Research on the Health Intelligent Management System of Large Wind Tunnel

Hao Zhang, Zongzheng Liu*, Wenlin Liao, Xiaoguang Chen and Zhenhua Chen
China Aerodynamics Research and Development Center, Mianyang, China

*Corresponding author email: lzzcd@163.com

Abstract. In the national major projects, health management of key infrastructure has been paid more and more attention. Wind tunnel is a national strategic infrastructure. The health management system is of great significance to promote the safe, efficient and reliable operation of large-scale wind tunnel. In order to establish a wind tunnel health intelligent management system, it is necessary to realize the dynamic state monitoring, intelligent fault diagnosis, intelligent fault prediction, independent maintenance support and integrated equipment management. Facing the great demand of designing and constructing the world's top wind tunnels, this paper makes an exploratory research on the health intelligent management system of large wind tunnel. By means of data mining, machine learning and virtual reality, the health management system can have the ability of self-study and self-improvement. So as to realize the development of the health management of wind tunnel to the depth intelligent.

Keywords: Health intelligent management; Artificial intelligence; Large wind tunnel; Virtual reality.

1. Introduction
Wind tunnel is a strategic infrastructure supporting the development of aircraft. Advanced large-scale wind tunnel can promote the development of aerospace technology and lead the innovation of aerodynamics.

Health management system is an important system to ensure more efficient operation of large advanced wind tunnel. By using a combination of on-line monitoring, regular inspection and off-line detection of various sensors, it can widely obtain equipment status information. With the help of various data analysis methods and intelligent reasoning algorithms, it can evaluate the health status of the wind tunnel. It is expected that before the failure of wind tunnel, it can predict the failure of wind tunnel, make maintenance support decision, arrange maintenance implementation plans, etc. Finally, the purpose of improving the test ability of wind tunnel equipment can be achieved.

The research on health management system of wind tunnel started relatively late. With the efforts of relevant research units and scholars, some research results have been achieved. Li et al. designed the Φ 1m high supersonic wind tunnel [1]. Chen et al. discussed the application of self-service maintenance support technology in 2.4m Transonic Wind Tunnel [2]. Zhang et al. developed a platform for equipment health management and data validity determination of wind tunnel [3]. However, in order to support the operation safety of large-scale advanced wind tunnel in the future, the health management system of wind tunnel still needs to be explored and studied. In particular, the data fusion degree needs to be improved, the level of fault
diagnosis intelligence needs to be raised, and the level of maintenance support autonomy needs to be improved.

With the development of science and technology, the emergence of concepts such as artificial intelligence [4,5], big data analysis [6], virtual reality [7], human beings have entered the era of "industry 4.0" [8]. It also provides an opportunity for promoting the health management of wind tunnel to upgrade the intelligence.

This paper discusses the feasibility and application prospect of applying big data analysis, artificial intelligence and virtual reality to the health management system of wind tunnel equipment, the key scientific problems to solve the health intelligent management of wind tunnel, and some ideas about the health intelligent management system of wind tunnel.

2. General Framework of Wind Tunnel Health Intelligent Management System

Through the demand analysis, it is considered that the monitoring object of the wind tunnel health intelligent management system should include not only the tunnel machinery, power system and control system, but also the aerodynamic performance. It is necessary not only to monitor the health of mechanical and electrical equipment, but also to check the aerodynamic performance of the wind tunnel. In order to realize the intelligent management of wind tunnel health, the overall framework of wind tunnel health intelligent management is conceived, as shown in Fig. 1. From the bottom layer to the top layer, it is divided into data layer, support layer, application layer and presentation layer. Historical data and real-time data include structural stress / strain, load, displacement, vibration, temperature, humidity, pressure, voltage, current and other parameters. Combined with the big data analysis platform, expert knowledge base, fault diagnosis and prediction model in the support layer, the application functions of health management system such as condition monitoring, fault prediction, fault diagnosis, maintenance support and equipment management can be realized.

![General framework of wind tunnel health intelligent management system](image)

**Figure 1.** General framework of wind tunnel health intelligent management system.
3. Key Technology of Wind Tunnel Health Intelligent Management

3.1. State Monitoring Technology Based on Big Data Mining
The wind tunnel health management system is equipped with a large number of sensors to collect the wind tunnel operating parameters such as stress/strain, load, displacement, vibration, temperature, humidity, pressure, voltage, current, etc. Through the signal feature extraction of real-time data and historical data, some abnormal states can be found directly from a single parameter image waveform. However, more often, exceptions are hidden in a large number of messy data. It is necessary to build a data algorithm model and analyze data mining to find exceptions. Big data mining technology is the process of extracting valuable knowledge from a large number of data. Common big data mining methods include clustering, classification, regression, association, etc. The core technology of big data mining is to build data algorithm model, which usually includes decision tree, artificial neural network, rough set and genetic algorithm.

3.2. Fault Diagnosis Technology Based on Self-Learning
The fault diagnosis business process based on self-learning is shown in Fig. 2. In the process of fault information diagnosis, on the one hand, the existing expert knowledge base is used for fault identification; on the other hand, the fuzzy mathematics, neural network and other artificial intelligence algorithms are used for fault identification. And the identified fault is stored in the expert knowledge base, so that it has the function of self-learning and self-improvement.

![Figure 2. Fault diagnosis process based on self-learning.](image)

The expert knowledge base integrates many experts’ practical knowledge and experience in many years, and then through the computer level programming, forms the intelligent large-scale computer program. This analysis method does not need to analyze the details of equipment system structure, working principle and so on. The establishment of knowledge base can come from actual samples, documents, etc., avoiding the performance of mathematical and physical models. It is characterized by a wide range of applications, high level of diagnosis and high efficiency of diagnosis.

The artificial neural network diagnosis method makes full use of the fault examples. On the basis of training, associative memory and pattern matching, fault diagnosis can be carried out by back propagation (BP) algorithm of perceptron network. The application of neural network to fault diagnosis also needs to count out the fault mode, and then classify the input data, but the requirements of neural network for input and output are not very strict.
3.3. Intelligent Fault Prediction Technology

Intelligent fault prediction technology is based on the current use of equipment as the starting point. It combines the structural characteristics, parameters, environmental conditions and historical data of the prediction object, and uses artificial intelligence algorithm to predict, analyze and judge the future fault of the equipment. Thus, determine the nature, category, degree, cause and location of the fault, point out the development trend and consequences of the fault, and ensure the normal operation of the equipment.

A common intelligent fault prediction method is based on neural network. Which first selects a number of historical data sequences as training samples, then constructs a suitable network structure, trains the network with a certain training algorithm to meet the accuracy requirements, and then forecasts, as shown in Fig. 3.

![Prediction process based on Neural Network.](image)

**Figure 3.** Prediction process based on Neural Network.

The specific steps are as follows: The first step is to establish the relationship between the measurement data and the failure mode of wind tunnel. The second step is to set the node weight and threshold. The third step is to train the network. By training the sample data recorded in the wind tunnel test, the optimal training network is obtained by finding the appropriate weights and thresholds. The fourth step is fault prediction. The wind tunnel test data recorded in real-time is input into the trained neural network to predict the corresponding variable value, so as to judge the predicted object and predict the failure mode. The fifth step is model optimization. After each real-time data analysis, it can continue to train the new neural network as a sample. Of course, the neural network will continue to update with the continuous updating of the sample data, so the related analysis workload will be large.

3.4. Maintenance Supportability Maintenance Platform Based on Virtual Reality Technology

Large wind tunnel is not a mass production, so the difficulty of its maintainability design is particularly prominent. Virtual maintenance technology can obtain the visual product appearance and structure expression characteristics in the design stage, and also play a good human-computer interaction effect in the maintenance support business.
Virtual maintenance support process of wind tunnel. Virtual maintenance is of great significance of mastering the maintenance characteristics after the failure of wind tunnel. At the same time, it also plays an important role in the improvement of wind tunnel supportability, such as the installation and replacement of aircraft test model, structural replacement of functional requirements and other processes. As shown in Fig. 4, according to the proposed maintenance and support strategy, the whole maintenance and support process can be simulated through two different interaction modes between human and virtual model to obtain the maintainability and support characteristics of the wind tunnel. If the performance index of maintenance support can't be reached, the maintenance support strategy of the wind tunnel should be changed in time, and the simulation should be carried out again until it reaches the predetermined index. After this iterative and iterative process, the maintenance process and aerodynamic test process of vulnerable parts are optimized to reduce the total cost of aerodynamic test.

4. Technical Challenges of Wind Tunnel Health Intelligent Management

With the new technologies and methods such as artificial intelligence and big data analysis, the wind tunnel operators can understand the operation of the wind tunnel from a higher level and a broader perspective, improve their insight and decision-making efficiency. But at the same time, the technical difficulty is also increased, which also brings new challenges. The first is the establishment of large database. Data is the basis of big data analysis and an important resource for wind tunnel intelligent health management research. Each wind tunnel has its own uniqueness, so in the design and construction stage, even in the early stage of operation, there is not enough data to support fault warning, fault diagnosis and fault prediction. This requires gradually accumulating data and improving the database in the process of wind tunnel operation. Secondly, the relationship between aerodynamic parameters and wind tunnel failure should be constructed. The main demands of general mechanical equipment for health management are mainly reflected on safety. The function of wind tunnel equipment is to provide high-precision aerodynamic data for flight equipment. The main demands are not only the safety of wind tunnel equipment, but also the accuracy of aerodynamic performance. Therefore, in addition to the relationship between wind tunnel equipment failure and mechanical parameters such as vibration and stress, the relationship between wind tunnel equipment failure and aerodynamic parameters should also be constructed.
The third is to establish virtual reality model of wind tunnel. The model in the process of human-computer interaction puts forward direct requirements for the performance of virtual reality supporting equipment and tools.

5. Conclusion
This paper focuses on the health intelligent management system of large wind tunnel. The combination of big data analysis, artificial intelligence, virtual reality and wind tunnel health management system, the key scientific problems to solve the wind tunnel health intelligent management, and gives some ideas about the wind tunnel health intelligent management system. The feasibility of the combination of big data analysis, artificial intelligence, virtual reality and wind tunnel health management system has been discussed. The key scientific problems of wind tunnel health intelligent management have been summarized. In addition, some ideas of wind tunnel health intelligent management system have been given.

Acknowledgement
This research was financially supported by the National Natural Science Foundation of China (Grant Nos. 51805530, 51905532) and the FengLei Youth Innovation Fund of CARDC (Grant Nos. FLYIF201805).

References
[1] J. Li, T. Zhu and X.B. Xu. Design of autonomous maintenance support system for Φ 1 m high supersonic wind tunnel, computer measurement and control, 24 (2016) 126-129.
[2] H.T. Chen, Y.H. Wu, F. Yi. Application of self-service maintenance and support technology in 2.4m Transonic Wind Tunnel. 6th measurement and control academic exchange meeting of aerodynamics society.
[3] W. Zhang. Research on equipment health management and data validity judgment platform based on wind tunnel, computer measurement and control, 25 (2017) 30-34.
[4] L. Wang. Research on Intelligent Fault Diagnosis Technology of complex equipment, Master's thesis: Shenyang Normal University (2011)
[5] Y.H. Li. Analog circuit fault diagnosis based on BP neural network. Computer and digital engineering, 37 (2009) 192-194
[6] G.J. Li, X.Q. Cheng. Big data research: a major strategic area of future science and technology and economic and social development - research status and scientific thinking of big data, Journal of the Chinese Academy of Sciences, 27 (2012) 647-657
[7] Q.P. Zhao. Virtual reality review. Chinese Science (F series: Information Science), 01 (2009) 2-46
[8] J. Li. Industrial big data - Industrial Transformation and value creation in the era of industry 4.0, China Machine Press, 2015 6-15