Design and Implementation of FOD Detector for Airport Runway

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Abstract: Safety is the eternal theme of civil aviation. The flight safety of domestic civil aircraft affects the hearts of millions of people. Among the many factors that affect the flight safety of aircraft, foreign objects on the airport runway play an important role. Every year, there are many cases to remind us to guard against the significant impact of FOD on the flight safety of aircraft. In terms of FOD protection, China is still in the stage of artificial detection. On the one hand, it causes huge waste of human resources; on the other hand, it increases the probability of human error and seriously affects the flight safety of aircraft. Therefore, the current technological means can be used to detect FOD, so as to reduce the inspection omission caused by human error and protect the flight safety of the aircraft.

1. Introduction
A small piece of garbage that seems inconspicuous may damage multiple parts such as the engine and tires of the aircraft, causing hundreds of thousands or even millions of dollars in damage, causing a security accident with unimaginable consequences.

Foreign objects on the runway have a serious threat to the taxiing, take-off and landing of the aircraft on the runway, causing flight delays, interruption of take-off, and even life-threatening passengers. There are many aviation accidents caused by foreign objects on the runway every year, causing huge direct or indirect losses.

On July 25, 2000, a Concorde supersonic airliner belonging to Air France suffered a fatal accident of 113 people. The flight took off from Paris Charles de Gaulle Airport and crashed only 56 seconds after being lifted off. All 109 people were killed and 4 people died on the ground, causing extremely huge economic losses and casualties.

The final air crash investigation revealed that not long before the Concorde supersonic passenger plane took off, another DC-10 passenger plane also took off on the same runway.

It is precisely because of the deflector fragments dropped on the DC-10 passenger plane that cut the right front wheel of the main landing gear on the left side of the Concorde supersonic airliner, causing the rubber debris after the tire burst to hit the wing of the Concorde supersonic airliner.
The fuel tank, which caused the fuel tank to fire and explode, eventually led to the destruction of the Concorde supersonic airliner. This was the biggest air disaster caused by FOD in history.

The accident resulted in the complete decommissioning of the Concorde in 2003. The crash site and the FOD that caused the accident are shown in Fig. 1 [1, 2].

![Fig. 1. The scene of the Concorde crash.](image)

In 2005, the left engine of an airline flight sucked in small pieces of cement, many blades were damaged, and the aircraft was parked to replace the blades.

In 2006, an airline flight was affected by foreign objects, resulting in damage to the engine fan blades and air intake.

In 2007, an airline flight pressed foreign objects on the ground, causing the tire to burst. Tire fragments caused serious damage to the lower half of the right fuselage of the aircraft, the right landing gear, the landing gear compartment, and the hydraulic system piping.

In 2011, the tire of a Xiamen Airlines flight was punctured by nails, and the aircraft was grounded to replace the tire.

2. Research contents

Currently existing foreign countries used the means such as nano wave radar to test the airport FOD, for our country, the expensive imported testing equipment, at the introduction of millions of millions of cost, in addition to consider the late maintenance, especially for many small and medium-sized airport navigation airport is a not small cost.

For the above reasons, FOD detection equipment from abroad has not been purchased by major airports in China.

At present, there is no technically mature FOD detection system in China. At present, major airports still rely on the original method of manual detection, as shown in Fig. 2 [3, 4].

![Fig. 2. Regularly organize the inspection of foreign objects.](image)
As we all know, there are unpredictable human factors affecting the detection effect in the case of fatigue. Similarly, the weather and light will also cause the wrong detection of inspectors, which will bring a direct negative impact on aviation safety.

In summary, it is urgent to develop an airport runway FOD detector. In the work, it can not only effectively detect the small FOD in the airport runway, but also has the advantages of high detection efficiency, reliable detection results and easy maintenance.

Artificial detection at the same time, because there is a man-made-errors, such as great potential safety hazard, in order to bring the operators from heavy, repetitive production.

Therefore, the automatic navigation control system into the airport runway FOD detector, not only effectively improve the accuracy of FOD detection operation, and reduces the waste of human resources in the process of testing [5, 6].

Finally, the development of FOD detector prototype put in airport runway test for many times, to verify that actually recorded in performance and related parameters, focus on the detection precision and the automatic detection, early have the necessary theoretical research.

At the same time, and do the related patent (patent number: ZL201820830111.9), as shown in Fig. 3. Applying for jobs after the completion of the products can be on the basis of this, a line at the airport, which will be directly applied to the automatic detection and repeatability of the airport runway FOD regularly has a high practical value [7, 8].

Fig. 3. FOD detector patent authorization.
3. Technical solution

3.1 Execute solution

Design and development of FOD detector for airport runway, including integrated system of laser transmitter, induction device, transmission device, receiving device and vehicle, and automatic navigation control system.

The laser emitting, sensing, transmitting and receiving equipment includes the laser transmitting end circuit system and the laser receiving end circuit system. The former includes laser sparring device, 4G signal transmitting system and transmitting terminal information processing system. The latter includes a 4G signal receiving system and a receiver information processing system [9, 10].

Laser correlation device assembled on a fixed and on the end of a long rod in the level state of laser beam scanning can be close to the ground, when the laser beam is FOD stop when the signal is blocked and pass to the information processing system.

Information processing system through information identifying alarm and the result was sent to carrying on the alarm signal at the receiver (both take a wireless connection). The signal alarm receiver senses the signal and begins to send an alarm through the loudspeaker.

The schematic diagram of the transmitter and receiver modules of the FOD detection system is shown in Fig. 4 and Fig. 5 [11, 12].

The detector circuit board is designed and made to operate in coordination with the laser lamp to detect the airport runway FOD. The circuit diagram is shown in fig. 6.

![Fig. 4. Schematic diagram of the transmitter module.](image-url)
Fig. 5. Schematic diagram of the receiving module.

Fig. 6. FOD detector circuit board.
3.2 Patent and prototype

After thorough theoretical research in the early stage, continuous experiments and system tests in the later stage, fruitful results have been achieved. At the same time, the project team learned a lot of knowledge and accumulated valuable engineering research and development experience.

Final prototype of FOD detector is shown in fig. 7.

![Fig. 7. FOD detector.](image)

Compared with the speed and endurance of manual FOD detection on the airport runway, this prototype has unmatched advantages. The FOD detector is more stable in quality, faster in speed and more efficient in detecting the same area of track.

At the same time, this prototype also has its own advantages in environmental adaptability: currently, the six main width types of international civil aviation runway are A(0-15m), B (15-24m), C (24-36), D (36-52), E (52-65), F (65-80). The detection vehicle can adjust the appropriate detection width for different airport runway widths [13, 14].

In addition, the car can be made of composite materials to adapt to extreme weather conditions. The important parts and modules of the car can be sealed with glue to ensure that the detector's interior is not affected by the external environment, and it can detect and exclude FOD under harsh environmental conditions, which reflects its strong environmental adaptability [15-18].

In May 2019, the project team participated in the 15th "challenge cup" extracurricular academic science and technology works competition for Guangdong college students in Foshan, and won the third prize in more than 2,000 projects in the province.

4. Conclusion

In this study, laser beam blocking was used as the FOD detection basis, and the image acquisition system mounted on vehicles was used to judge the truth and fallibility of laser FOD results through image deep learning, so as to improve the FOD detection reliability and ground maintenance efficiency.

The navigation control system of the vehicle mounted on the detector mainly plans the path of the FOD system based on the positioning data provided by the GPS system.

In order to improve the operation safety of the FOD detection system, the data acquired by the vehicle-mounted image acquisition system is processed by machine vision to judge the correctness of the vehicle's travel path and avoid navigation misalignment and operation failure caused by GPS signal distortion.
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