New Technologies for FRMS

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Abstract. Today, Fatigue is one of the hottest issues discussed in civil aviation of the world. However, because the numbers of the contributing factors and the diversity of symptoms, it makes the fatigue monitoring and the fatigue management as a problem. Based on the FRMS framework of Canada, this article will focus on the fatigue monitoring technologies of China, they are the methods on the assessment of work schedule, fatigue symptoms and the actual sleep time. These fatigue risk control measures and tools are designed for the pilots at present, and then it will be gradually developed for ATC and maintenance personnel.

Keywords: Fatigue Risk Management System, Monitoring, Circadian Rhythms, Fatigue Symptoms, Actually Sleep Time.

1 Introduction

Today, fatigue is one of the hottest issues discussed in civil aviation of the world. However, the numbers of the contributing factors and the diversity of symptoms make the fatigue monitoring and the fatigue management as a big problem. As we know, the traditional fatigue risk management based on Flight Time Limitations (FTL) cannot meet the demands of airlines' safety management. At the same time, the new fatigue risk management system (FRMS) has been developed based on SMS. The senior managers of airlines have learned from FRMS that fatigue management should not only consider the length of work hours, but also need to focus on the synchronization of work schedule and circadian rhythms, the actual effective duration of sleep and the severity of mental fatigue under certain work mode.

Just as FRMS advocates, FRMS is an organizational approach, it is also an on-going, adaptive, data-driven and continuous improvement programme based on science and empirical findings for managing fatigue. It aims to find and manage the relevant factors that may lead to fatigue, and enable greater operational flexibility of the organizational management.

China has been promoting the establishment and implementation of SMS for a few years, yet most airlines' safety managers feel that the effect of SMS is not significant. Usually, they often can find some references for the hazard identification and the risk

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evaluation, but cannot find a particularly effective method for the risk management. We like to use the word "no grasp" in Chinese to describe this situation. The reasons are that the risk management measures are too vague to operate or the implementation of the measures affects some stakeholders' interests or causes trouble among different departments. In a word, the biggest challenge of SMS which the China's airlines face is whether there is any available technology or method to manage the different risks. For example, the airlines' managers might know their own pilots are facing fatigue, but the method to reduce the time of flight simply is impossible because it would be detrimental to the profitability of the company. In fact, there are many ways of fatigue risk management and it is the essence of a flexible FRMS to use diverse risk prevention at different levels. Also, as mentioned above, FRMS includes fatigue monitoring technology, and it is a continued program by supporting data analysis.

Based on the FRMS framework of Canada, we will focus on the fatigue monitoring technologies of China, they are the methods on the assessment of work schedule, fatigue symptoms and the actual sleep time. These fatigue risk control measures and tools are designed for the pilots at present, and then it will be gradually developed for ATC and maintenance personnel.

2 Technologies for Fatigue Monitoring

2.1 Pre-flight Fatigue Prediction System

During 2010 to 2011, we carried out a research on the fatigue monitoring model. As figure, we considered the effects on fatigue of circadian rhythms, sleep situation and workload, and designed a fatigue effect factors questionnaire. We collected and analyzed the 60 pilots' test results, and after the validity examination (Cronbach's alpha =0.91), we determined the effectiveness of the model.

In 2012, we developed a network-based fatigue monitoring software named "Pre-Flight Fatigue Prediction System" based on the fatigue predict model. It involve the

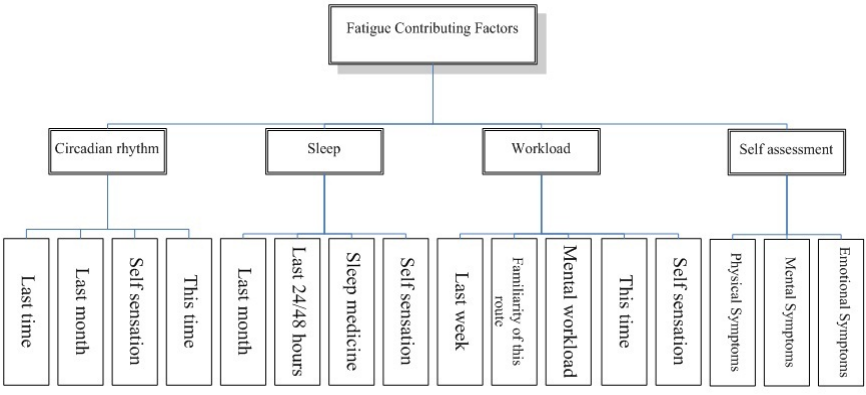

Fig. 1. The Framework of the fatigue monitoring model

main contributing fatigue factors which are circadian rhythm (such as a real flight time and rest time), sleep situation (such as the last month's sleep quality and duration) ,workload(such as the familiarity of this route and the aircraft), and plus the self-assessment factor.

The whole assessment will take about 10-15 minutes to finish. It needs pilot to do it on the given website before starting the flight of the whole day. The assessment results can be obtained immediately, and it can display the individual fatigue level (as figure 2) of each pilot directly and the average fatigue level of the company's pilots for their supervisor. So it can help the manager to decide to change the flight plan in the crew's preparatory stage according to the level of fatigue severity.

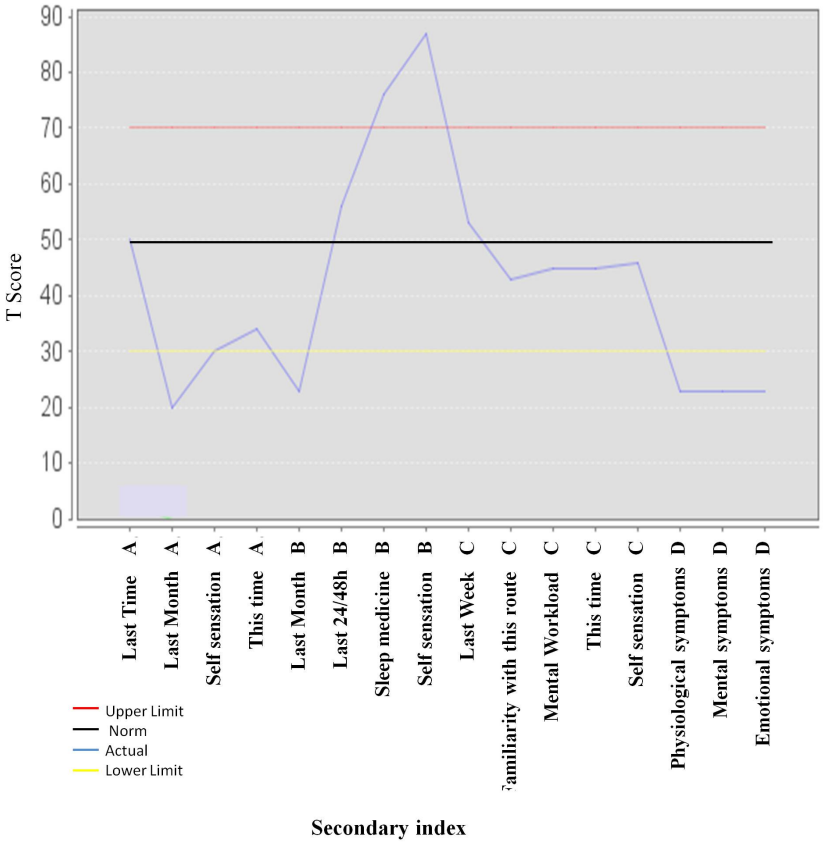

Fig. 2. The display of individual fatigue level

2.2 Orthostatic Detection Platform

During 2008 to 2009, we carried out a study of the relationship between fatigue and postural stability. We assessed the performance of 12 subjective twice at the begging and the ending time of 24 hours sustained wakefulness. After analysis, we indicate

that sleep deprivation can arouse a feeling of fatigue and can affect postural stability; hence an objective posture graphic test score may be useful as an indicator of mental fatigue.

Based on this study, we developed an orthostatic detection platform (as figure 3), which consists of stress detection stand, computer and fingerprint input system. The stress detection stand has four separate sets of metal plates. When the individual stand

Fig. 3. Orthostatic Detection Platform

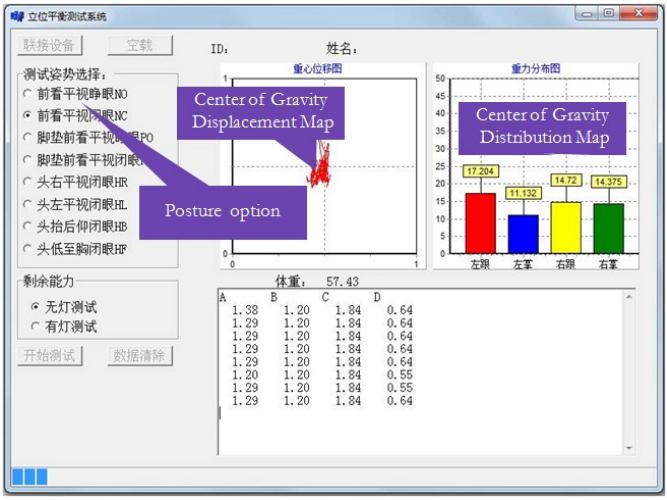

Fig. 4. The display of the assessment

on the pressure platform, making each heel and toes in accordance with the shape of the metal footprints on the corresponding metal plate, the vertical pressure changes on the platform are transmitted into a wave signal to the computer, and then processed by the computer to analyze the individual balance and posture.

According to the test type, the shortest assessment will take about 2.8 minutes and the longest assessment will take about 7minutes. The system can measure the pilot's basic stability, weight distribution and its harmonious degree, then to detect the Individual's vestibular problems, drunkenness, fatigue level(as figure 4), strength loss, and other physiological phenomena in a short time. This platform can be embedded in the pilot's check-in system to use before the flight and also be used to check after each mission.

2.3 Real Time Physiological Monitoring Belted Device

During 2009 to 2011, we developed a real time physiological monitoring belted device named "physiological monitoring watch". It can record and save the physiological and psychological signals such as skin resistance, three degrees of hand freedom, environmental pressure and other data as shown in figure 5.

Fig. 5. Physiological Monitoring Watch

The physiological monitoring watch need to record the change of state of the individual in the period of time, such as fatigue state changes, the duration of actual sleep, hand activities during actual flying and so on. Thus, the pilots need to equip with the watch during a continuous process. It asked the pilots to wear it 10 hours before the flight and take off it until 4 hours to the end of the flight.

We can analyze the pilots' equipped situation, the basic state of the body, the rest and sleep conditions, workload, operating trajectory, flight altitude, flight acceleration and speed indicators based on the basic data obtained by the physiological monitoring watch as shown in figure 6. These results can help the supervisor to assess the real sleep time and physiological state of pilot.

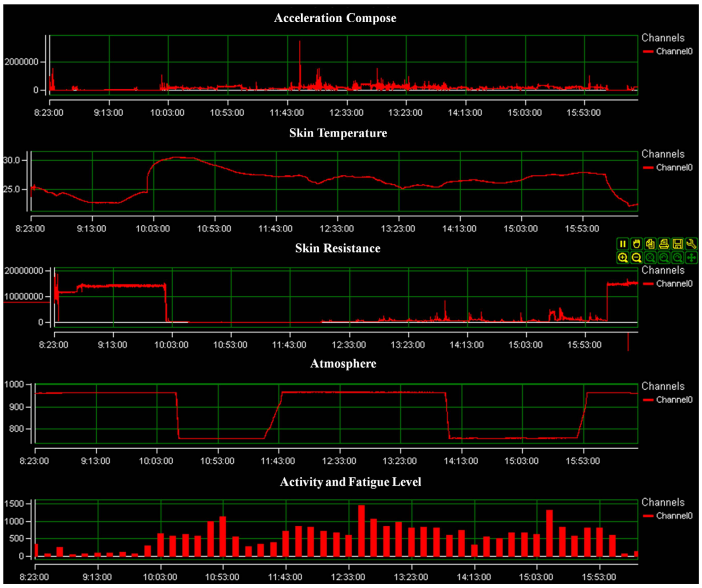

Fig. 6. The result display of Physiological Monitoring Watch

2.4 Comparison

In summary, these three assessment devices have their own advantages and disadvantages, and the obtained data are different. We suggest the supervisor use a

Table 1. Comparison of Three Assessment Devices

	Pre-Flight Fatigue Prediction System	Orthostatic Detection Platform	Real Time Physiological Monitoring Belted Device
Obtained Data	Fatigue level before flight	Current functional level	The changes of fatigue state, the duration of actual sleep, hand activities
Measuring Time	10-15 m	• Shortest: 171 s • Longest:441s • Fingerprint Identification:10s • Balance Test 1:32s • Balance Test 2:32s • Balance Test 3:32s • Heart Rate Measurement:30s • Heart Rate Variability Measurement:5m • Body Temperature Measurement:3s • Reaction Time:32s	Continuous Monitoring, staring from 10hours before the work to 4 hours after the work
Advantages	• Lower cost • Only once measured	The objective results	• Portable device • The objective results • Reflect the dynamic changes and trends of fatigue .
Disadvantages	• Longer time-consuming • The results are easier by subjective.	• The equipment need to be installed in a fixed place. • Pilots need to be measured twice before and after flight.	It needs to take a long time to wear the equipment.

combined assessment methods to assess the individual fatigue level accurately if the condition is permitted. The performance of three different assessment devices is listed as table 1.

3 Prospects

In order to assess the fatigue risk for the airlines company, we have formed a detailed fatigue risk control program based on the three monitoring technologies which mentioned above. According to the program, The Civil Aviation Administration of China has planned to carry out a one-year experiment in a selected airline in 2013. This program would verify the effectiveness of the fatigue assessment tools and it will help the supervisor to determine the fatigue degree of the pilots before and after the flight, and take effective fatigue risk control measures for aviation safety.

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