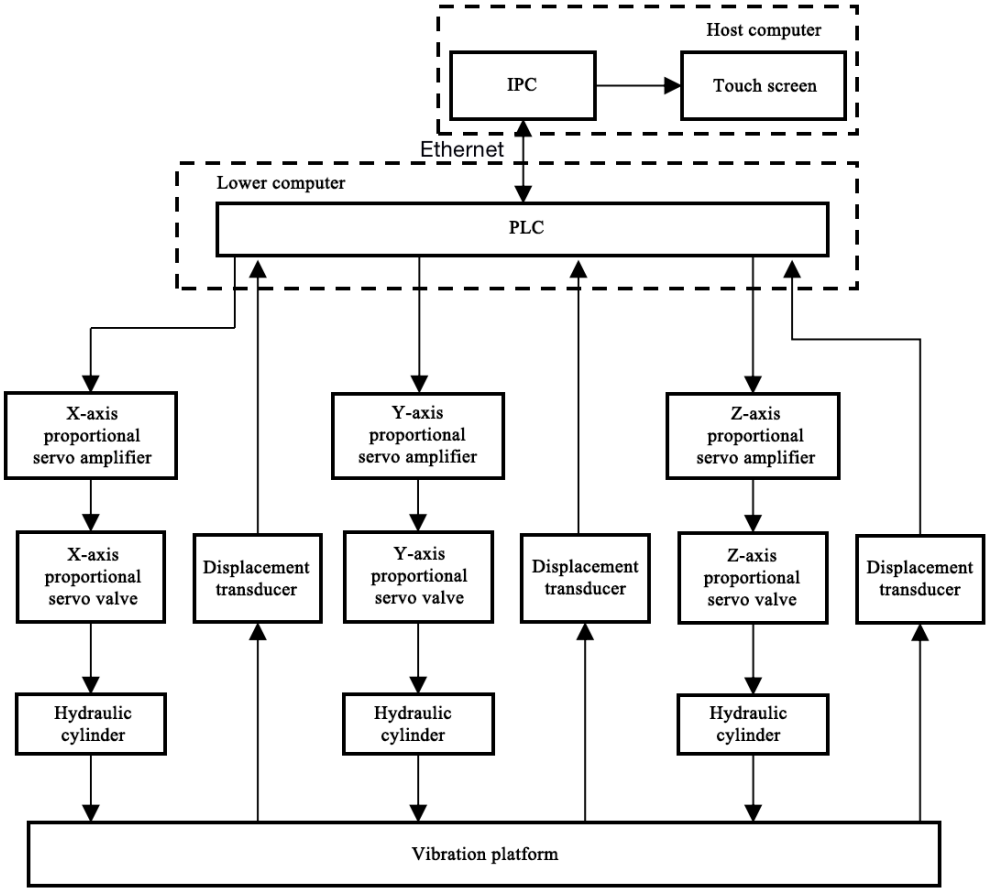


Figure 4. Control structure diagram of seismic simulation platform

The vehicle-mounted earthquake experience platform designed in this research takes the daily home environment as the object, showing the sensation and collapse effect of an earthquake, creating an immersive earthquake experience, and ultimately achieving the purpose of enhancing the effectiveness of earthquake science publicity.

References

U.S. Geological Survey. (2016). Largest Earthquakes in the World Since.

Petrovski, J. T. (2004, January). Damaging effects of July 26, 1963 Skopje earthquake. In *Middle East Seismological Forum, Cyber Journal of Geoscience Volume Two*.

Algermissen, S. T., Dewey, J. W., Langer, C. J., & Dillinger, W. H. (1974). The Managua, Nicaragua, earthquake of December 23, 1972: Location, focal mechanism, and intensity distribution. *Bulletin of the Seismological Society of America*, 64(4), 993-1004.

Tait, P. (2016, April 10). Strong earthquake shakes buildings across South Asia. *Reuters Wolrd News*.

NHKNEWS. (2016, April 26). Kumamoto earthquake toll rises to 14 people. *NHK*.

Li, S. W. (2016, April 20). The Kumamoto earthquake caused Toyota to suspend production in Japan on a large scale. Assessment of the damage today. *China Business News*.

Zhou, W. Y. (2016, April 19). The Kumamoto earthquake hits multiple industries in Japan. *Economic Information Daily*.

Li, X. J. (2016, April 14). Many countries felt the magnitude 7.2 earthquake in Myanmar suffered at least dozens of injuries in Bangladesh, India. *China News Service*.

Zhou, N. (2016, April 23). Experts explain why the earthquake in Ecuador suffered heavy losses. *Xinhua News Agency*.

Chen, K. (2011). The enlightenment of the operation mode of international earthquake insurance to our country. *Journal of Hubei University of Economics (Humanities and Social Sciences Edition)*, 8(12), 56-57, 71.

Science and Technology Daily. (2013). Viewing crisis awareness from Japan's disaster prevention experience. *Science and Technology Communication*, 4(8), 226.