Study on Crack Leakage of Aircraft Hydraulic Pipeline

Zhao Jinfang[1,*], Li Chong[1,2], Sun Dan[1], Fu Xiaopu[2] and Tian Linhui[2]
[1]*Civil Aviation College, Shenyang Aerospace University, Shenyang, China*
[2]*General Assembly Workshop, Shijiazhuang Haishan Industrial Development Corporation, Shijiazhuang, China*

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Abstract: The problem of aircraft hydraulic pipe is one of the frequent problems in the daily maintenance process. After a long flight, it will gradually expose structural scratches, pipe extrusion, longitudinal cracks, oil leakage, blasting, etc. Based on the big data of the quality report of a single flight, this paper studied the main causes of cracks at the root of the flat nozzle, and proposes targeted improvement measures from the structural layout, operation mode, typical leakage. ANSYS simulation shows that the root of the flat nozzle of the guide pipe is at the rear of the fuselage under different frequencies and forces. The equivalent stress and elastic deformation were observed by metallography analyzer and X-ray spectrum analyzer. It was concluded that under the installation stress of the tube itself, the root of the nozzle of the flat tube would produce extrusion friction with the tube under the condition. The tube body was resonated with the body of the body, leading to the fracture from the outside to the inside.

1 INTRODUCTION

The aircraft hydraulic pipeline system is the main executive system of the aircraft to complete various actions, which provides the pilot with the control and power assistance of the aircraft. The fuselage of the military aircraft is covered with densely packed aviation pipelines, the number of individual aircraft pipes about 2000, about 800 straight-through joints, which is particularly large. After a long flight, quality problems are gradually exposed. For example, hydraulic pulsation is very harmful to the hydraulic system, which not only degrades the dynamic characteristics of the system, affects the service life of the components and pipelines, but also causes resonance or resonance to damage the system components, even paralyzes the system and causes catastrophic accidents (Cheng et al., 2011). In the past two years, there were 120 oil leakage faults fed back from the outfield of a certain type of aircraft. The major accidents caused by the pipeline system accounted for 38% of the total faults. The root cracking of nozzle is one of the most common feedback problems followed by pipe explosion.

2 RELATED WORK

2.1 Analysis of Aircraft Hydraulic Pipeline Problems

Flared connection is the most widely used connection method in the active aircraft hydraulic system (Chen et al., 2021). According to the data analysis, the explosion of the aircraft hydraulic system mainly occurs at the attachment connection, the connection of the hydraulic pipe around the engine, the connection of the suspension straight pipe and the three-way pipe (Quan et al., 2020), secondly, it occurs at the dense connection of the hydraulic fuel pipe, which produces friction, which generates friction, indentation, compression, pulse, etc. due to the restriction of the structural space. The main problems focus on the following aspects.

In the actual operation of the project, during the quarterly general inspection and spot-check of the pipe disassembly, it was found that there was stress assembly in many pipes, and forced assembly was carried out without qualified adjustment in the process, which also indicated that the stress release was not achieved during the flight (Xia et al., 2021). Due to the restriction of space, the installation of hydraulic system pipelines is inconvenient and prone to friction, which is mainly manifested in severe pressure pits,

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friction of structural stringers, wear through and compression of peripheral pipelines (Heng, 2014). The cause of the problem comes from the deficiencies in the aircraft design.Most of the special frequently occurring pipelines are located behind the inlet with strong vibration, and the inlet is the boundary, except for the front part of the fuselage of the main landing gear, they are more stable (Meng et Yang, 2022). The leakage rate of the rear fuselage is 85% of that of the whole fuselage, and the tube is installed near the aircraft engine, and the working temperature is about 550°C. The flat nozzle is an integral life part of aircraft, which is easy to produce longitudinal fatigue crack in its horn and pipe bushing (Liu and Xao, 2016). The failure fluctuates during the training period. The failure of the aircraft just completed the test flight is extremely low. When the flight time is 300h-400h, the failure rate of the aircraft is high, and the failure rate increases with time. The cause of correction is related to failure on the one hand and stress assembly in actual operation on the other hand.

The occurrence of problems can be described as diverse and complex. According to the statistical chart of oil leakage locations as shown in Figure 1, the oil leakage at the root of the nut accounts for 59% of all oil leakage locations. The root of the nut is the location where the nut contacts the flat nozzle. It can be seen that the contact between the nut and the pipeline is the main problem of oil leakage at the joint with lock nut(Chen, 2021; Du et al., 2021).

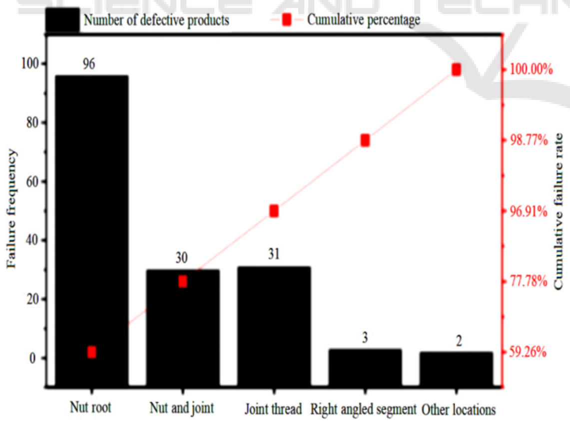

Figure 1: Statistical Diagram of Oil Leakage Location.

2.2 Analysis of Crack State of Aircraft Pipeline

2.2.1 Post Damage Caused by Aircraft Engineering Specifications

The aircraft hydraulic pipeline can be installed in two ways, the first is divided by system, and the second is divided by location. The hydraulic system installed according to the system division is assembled by a single operator, who will adjust and control according to the overall length; The hydraulic system installed according to the location division is usually assembled by multiple operators. For example, one operator is responsible for the front of the air inlet and another operator is responsible for the rear of the air inlet. This will lead to poor stress control on the pipeline butt joint after the hydraulic system is assembled. Sometimes, it can not even be assembled normally, and the pipe can only be sawed for new assembly.In the process of pipe assembly, some aluminum alloy pipes are affected by the manufacturing tolerances of pipe materials and flat nozzles, as well as the manufacturing errors of flared taper, outer sleeve nuts and straight joints.Therefore, the fit gap between the pipe and the flat nozzle tube will be randomly distributed, and there are different coaxial phenomena, once it happens, it is an accident sign(Du et al., 2021). From the project management mode, the first operation assembly mode is to install according to the system division, the whole hydraulic system installation by the operator single assembly, will be adjusted according to the overall length of processing; The second is divided by position, such as one operator before the intake port and another operator after the intake port, after the assembly of the hydraulic system, the connection of the two pipelines will result in poor control and produce stress, sometimes resulting in stress installation. If the normal assembly can not be achieved, the saw pipe can only be reassembled, so most of the stress is difficult to control, complex pipeline network even more than 10 mm there will be a big problem. At the same time, some aluminum alloy pipes are affected by the manufacturing tolerance of pipe material, flat nozzle, taper deviation of flaring, outer nut and straight through joint and so on, the fit gap between the pipe and the flat nozzle will be randomly distributed, and the pipe and the flat mouth tube have different axis phenomenon (Du et al., 2021). When it happens, it is a symptom of an accident.

In the outfield flight mission, it was reported that more pipeline cracks were generated at the root of the flat nozzle. At the same time, it was found that there were metal chips like foreign matters with the same material as the pipeline between the pipeline and the flat nozzle, mainly concentrated in the longitudinal cracks between the pipeline and the bushing, and the cracks between the pipeline and the bell mouth. Due to the deformation caused by vibration, pulling and force, the pipeline cracks often occur at the root of the sleeve. Figure 2 shows the internal morphology of high circumferential cracks.

Figure 2: High cycle crack at sleeve root.

The reason for the crack at the root of the flat nozzle is that there is a stress at this position, which causes the extrusion between the pipeline and the flat nozzle. In addition, the aircraft will generate vibration during flight. The two factors act at the same time, causing the abrasion of the pipeline and eventually leading to the breakage of the pipeline.

2.2.2 The Frequent Problems of Pipelines Leakage

After the actual assembly, the stress of the aircraft will be released after a long period of pressure. However, if the release is not complete enough, the vibration of the aircraft and the start of the engine will cause great vibration damage to the hydraulic pipe. If the problem of excessive stress is encountered, the operator will usually fine tune the angle or select the saw tube installation. At present, L2FM pipes in China are often found with surface defects such as indentation, scratch and other problems in the process of use, which are caused by cracks in the pipe under the vibration environment after the aircraft has been flying for a long time.

The pipeline for body installation is divided into formed tubes and non formed tubes. There are strict requirements for unformed pipes to be self calibrated. The bending radius should not be less than 3*d* (*d* is the diameter of the pipe). The linear distance from the beginning of the pipe bending to the flat nozzle should not be less than 5mm. The pipe should not be twisted after connection. The cause of scratches is usually that the bending radius is too small, and the stress is formed at the root of the catheter and the sleeve, which causes the pipe to bend directly at the sleeve, resulting in root leakage.

2.2.3 Leakage Caused by Repair and Maintenance

In order to improve the maintenance efficiency and eliminate the leakage in time, the maintenance personnel usually dismantle the pipeline at the connection and then forcibly connect it. This process often does not consider the requirement of force limitation. Such disassembly and assembly will not only cause transverse cracks at the pipe bell mouth, but also easily lead to sudden changes in the contact surface, resulting in pressure or contact clearance, which will lay hidden dangers for safe flight. For example, When disassembling the two-way connecting pipeline, if the two ends of the fixing nut are forcefully disassembled, the pipeline about 10mm behind the bell mouth at the other end will be bent at 60° , and even if it is recovered, there will be poor contact.

3 METHODOLOGY

3.1 Control Measures to Prevent Pipeline Damage in the Later Stage

According to the theory of total quality management, the factors affecting the damage of the pipeline are studied, and the damage caused by vibration or wear is controlled through feedback improvement.

3.1.1 Improve Maintenance Project Management Mode

A typical "star" pipe after complete installation is tested for stress compliance during installation.

(1) 70% of the faults in the hydraulic system are caused by the oil pollution of the hydraulic system. Therefore, it is extremely important to strengthen the control of oil pollution and surplus in the production process to improve the reliability of the hydraulic system. The timing of oil filter connection shall be strictly controlled (Zhu et al., 2015). The equipment shall replace the oil filter in strict accordance with the implementation standards to avoid the frequent infiltration of surplus materials into the system.

(2) Adjust the process to avoid multiple disassembly and assembly in the later period, which may lead to poor contact of the catheter. The pipeline shall be strictly checked to see if there is scratch inside it and if there is cone indentation.

(3) The important connection position of the pipeline more or less caused uneven stress release due to improper adjustment in the early stage, resulting in

smaller gap and larger stress at the connection. The system connection can release the whole to the optimal configuration range to solve this problem. The pulsating production line shall be established for the installation of hydraulic pipelines to avoid the whole machine spreading for operation as far as possible. The accessories of the hydraulic system department shall be taken as the starting point for treatment, and the work rhythm shall be adjusted to improve the quality of pipeline maintenance.

(4) The pipeline shall be protected in a timely manner by professional binding, and the paint at the root of the pipeline shall be repaired in a timely manner to prevent corrosion of the pipeline caused by moisture, acid and alkali substances. In addition, dust and air shall be prevented from entering the system.

3.1.2 Ensure the Process Control of Pipeline

The pulsatile production mode can realize the transformation of the position set by the system, so as to reduce the excessive stress at the junction.

(1) Correct sizing and stress relief of the pipeline. Due to the influence of the material of the hydraulic pipe itself and the large bearing pressure, there is a large stress in the hydraulic pipe during flight, which may lead to air blasting. When installing the pipeline, install the nut, and then gently pull it with your hand to conduct stress free installation. Do not force installation.

(2) Strictly enforce the torque requirements of the pipe, do not bear too much force, according to the pipe diameter to apply a considerable force, in practice due to poor contact, want to use the way of screw die is not right, there are also short horn, stud scratches generated by the surplus caused by system pollution. Each type of pipe has torque requirements, according to the different torque to tighten.

(3) Each type of pipeline has torque requirements, which shall be tightened in strict accordance with the torque requirements of the pipeline, and excessive force is not allowed. In actual operation, it is not advisable to deal with the problem of poor contact by screwing the nuts. This practice will cause the stud to scratch and produce surplus material, which will cause system pollution.

(4) For the pipelines near the engine, try to avoid the hard connection mode of empty three-way and four-way pipes. If this mode is necessary, fix the three-way and four-way pipes on the engine body and accurately measure the distance (Zhang et al., 2019).

(5) If the pipeline leaks, the cause shall be analyzed in a timely manner, and the troubleshooting cannot be carried out simply by tightening. In addition, protection measures shall be taken during installation to prevent foreign matters from entering the system and damaging the inner wall. The causes of frequent catheter damage should be found by combining data analysis.

4 CONCLUSIONS

Pipeline failure is a system engineering, and the failure process is relatively complex, usually caused by multiple factors. There is no obvious plastic deformation in the fatigue crack of the pipeline. Without obvious signs before fracture, it will suddenly cause damage, and the fatigue fracture stress is very low, often lower than the yield strength under static load.

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