Transitory Dynamic Simulation Analysis of Pressure Sensor for the Electrothermal Chemical Gun

Na ZHAO*, Yuan LI and Wei-wei ZHANG
Northwest Institute of Mechanical and Electrical Engineering, Xianyang, Xian, Shaanxi, 712099, China
*Corresponding author

Keywords: Pressure sensor, Transient dynamic simulation, Electrothermal chemical gun.

Abstract. The electrothermal chemical gun's pressure sensor is impacted by the high pressure, strong transient gas during the firing. By using the finite element method, combining the theory of interior ballistic, the transient dynamics response simulation calculation of electrothermal chemical gun pressure sensor by the action of high pressure gas was carried out during the launch. The change of stress and strain for each part of the pressure sensors under loading was obtained. Results show that the sensor structure deforms under the action of high-pressure gas, and the stress and strain value of the sensor components reaches the maximum when the loading pressure is maximum, among which the stress and strain of seal diaphragm of the sensor is the maximum. the results can be used as reference for the design of the pressure sensor of electrothermal chemical gun.

Introduction

In order to complete the combat mission of the artillery better, the performance of the future artillery must be greatly improved, but the traditional launch methods are approaching the limit. Various military powers have conducted extensive research and exploration on new artillery launch sources, among which electric energy weapons represented by electrothermal chemical gun have developed the most rapidly. The initial velocity of its projectile can reach up to 3 km/s ~ 4 km/s, with a long firing range. The muzzle kinetic energy is increased by about 25% ~ 55% compared with traditional artillery [1-3]. How to get accurate and reliable bore pressure parameters of electro-thermal chemical gun are very important for studying the rationality of plasma ignition, enhancement and charging structure, prediction of projectile external ballistic initial velocity, and design of gun frame strength and stiffness [4].

In the design of pressure sensor, the structural strength of the structural components should be considered first. Some scholars [5,6] used finite element analysis software to conduct finite element simulation analysis on different types of pressure sensors.

In this paper, the dynamic theory is used to simulate the stress variation of the electrothermal pressure sensor which is subjected to the load changing with time.

Geometrical Model

The geometric model and internal composition of the electrothermal pressure sensor are shown in Fig.1 below. The sealing gasket is made of alloy steel with good elasticity and high strength, forming a line seal between the end face of the sensor and the pressure test hole, ensuring the sealing performance of the sensor under high pressure conditions. The sensor body is made of high strength martensitic aging steel, and the silicon-germanic-manganese-copper material is selected as pressure sensitive material. The designed pressure measuring range of the sensor is 0 ~ 1000MP.
Calculation Model

The electrothermal pressure sensor is mainly subjected to the loading action of high temperature and high pressure gunpowder gas in the electrothermal chemical gun. On the basis of internal ballistic model and the dynamic model, the internal ballistic process of ETC gun simulation was carried out to obtain the chamber pressure curve of the gas of gunpowder in the chamber, as shown in Fig. 2. The finite element method was used to simulate the stress change process of the electrothermal pressure sensor under the condition of changing bore pressure. The red marked surface is the stress surface.
The Calculation Results

Finite element simulation software was used to simulate the stress and strain process of the electrothermal pressure sensor under the action of the transient pressure of gunpowder gas.

Fig. 3 shows the total deformation curve diagram and the maximum strain cloud diagram of the sensor under the action of transient pressure of gas in the chamber. It can be seen that the maximum deformation position is on the diaphragm, and the maximum strain of the structural member under the maximum pressure is up to 0.27mm, which is smaller than the maximum allowable deformation of diaphragm.

Figure 3. Total deformation diagram.

Fig. 4 shows the total stress curve diagram and the maximum stress cloud diagram of the sensor under the action of the gas transient pressure in the chamber. It can be seen that the structural parts are subjected to the maximum stress when the pressure is the highest, and the maximum stress position is also on the diaphragm. Metal diaphragm as the sensor protective cover, it contacts with the powder gas directly, through the metal diaphragm and hydraulic oil the pressure is passed. And pressure sensitive material can avoid the ablation of powder gas, improves the life span of pressure sensor. Also the center diaphragm structure can be used to promote ability of resistance to overload. Due to 17-4ph (630) has the high elastic energy storage performance and smaller lag creep tendency, easy processing, and has high corrosion resistance and oxidation resistance. 17-4ph(630) is choosen as membrane processing material during the electric heating pressure sensor design, its compressive strength of about 1300 MPa. From Fig. 4 it can be seen that the maximum stress under about 1250 mpa, meets the requirement.
The ceramic cone plug in the sensor is made of high strength ceramic, which is mainly for the purpose of making a high pressure sensor that meets the insulation requirements under the condition of not increasing the volume of the sensor. Fig. 5 shows the cloud diagram of the maximum stress of the ceramic cone plug in the sensor under the action of the gas in the chamber. It can be seen that the maximum stress is at the edge of the wire hole, about 650MPa, and the strength of the high-strength machined ceramic is about 1000MPa.

By filling the pressure chamber of the pressure sensor with medium oil, the sensitive element is completely immersed in a closed chamber. The pressure is transferred around the sensitive element by medium oil, and its stress is equal everywhere, which can effectively transfer pressure, but also play a protective role. Fig.6 shows the diagram of the maximum stress of the hydraulic oil in the sensor under the action of the gas in the chamber. It can be seen that the maximum stress is at the contact position with the diaphragm, about 62MPa.
Conclusions

As electric sensor of gas in the chamber pressure changing with time under the action of the stress and strain of the finite element simulation, the results show that the pressure sensor maximum stress and strain on the maximum bore pressure effect, the sensor structure diaphragm were also the largest stress and strain values, the calculation results can provide reference for design of sensors.

References

[1] A. J. Porwitzky, M. Keidar, D. Iain. Numerical Parametric Study of the Capillary Plasma Source for Electrothermal-Chemical Guns. IEEE Transactions on Magnetics, 2009, Vol: 1, pp: 574-577.

[2] J. Di, M. Yang, M. Zhang, B. Zhao. Electrothermal-Chemical Launcher Technology in Large Caliber Gun. Journal of Gun Launch & Control, 2010, Vol: 2, pp: 24-27.

[3] H. Li. Progress in the Research of Electrothermal Chemical Launch Technology. Journal of Nanjing University of Science and Technology, 2003, Vol: 27, pp: 449-465.

[4] Q. Li, W. Wu, X. Li, P. Fan. Finite element analysis of the constantan thin-film pressure sensor. Manufacturing Automation, 2013, Vol: 35, pp: 99-101.

[5] W. Tang, B. Shen. Stress analysis and optimization of embedded pressure sensor in composite fiber material. Transducer and Microsystem Technologies, 2017, Vol: 36, pp: 45-48.