Study of Typical Equipment Health Monitoring of Rocket Filling System

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ABSTRACT: The filling system composition were analyzed briefly from two aspects of conventional and cryogenic propellant loading system, summarize the common fault of filling system and analyses its fault characteristics, and typical equipment was selected based on the analysis of filling system. The typical equipment characteristics were analyzed, and the typical equipment health monitoring information were clear, and a good foundation of further research of typical equipment health monitoring of filling system has been laid.
KEYWORD: filling system; health monitoring; fault characteristics analysis; health monitoring information analysis

1 INTRODUCTION

Rocket filling system is a system level device with complex mechanical, hydraulic, pneumatic dynamic, electronic components. Working process of the filling system in different working conditions is also a very complex flow process. According to statistics, as the filling system of a launch site was completed and put into use for many years, there were lots of failures happened, such as meter damage in XX task; rocket tank liquid level signal failure and level signal error in XX task; and fuel injection valve inside leakage in XX task, et al. These failures of filling system produced a very bad influence on smooth completion of filling tasks, and seriously hinder the process of the launch task. Therefore, the health monitoring of filling system shall be carried out. The composition and fault characteristics of filling system are briefly summarized and analyzed, the typical equipment of filling system is selected on the basis of this, and the typical equipment health monitoring information were clear, and made a good foundation for the further research of typical equipment health monitoring of filling system.

2 THE COMPOSITION ANALYSIS OF FILLING SYSTEM

The filling system can be divided into liquid road and gas road subsystem according to the structure and function of components; and into conventional and cryogenic propellant loading system according to the different types of propellant filling system; and into the pump pressure filling system and gas pressurized filling system according to the difference of system power source. This paper carries on the composition analysis of filling system according to the category[1].

2.1 *Conventional filling system*

The conventional filling system is composed of two parts of UDMH and dinitrogen tetroxide filling system.

UDMH filling system (also known as the fuel filling system) is mainly to complete the filling or discharging of UDMH of the1 stage, 2 stage, and booster of rocket, Also including the transfer, storage, temperature, exhaust gas treatment and other tasks, with simulation of filling and signal joint test, small flow meter calibration functions. Storage and transportation system has two sets of storage tank, relatively independent of the pump, flow meter, electric regulating valve and the valve and pipe system, named 1th system and 2nd system. During the filling process, filling pump can be single or two units in parallel, and the filling pump and tank can be used to switch between the two systems. Dinitrogen tetroxide filling system (also known as oxidizing agent filling system) is mainly to complete the filling or discharging of dinitrogen tetroxide of

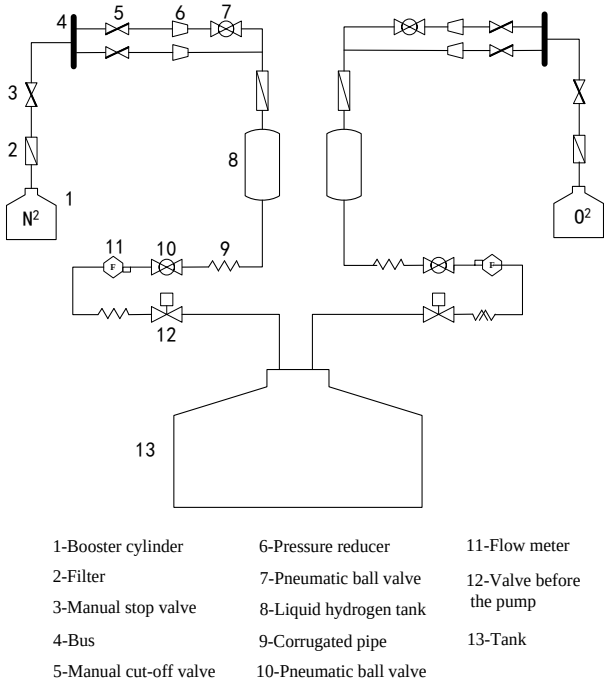
the1 stage, 2 stage, and booster of rocket, Also including the transfer, storage, temperature, exhaust gas treatment and other tasks, with simulation of filling and signal joint test, small flow meter calibration functions. Dinitrogen tetroxide filling system composition in addition to storage and delivery systems and exhaust gas treatment system with unsymmetrical dimethyl hydrazine filling system is slightly different, the composition of system and the rest of the filling process are basically similar, is not mentioned here.

2.2 *Cryogenic propellant loading system*

The cryogenic propellant loading system is mainly composed of liquid oxygen filling system, liquid hydrogen loading system and the liquid nitrogen filling system.

The liquid oxygen filling system is mainly used for the adding, supplementary filling, unloading back of liquid oxygen of rocket three stage, and also for the transport, transfer, storage of liquid oxygen, and the storage tank or pipeline gas oxygen emission. Oxygen filling system can be divided to the loading control, the LOX loading fill library, liquid oxygen emission tower and pipeline according to facilities, to oxygen filling pipeline system, exhaust system, measurement and control system according to the functions. The liquid hydrogen filling system is mainly used for the adding, supplementary filling, unloading back of liquid hydrogen of rocket three stage, and also the transport and short-term storage of liquid hydrogen. The combustion of gas hydrogen of tank or pipe will be done, and the liquid hydrogen filling system have the nitrogen and helium replacement function. The liquid hydrogen filling system can be divided to hydrogen combustion control room, hydrogen fuel tank, computer room and magnetoelectric pipeline according to the facilities division; to combustion system, measurement and control system, hydrogen combustion system by burning pool and filling pipeline system according to the functions.

For the convenience of intuitive understanding of the composition and work process in filling system, make gas booster type cryogenic propellant loading system as an example, a brief analysis of filling principle of filling system is done, as shown in Figure 1[2].



1-Booster cylinder
2-Filter
3-Manual stop valve
4-Bus
5-Manual cut-off valve
6-Pressure reducer
7-Pneumatic ball valve
8-Liquid hydrogen tank
9-Corrugated pipe
10-Pneumatic ball valve
11-Flow meter
12-Valve before the pump
13-Tank

Figure 1 Schematic diagram of the cryogenic propellant loading system of gas booster type

3 ANALYSIS OF FAULT CHARACTERISTICS OF FILLING SYSTEM

The medium of the conventional filling system is corrosive, and the working environment of equipment is serious. At the same time, there is a big difference between usual check state and work state, so it is difficult to simulate the test task state and carry out the daily check and maintenance. Compared to the conventional media, geysering phenomenon will be easily generated if the pre cooling is not full during the transmission of low temperature medium because of its strong low temperature. When geysering phenomenon begins, equipment of filling system will be affected by strong shock pressure, shrinkage stress, dynamic impact and pressure fluctuations. At the influence of these stresses, the explosion will occur when the leak of low temperature medium happens, and serious consequences will come out[3]. Make a summary of the conventional filling system and the cryogenic propellant loading system fault during the filling process, and the fault characteristics can be drawn as follows:

(1) kinds of faults such as “Liquid level signal false alarm”, “An reading error of the treasury meter”, “No output of temperature sensor”, “Beyond the limit of propellant temperature”, “Feedback signal can not be received”, “Beyond the limit of predetermined value of tank pressure”, “Signal of liquid level meter can’t be received”, “hydrogen concentration can’t be received”, “A stop happens when booster does not reach or beyond the desired value”, “Signal of unloading pressure can’t be received” which are both sensor failure are very

usual to find. The sensors failure mainly included failure of liquid level meter, flow meter, temperature sensor, pressure sensor and echo signal monitoring. Therefore, sensor failure should be paid more attention of the filling system health monitoring.

(2) From the conclusion of failure mode statistics analysis of filling system, propellant leakage and blocking failure in a liquid system has a highest frequency and a biggest risk coefficient[4]. As the filling system is under a high presser and strong vibration condition, so kinds of pipe joints, sealing members and valves has a high possibility of leakage. Especially for The cryogenic system, the liquid hydrogen which is Cryogenic Propulsion Medium has characteristics of low temperature, high pressure, flammable, explosive, and easy diffusion, etc. So once the leak happen, a serious consequences will appear. There are two kinds of leak failure, one is the connection of pipeline leakage, which is due to installation not close enough or overuse. And another one is due to the open and close failure or abnormal opening degree of valve. The metal impurities are caused by the influence of abrasion, cavitation and aging of components. When the metal impurities are flow through the small aperture devices such as valve hole and filter, the jam fault is easy to happen. And then the failure of flow meter numerical dropping and pre pump reducing will happen, and the failure of launch mission come out[5]. Forever, this two kinds of failures should also be paid more attention.

4 TYPICAL EQUIPMENT SELECTION OF FILLING SYSTEM

Based on summarizing and analyzing the characteristics of the common faults of the filling system, typical equipment of filling system was selected. The typical equipment mainly included the tank, pipeline, valve, and filling pump etc. By the analysis of the characteristics of typical equipments, make clear that which information should be monitored of the typical equipment.

4.1 *Storage tank/tank*

During the filling process of rocket, kinds of equipments of filling system have a strong connection with the tank of rocket, so the tank is also classified as a part of filling system like the storage tank in this paper. And because of the similar characteristics of storage tank and tank, the two are analyzed together. For the health monitoring of Storage tank and tank, the metering device s as follows are mainly concerned:

(1) Liquid level meter of Storage tank/tank

The Liquid level meter of tank would be analyzed as an example in this section. During the large flow of propellant filling of rocket, the “rocket-ground” combined determination of filling flow size mode was used. The basic amount of filler based on the Liquid level signal of rocket tank, and the ground filling flow would be a supplementary[1]. The actual liquid level information of rocket tank was monitored by the Liquid level meter during the filling process.

(2) Temperature sensor of Storage tank/tank

The temperature information of Storage tank/tank was monitored by the built in temperature sensor during the filling process.

(3) Pressure sensor of Storage tank/tank

The pressure information of Storage tank/tank was monitored by the built in pressure sensor during the filling process.

Therefore, information of pressure, temperature and liquid Level back signal were monitored about Storage tank/tank during the filling process.

4.2 *Storage tank/tank*

As the final form of the valve or a pipeline failure is propellant leak or blockage[6], so the two typical equipments are analyzed together in the paper. Information of valve back signal, valve pipeline pressure, valve pipeline flow and pressure before the pump was monitored about valve during the filling process. Information of pipeline presser, pipeline propellant flow and propellant flow rate was monitored about pipe during the filling process.

4.3 *Filling pump*

Filling pump is a very important device of the whole filling system. If there is fault of filling pump, a incalculable consequences would come towards to the whole filling system, even lead a failure of filling task[6]. In consequence, the filling pump was chosen as the most important part of the filling system. For the health monitoring of filling pump, the metering devices as follows are mainly concerned:

(1) Flow meter

Flow meter is an important device which can quantitatively calculate of the amount of propellant filling. In the present filling mechanism, Large flow meter usually are for reference only, small flow meter can precisely control the quantity of adding. In general, the higher accuracy of the flow meter, the better of performance.

(2) Pressure sensor

The monitoring information of the pressure sensor comprises a pump entrance pressure and the outlet pressure of the system.

(3) Current sensor

The monitoring information of the current sensor is the current value of pump during the filling task.

(4) Temperature sensor

The monitoring information of the temperature

sensor is the temperature value of pump during the filling task.

5 CONCLUSION

The filling system composition were analyzed briefly from two aspects of conventional and cryogenic propellant loading system, the common fault of filling system was summarized and its fault characteristics were analyzed. The typical equipments were selected based on the analysis of filling system. The typical equipment characteristics were analyzed, and the typical equipment health monitoring information were chosen and determined .And with this a good foundation of further research of typical equipment health monitoring of filling system has been laid.

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