Prognostics and Health Management technology of Armored Gun Control Subsystem

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Keywords: Gun Control Subsystem, PHM, Feature Extraction, Sensor Fusion

Abstract. Prognostics and Health Management (PHM) achieved the transformation from the traditional fault diagnosis to the intelligent fault prediction, it can achieve autonomous security and maintenance functions, as appropriate. Military armored equipment needs to integrate this technology to improve troubleshooting and predictive capabilities. This paper described the PHM technology, and to a certain type of armored equipment gun control subsystem, for example, designed the gun control subsystem PHM system, and verified with the stabilizer of gun control system by using fuzzy logic approach for fault prediction, it gave some reference and guidance for the development of PHM technology in armored equipment.

1. Introduction

Prognostic and Health Management (PHM) is an advanced testing, maintenance, predictive technology that enables autonomous security and maintenance functions, as appropriate. It succeeded in passively managed device for the purpose of restructuring initiative intelligent management, especially in troubleshooting and equipment maintenance research, which implements the reverse service that is based on the state of repair. In modern armored military equipment, the gun control subsystem complex structure, a wide range of failures, maintenance personnel need to fully grasp the gun control subsystem features, which uses high side technical requirements. Since PHM is subjective, precision and purpose, it can save a lot of manpower, material and financial resources in battlefield environments and rear maintenance, so it caused widespread concern in recent years of the military and industry.

2. PHM technology and its application

2.1 PHM Technology Status

At the end of the 20th century, PHM, as a key technology of JFS program of the US military, gradually be applied to aerospace, large ships, nuclear technology. But the technology mainly for equipment with high value such as the space shuttle, satellites, aircraft carriers and other, specific research methods are not universally applicable, and there is no extensive research on the relatively lower value of the equipment army armored vehicles and ground weapon systems . With the deepening of the study, integrated electrical, mechanical, optical and other advanced technology and equipment also need PHM armored ground technical support, in order to reduce the increasing cost of equipment maintenance support, to achieve efficient management of equipment and to meet the information War needs, PHM technology needs research. Army in the research and application of this technology started later than the U.S., through independent study, learning from the advanced experience of the U.S. and other developed countries, we are forming a kind of technology as the core of PHM Armored Equipment Maintenance Support System, at the same time, we are also progressing steadily on fault diagnosis, health Correlation method of management, failure prediction and other aspects.

2.2 Fault Prediction Technology

Failure prediction technology is the core of PHM system. Based on the accumulation of historical fault data, it will analysis to predict the nature, categories, and reasons of the equipment malfunction that may occur in the future, it can remind at the fault point in time, thereby eliminating hidden faults, saving maintenance costs and to ensure training and combat missions completed. Currently, fault prediction technology mainly in the following ways:

(1) Fault prediction method based on empirical knowledge

The method is based on historical data and expert experience to predict the equipment's life cycle, while the credibility is not high though spending low, we need to be combined with other technologies for better forecast results.

(2) Fault prediction method based on physical models

This method is through the establishment of a physical model, making it clear of the relationship between the model parameters and fault feature, using correlation algorithm to predict and to assess the running status the residual life. Although this method requires complex modeling and cost more, but the results are more accurate and can achieve real-time forecasting capabilities.

(3) Fault prediction method based on data mining

This method makes full use of operation and management of historical data, it is based on data mining techniques to achieve fault prediction by extracting implied meaningful information from the database. It gets results through integrated reasoning by using fuzzy mathematical method and analyzing quantitatively of the relationship between the fault and its influencing factors. Gun Control subsystem, for example, will use this method to predict the fault.

3. PHM technology on gun control subsystem

Under normal circumstances, armored vehicles operate in the harsh environment, a large number of integrated instrumentation in control system prone to failure, it gives more difficulties. Current maintenance mode mainly uses corrective maintenance and regular maintenance, it leads low maintenance efficiency and the waste of resources. PHM technology can be found in the use of gun control system fault of critical components and gives proper maintenance recommendations to achieve transformation from regular maintenance and corrective maintenance to the state-based, predictable maintenance mode, it can guarantee the effective functioning of the vehicle.

3.1 Fault performance of gun control system

The common faults include console fault, the motor amplifier fault, power cylinder fault, inverter fault, gyroscope fault and hydraulic amplifier fault. Among them, the manifestation of console fault is that the gun control electronic box power signal be unusual, cradle gyroscope Gyro system motor abnormal sound, the console HLI fault indicator; the manifestation of power cylinder is that artillery position locking, pump motor abnormal sound, power cylinder lock solenoid is not working and so on.

3.2 Design of gun control PHM system

Based on the prediction and management features of PHM, using functional division and modular design, we show the design of gun control PHM system in Figure 1.

Data collecting. Data collecting is automatically collected from the sensor signal data and upload it to analyze the process of treatment, which is a key step in PHM technology. Comprehensive gun control system fault modes described, we need to collect the sensor data including displacement, voltage, current, vibration, temperature and so on. Data processing method using a filter, average, statistical analysis, and data processing process should pay attention to convert the data into a database or a health management system in order to manage a unified format.

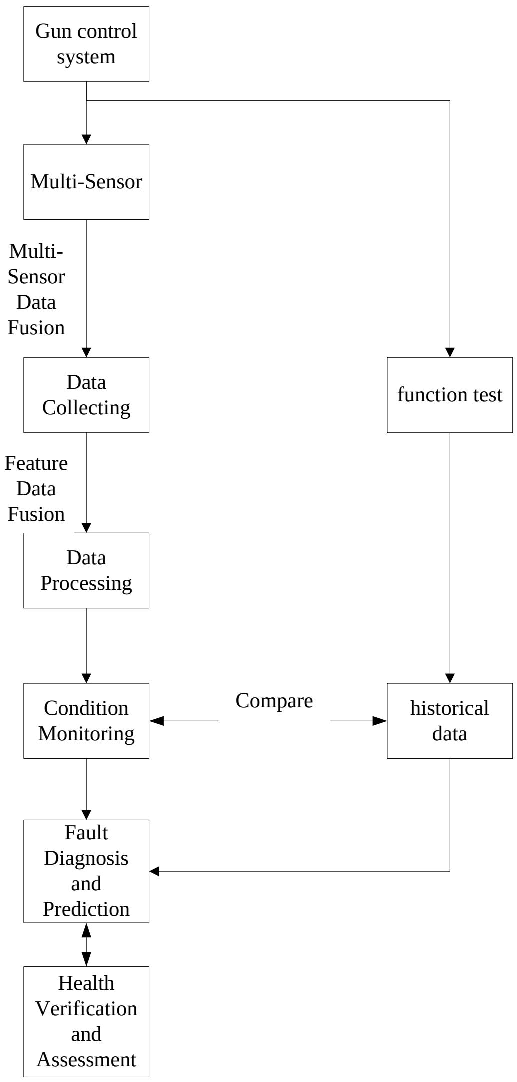

Fig. 1 Gun Control PHM System

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Data processing. In the data processing phase, we should focus on the feature amount extraction. Combining with the fault characteristics of gun control system, we use principal component analysis, matching tracking, time-frequency analysis, signal processing techniques to extract fault feature. The main feature amount extraction include the following: kurtosis index is mainly used to detect if there is a collision friction gyro system failure; peak - both variance and the variance of the cylinder barrel vibration control for detecting abnormal power; skewness indicator reflects the asymmetry of the vibration signal, friction or impact in one direction causes the skewness index increases; margin index for wear detection turret motor, when the ratio of the peak and mean-square value increases, while only partial index when subtle change, that indicates the gap increases, wear increasing, thus increasing the peak vibrations faster than mean-square value, its margin index also increased.

Condition Monitoring. There are two kinds of common condition monitoring means. The one is by setting a stable condition indicators specified threshold, to monitor the tested unit in real time. An exception occurs when the characteristic parameter value overflows, and then determine the fault status through troubleshooting. Another one is to enter the parameters of the unit under test, using fuzzy logic methods to realize condition monitoring. When the gun control system adjusts the gun links, the failure occurs mainly in the motor mechanical and electrical levels. When electrical faults occur, we can determine by measuring currents, winding DC resistance and other methods; when mechanical faults occur, we may use vibration monitoring and diagnosis, current diagnostic methods and spectral analysis method.

Fault Diagnosis and Prediction. Fault diagnosis and prediction are based on current health status of gun control system, facing to its key components to predict the life lift and the future faults. As in the gun control system fault analysis, acoustic emission signal and a vibration signal to conduct information fusion, it can provide the turret microscopic features (such as stress waves) and the macroscopic properties (such as vibration) related information.

We will predict the fault with an example of gun control subsystem as follows:

We define reasons fault set A of the gun control system first and with Euclidean vector is represented as A $=\{a_1, a_2, \ldots, a_n\}$; followed by the definition of gun control system fault symptom set B={b1 ,b2 ,…,bm}; Finally, since the fault symptom is uncertain, we use fuzzy logic and distributed data fusion technology, construct existence of a fault with the membership function credibility, the definition of m×n dimensional matrix C is the fuzzy relation matrix with membership function, $C=\begin{bmatrix} C11 & \cdots & C1n \\ \vdots & \ddots & \vdots \\ Cm1 & \cdots & Cmn \end{bmatrix}=(Cij)m\times n$, each row represents fault symptoms, each column represents the cause, Cij shows the i symptom of the membership of the j reason. The operational relationship of A, B, C is that A = A=B∘ C, where "∘"named fuzzy operator.

Exemplified in some equipped stabilizers of gun control system, its fuzzy relation matrix C as shown in Table 1:

Table 1. Fuzzy relation matrix

Fault symptom / phenomenon	stiffness small	overshoot large	stability moment large	drift speed large	atresia migration velocity large	maximum speed small	minimum speed large
Control panel fault	0	0.5	0	0.98	0.6	0.92	0.92
Power cylinder fault	0.67	0	0.75	0.5	0.68	0.62	0.62
Hydraulic amplifier fault	0.86	0.1	0.8	0.2	0.22	0.8	0.21
Gyroscope fault	0.95	0.9	0.78	0.98	0.92	0.5	0.5
Converter fault	0.27	0	0.44	0	0	0.85	0.1

For example, when using fault detection device detects the overshoot is too large, the minimum speed is too large, the fault symptom expressed as $B_1=\{b1=0, b_2=1, b_3=0, b_4=0, b_5=0, b_6=0, b_7=1\}$, fault reason vector $A_1=B_1\cdot C$, We can draw the following matrix:

$$A_1=B_1\cdot C=(0,1,0,0,0,0,1)\cdot\begin{pmatrix} 0 & 0.67 & 0.86 & 0.95 & 0.27 \\ 0.5 & 0 & 0.1 & 0.9 & 0 \\ 0 & 0.75 & 0.8 & 0.78 & 0.44 \\ 0.98 & 0.5 & 0.2 & 0.98 & 0 \\ 0.6 & 0.68 & 0.22 & 0.92 & 0 \\ 0.92 & 0.62 & 0.8 & 0.5 & 0.85 \\ 0.92 & 0.62 & 0.21 & 0.5 & 0.1 \end{pmatrix}=(1.42, 0.62, 0.31, 1.45, 0.1)$$

When we analysis from the maximum membership degree principle, the possibility of failure in five groups will be the fourth C_4, which is the gyroscope fault. Compared with the actual working conditions, the predictions coincide with the actual situation, the gyroscope fault does cause the fault symptom.

Health Verification and Assessment. Over the years, we accumulated a lot of fault empirical data of gun control subsystem in daily training and maintenance process, which provides the theoretical guarantee for the experiment. In the testing and validation process, the system can use a lot of important actual fault data that has been accumulated for verification and evaluation, it provides evidence to improve gun control subsystem performance.

4. Summary

In this paper, we designed gun control system PHM system targeted at a type of armored equipment gun control system fault features. In the design, we firstly used a variety of sensors, such as displacement sensors to collect data, and then by extracting feature quantity parameters, we used data mining techniques to predict the gun control system critical components faults, ultimately conducted gun control system health verification and evaluation. The system implements a fault prediction and Health Management for a certain type of equipment gun control system, providing a reference for other subsystems, such as sighting subsystems, and fire control computer in failure prediction and Health Administration. It reduces the risk of failure during the task, improving the equipment maintainability, testability and supportability, reduced equipment maintenance and support costs.

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