Research on Automatic Detection Method of Minor Faults in Electrical Components of Ejection Seat

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Abstract: In order to solve the problems of high error rate and poor efficiency existing in the current ejection seat electrical fault detection process, the automatic detection method of ejection seat electrical component minor faults was studied, and the original features of component minor faults were effectively extracted with ant colony algorithm as component fault diagnosis comparison data. Combined with the minimum binary algorithm, the safe operation parameters of seat electrical components are calculated. Combined with the safe operation parameters, the mini-fault diagnostic device of ejection seat electrical components is constructed, and the original feature parameters of mini-faults of components are input into the underlying database of the diagnostic device. Once the operating parameters of seat components exceed the range of safety parameters, the original feature data of mini-faults in the database are extracted to screen and detect the mini-faults of seat, so as to quickly obtain the cause of the faults and complete the automatic detection of mini-faults of ejection seat electrical components. Finally, experiments show that the error rate of this method is reduced by more than 50% compared with the traditional component fault location detection method, which fully meets the research requirements.

1. INTRODUCTION
With the continuous improvement of modernization level, the aviation and aerospace field has put forward higher requirements for the safety of ejection seats. In order to promote the prosperity and development of the aerospace industry and ensure the health and safety of related personnel, the current automatic detection methods for minor faults of electrical components of ejection seats are analyzed through a large number of investigations, and it is found that although the current automatic detection methods for electrical components of ejection seats are relatively reasonable, there are still problems such as insufficient detection accuracy, especially the detection results for minor faults of components are relatively poor [1]. In order to solve the above problems, this paper puts forward optimization suggestions for automatic detection method of minor faults in electrical components of ejection seat, so as to effectively solve the current problems such as insufficient detection of minor faults in electrical components of ejection seat and provide a reference for the development of aerospace industry.
2. AUTOMATIC DETECTION METHOD FOR MINOR FAULTS OF ELECTRICAL COMPONENTS OF EJECTION SEAT

2.1 Original Feature Extraction Algorithm for Electrical Components of Ejection Seat with Minor Faults

The traditional ejection seat electrical component detection is not sensitive enough to abnormal noise detection of seat electrical components, which is easy to cause problems such as fault expansion. Therefore, the distribution of signal characteristics and fault signal characteristics under the normal operation state of seat electrical components are extracted and recorded in the database. The artificial bee colony algorithm is used to search the optimal signal classification parameters\[2\]. Finally, the combined seat electrical component fault diagnosis algorithm is used to judge the micro-operation parameter acquisition result of the seat electrical component. At present, the types of components on the ejection seat are relatively complex, with various data lines and low-voltage power lines, and the distance is short, covering all positions of the ejection seat. Long-term use can easily lead to various potential safety hazards such as wear, corrosion and deformation of components. At present, the method of using multimeter to detect component fault location is relatively complicated, time-consuming and labor-consuming, and the reliability is not high\[3\]. In order to solve the above problems, it is proposed that the electrical components of the seat often run abnormally during the ejection seat can run, and the operating noise of the electrical components of the seat will be abnormal at this time, thus indicating that there is a potential safety hazard in the electrical components of the seat. Assuming that the extracted vibration signal frequency of seat electrical components is \( A \), the variance of equipment running wear parameters is \( I \), the peak value of fault parameters is \( J \), and the time domain feature vector of seat electrical components is \( V \), the parameter diagnosis algorithm is as follows:

\[
P = \frac{1}{2} A \left[ (v_i - v_j)^2 \right] \quad (1)
\]

If \( k \) samples the data, \( r \) is the standard value under normal operation of the seat electrical components and \( n \) is the fault noise parameter value, then the vibration signal frequency algorithm of the seat electrical components is:

\[
A = \sqrt{\frac{R(v_i - v_j)^2}{\frac{1}{n} - \sum_{i=1}^{n} (v_i - \bar{v})^2}} \quad (2)
\]

Combined with the above algorithm, the extreme value of the frequency component of the original noise signal is calculated, and the obtained noise characteristic component signal is extracted and cancelled, thus effectively solving the phenomenon of confusion and discontinuity due to the fault noise detection mode, so as to analyze the frequency domain characteristics of the signal more clearly. Combined with the above method, the frequency domain characteristics of the minor fault signal of the electrical components of the ejection seat are extracted and preliminarily analyzed, and the flow chart is shown in the figure.
The frequency domain feature detection system for the minor fault signal of the ejection seat electrical components can effectively improve the local hidden trouble searching ability of the detection system. This method is superior to the traditional detection system based on genetic algorithm and ant colony algorithm, and can quickly search the local area in time, more adapt to the detection environment and requirements, and then quickly converge to the abnormal situation of the seat electrical components. In recent years, the application range of electrical control technology for ejection seat electrical components in the field of industrial processing has become wider and wider, and the market demands for control of ejection seat electrical components and reduction of hardware costs have become higher and higher\[4\]. There are many kinds of problems and the situation is complicated in the processing of seat electrical components. Therefore, how to accurately determine the cause of the problems and timely eliminate the faults is a big problem that must be solved at present. Analyze and solve the problem according to the different parts of the fault. There are mainly two parts of failure of electrical components: hardware failure and software failure. One of the hardware failures is that the control electronics, low-voltage switches, circuit boards, ribbon cables and other parts of the machine tool slide down, loosen or even burn down due to some reasons. When such problems occur, the light ones need to simply repair the faulty parts and the heavy ones only need to replace the faulty parts. The other is software failure, which refers to the software failure of ejection seat. In general, when this problem occurs, it can be solved by making appropriate modifications to some data or modifying some programs\[5\].

2.2 Construction of mini-fault diagnosis device for electrical components of ejection seat
In order to further optimize the automatic detection effect of the ejection seat electrical components with minor faults, a corresponding fault analysis model is established after calculating the fault indicators of the ejection seat electrical components with minor faults, the fault parameters of the ejection seat electrical components are calculated by changing the ejection seat electrical components with minor faults model, and a deep neural network is set at the nodes of the input layer and the output layer of the fault detection system\[6\]. The automatic component fault detection and denoising encoder ( DSAE ) is used to effectively extract the micro-fault data features of the electrical components of the ejection seat, and the fault detection support vector machine classifier ( DNN ) is added to the top layer of the sparse denoising automatic encoder to classify the micro-fault features of the electrical components of the ejection seat. The model parameters are as follows:
Combined with the special structure of ejection seat electrical component micro-fault parameters in the above table, local fault feature classification and identification are realized, and ejection seat electrical component micro-fault mode classification is realized without knowing hidden layer expression, so as to improve its fault classification effect and fault maintenance efficiency. In order to effectively avoid electrical component failure\(^7\). It is proposed that a single submerged nozzle is fixed in the ejection, and four two-phase spoiler blades are installed at the outlet of the nozzle. The spoiler blades are driven to extend into or retract into the outlet flow field of the nozzle by the electro-hydraulic steering gear to forcibly change the jet direction of the airflow, thus generating a changeable reaction force\(^8\). The actuating control system adopts the steering gear system on the missile, uses the squeezing oil tank as the energy source, amplifies and processes the induction signal from the space posture of the ejection seat through the servo amplifier, controls the normal or reverse phase operation of the electro-hydraulic servo valve, thus controlling the amount of oil entering the actuating piston cylinder in the normal or reverse phase, pushing the piston rod to move at a speed proportional to the oil flow, connecting the piston rod with the spoiler, and finally achieving the goal of controlling the continuous movement of the spoiler back and forth and controlling the thrust direction. The advantage of this scheme is that it achieves stepless continuous control of the conical space in thrust direction, so it can generate different pitching and yawing torques and achieve the purpose of correcting the unfavorable attitude of the ejection seat in real time. In order to achieve the research goal of accurate and rapid automatic detection of minor faults in the electrical components of ejection seat, the structure of the electrical components of ejection seat was optimized.

![Fig. 2 mini-fault diagnosis device for electrical components of ejection seat](image)

As shown in the figure, under normal circumstances, the occurrence of minor faults in the electrical components of the ejection seat mainly depends on the frequency and the range of occurrence. The frequency of failure can be divided into two types: random failure and system failure. Random faults refer to occasional faults with low frequency and unfixed position. Therefore, it is difficult to diagnose random faults. It may be due to the fact that the ejection seat of the machine tool is not partially loose or dislocated, or due to the displacement of the static working point of the electrical circuit, the weakening of stability, or even the high temperature of the working environment of the electrical

| Table 1 Parameters of Fault Feature Detection Model |
|-----------------------------------------------|
| **Device status** | **Number of output layer nodes** | **Learning rate** | **De-noising ratio** |
| DSAE | M | 1900 | S2 | 650 | P | 0.09 | B | 0.42 | DENoise | 0.10 | DROPOUT | 0.34 | E | 1.00 | DENoise | 0.11 |
| DNN | M | 1900 | OUT | 5.90 | DROPOUT | 0.29 | E | 1.00 | DENoise | 0.40 | B | 0.40 | P | 0.10 | DENoise | 0.11 |
device. Any ejection seat will be worn out when it is in use. After the electrical component products have been in operation for a period of time, due to problems such as machine wear, there will be problems such as reduced flexibility of the movement system of ejection seat parts. For example, the displacement accuracy of electrical components is weakened, the reverse dead zone becomes larger, and the operation is not smooth. In the event of any of the above faults, it is necessary to stop the operation and solve the fault by adjusting the ejection seat in time. On the contrary, system failure refers to regular failure that occurs only under fixed conditions. In case of such failure, inspectors need to conduct repeated national day tests, synthesize the results, finally determine the cause of the problem, and then propose solutions. According to the modular design, the test bench is divided into R - L - C measurement module and switch module. The modular design pattern makes the test bench have considerable flexibility, expandability and versatility.

2.3 Realization of Automatic Detection Method for Minor Faults in Electrical Components of Ejection Seat

The mini-fault diagnosis device for electrical components of ejection seat can continuously, quickly and comprehensively measure many parameters of ejection seat, which largely determines the advanced, reliable, practical and real-time nature of the fault diagnosis method. Considering all kinds of factors, the software development of fault diagnosis under the management of Windows 2000 operating system is selected, and the fault diagnosis model is studied by using MFC with VC + + as the development platform. The self-inspection program is mainly used for the diagnosis of ATE equipment itself, and the ATE calibration program is mainly used for error correction of the measurement results, while completing the measurement of the process detection parameters of ejection seat components. If the parameters do not meet the requirements, the fault location shall be carried out according to the logic relationship. The minor fault parameters of all electrical components to be measured in the ejection seat are entered into the database through the database entry program so that ATE can automatically detect the faults. Fault detection results are automatically formed by the file generation program, and repair file case information is filled into OLE fields of the database in the form of binary large fields, so as to simplify data storage and reading, make the database operation more reasonable and convenient to query and use in the OLE field writing and reading test interface. In order to make use of the abnormal feature information in the time-frequency domain of the ejection seat electrical components obtained in the above system, the abnormal information classification results are calculated based on the integration algorithm of the evaluation matrix. If there are k classified fault information in the matrix, and n and m are the minor fault feature detection parameters respectively, the abnormal information classification confusion matrix is expressed as.

\[
R^k = \begin{bmatrix}
m_{1,1}^{(k)}, m_{1,2}^{(k)}, m_{1,3}^{(k)}, \ldots, m_{1,n}^{(k)} \\
m_{2,1}^{(k)}, m_{2,2}^{(k)}, m_{2,3}^{(k)}, \ldots, m_{2,n}^{(k)} \\
\vdots \\
m_{m,1}^{(k)}, m_{m,2}^{(k)}, m_{m,3}^{(k)}, \ldots, m_{m,n}^{(k)}
\end{bmatrix}
\]

Combined with the above matrix algorithm, the motor bearing abnormal diagnosis information is classified and the final diagnosis result is output. According to the structure of the diagnosis model, the mini-fault diagnosis model for the electrical components of the ejection seat is designed, and the model is as follows.
As shown in the figure, the main function of the fault control panel is to receive and translate commands from the industrial personal computer, generate corresponding decoding signals, control the operation of the relay board and the internal circuit principle in the model structure for automatic detection of minor faults in the electrical components of the ejection seat. Before failure detection, connect the ejection seat to the ATE through the transfer cable. The switch module selects the positive pole and negative pole of the measured parameter through the transfer cable according to the command sent by the industrial personal computer. The L-C-R measurement module and the insulation resistance measurement module measure the size of the measured parameters at both ends of the cable selected by the switch according to the command sent by the industrial personal computer. In the process of component failure detection, the insulation resistance test of the ejection seat cable network is an essential part. Because the cable network of ejection seat is complex and various, the method of measuring insulation resistance by megohmmeter has large error and low degree of automation. Due to any error in data, the overall performance of the ejection seat may be degraded. In the detection process, the switch needs to be used for additional protection in order to achieve the goal of automatic detection and switching and improve the reliability and efficiency of the test. After completing the above-mentioned parts and conducting on-line debugging, the system can completely meet the research requirements for the detection of minor faults in the electrical components of the ejection seat.

3. TEST BED AND MEASUREMENTS

After completing the design of the mini-fault diagnosis method for the electrical components of the ejection seat, in order to verify the actual effect of the fault detection, the correctness and effectiveness of the detection are further compared and verified. In the process of experimental detection, the experimental parameters are fixed. For the same minor faults, the traditional methods, expert diagnosis and experimental methods are used in a distributed manner, and the diagnosis results are recorded. The comparison data of fault diagnosis results are as follows:

| Diagnostic parameters | Traditional methods of diagnosis | Expert diagnosis | Experimental diagnosis |
|-----------------------|---------------------------------|------------------|------------------------|
| Stability             | 0.41                            | 0.43             | 0.78                   |
| Anti-interference is strong | 0.47                  | 0.45             | 0.77                   |
| Accuracy              | 0.39                            | 0.40             | 0.74                   |
| Others                | 0.42                            | 0.42             | 0.73                   |

The data in the table is not difficult to be retrieved. The automatic detection of ejection seat minor faults combined with the method proposed above has significantly improved the diagnostic efficiency.
compared with the traditional methods and expert diagnostic methods, and can more accurately judge ejection seat electrical components minor faults. In order to further detect the feasibility of the method, under the same experimental conditions and parameters, the accuracy of fault diagnosis is compared and detected through the distribution of traditional methods and experimental methods, and the images are plotted and compared to obtain the following figure.

![Fig. 4 comparison of experimental detection results](image)

From the above figure, it is not difficult to find that the error rate of fault detection by the experimental method is much lower than that by the traditional method under the condition that there is a slight fault in the seat electrical components, and the detection advantage of the experimental method shows a steady downward trend with the passage of time. This proves that the automatic fault diagnosis method for electrical components of ejection seat proposed in this paper has high practical value. However, due to the long fault location time in the early stage, the average detection time for minor faults in the electrical components of the ejection seat has been prolonged to a certain extent, so the method still needs to be improved, but the method as a whole is the research target of the automatic detection method for minor faults in the electrical components of the ejection seat, and the method has the function of accurately completing fault location, greatly improving the efficiency of maintaining the electrical components of the ejection seat. Experiments show that the method is stable in function, strong in anti-interference and small in error.

4. CONCLUSIONS

With the continuous development of ejection lifesaving technology, the research of ejection rocket thrust vector control technology has become the main trend of ejection rocket development in the future, and has also become the main symbol of lifesaving performance of a new generation of ejection seats. In order to further promote the development and progress of China's aerospace industry, the automatic detection method for minor faults of ejection seat electrical components is deeply studied and analyzed, and the optimization proposal for feature extraction and troubleshooting of seat faults combined with the minimum binary algorithm is put forward. Finally, the same experiment proves that the method can effectively improve the accuracy of the ejection seat fault detection and ensure the ejection seat to be in a stable and safe use state for a long time.

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