Analysis of Abnormal Sound of Automobile Engine Based on BP Neural Network

LOU Jie

Wuhu Institute of Technology
Anhui, China

Abstract - In this paper, the author studies on analysis of abnormal sound of automobile engine based on BP neural network. The analytical model is based on the introduction of the method, discussed in detail that the methods of their classification as well as lack of implementation are proposed. Additionally, introduce the knowledge-based method of fault diagnosis then based on signal processing methods to conduct a detailed classification analysis, and combination of the above-mentioned theory a real example is given, which based on neural network expert system for fault diagnosis. Furthermore, the use of fault diagnosis methods and virtual instrument combining virtual instrumentation based on the introduction Engine Fault self-diagnosis systems.

Keywords - analysis; abnormal sound; automobile engine; bp neural network.

I. INTRODUCTION

Engines are the main assembly of motor vehicles, are important power sources for vehicles. With its continuous improvement of working performance and the level of automation, vehicles’ structures also becoming more and more complicated, moreover, extremely poor working conditions increase engine failure incidence, which means that, also increase the difficulty to fault diagnosis. So the probability of engine failure is also growing, that lead to more difficult of its diagnosis. This makes automotive engine to be the important object of fault diagnosis and detection. With the rapid development of computer and software technology, the degree of modern automotive electronics continues to improve greatly, not only optimized vehicle performance greatly, but also complicated the vehicle control system's structure and function. However, once the control system took place fault diagnosis and repair has become more difficult, there will be higher demand to maintenance man’s knowledge and experience. With the reason that diagnosis of fault position rapidly and improve the efficiency of repair, automotive companies and research institutions which from all over the world have invested substantial funds and energy on the fault diagnosis research about electric automobile engine control system. Whilst automobile industry have just developed compared with the developed countries, automotive electronics industry lags far behind them, therefore the research about car fault diagnosis method is benefit to improve and enhance our country’s automotive diagnostic techniques, as well as it has important practical significance. Automotive engine fault diagnosis theory and method gradually improved with the continuous process of automotive technology. Set up a scientific, systematic, rational, comprehensive system for automotive fault diagnosis theory has become an inevitable requirement and an inevitable technological development trend to the car fault diagnosis. At present, however, there are many different types methods about the engine fault self-diagnosis system design, but many of them are varied and messy, there still blank in a detailed discussion at the implementation of their respective, except that general comparison of the advantages and disadvantages of different methods in this field, the purpose of this paper is to fill this blank, not only with a high theoretical value, but also easy to consult. This paper made clear and basic definition of fault diagnosis, and then leads to the concept and flow about engine fault diagnosis. Moreover, synthesize the research status at home and abroad of engine fault self-diagnosis, existing problems and future trends. Subsequently, there is an in-depth discussion about mainly testing and diagnostic methods in EFI engine fault diagnosis (based on signal processing methods, the analytical model, and knowledge-based fault diagnosis method). First and foremost, based on signal processing methods to conduct a detailed analysis, focusing on the wavelet theory and give an example of fault diagnosis to these theories. In the second place, the analytical model based on the introduction of the method, discussed in detail that the methods of their classification as well as lack of implementation and the proposed. Additionally, introduce the knowledge-based method of fault diagnosis then based on signal processing methods to conduct a detailed classification analysis, and combination of the above-mentioned theory a real example is given, which based on neural network expert system for fault diagnosis. Furthermore, the use of fault diagnosis methods and virtual instrument combining virtual instrumentation based on the introduction Engine Fault self-diagnosis systems; on the other hand, introduce the basic components of engine remote diagnosis system, analysis the structure of the remote diagnosis center, focus on the fault Reasoning System, both the two sides are based on the fault diagnosis technology and modern network technology.

II. THE FRAMEWORK AND MODEL

Fault diagnosis crosscuts multiple disciplines. With many recent technological advancements and improvements, this technology is playing a more and more important role in modern manufacturing industry. Therefore, studying the theory and the application of intelligent engine fault diagnosis will have a significant practical impact. Zhang’s [1] paper presents my research on the development of an intelligent engine fault diagnosis application. This application is based on the analysis of the sound intensity
characteristics for various faults. It uses a modular neural network for recognizing the sound intensity characteristics. The research makes the following contributions. Based on the sound intensity detection and virtual instrument technology, an automatic sound intensity collection and analysis system for engines have been developed. The sound intensity characteristics of engine faults are extracted by frequency and time domain analysis method. A detailed study is carried out on the near field sound intensity characteristics of typical engine faults. With the deep study on engine sound intensity knowledge fusion technology, information from different knowledge sources is processed and utilized together, and a fault diagnostic knowledge database of engine is built with UML. A modular neural network has been built for engine fault diagnosis. From the aspects of work, training, and study, the fusion diagnosis of diagnostic network and sound intensity knowledge are generated. Based on the frame of engine’s fault diagnostic model, via the analysis of diagnostic model tasks’ classification and mapping, an intelligent engine fault diagnostic model was confirmed by information flow integrated method. Through the analysis of each operation parameter in engine fault diagnostic model, an efficiency evaluation system on fault diagnostic model of engine is built, which includes efficiency, precision and reliability evaluations. Based on the engine fault diagnostic model, engine fault diagnostic application with the fusion technology of sound intensity and neural network is detailed described in He’s paper [2]. His application realizes engine working status non-touch collection, online diagnosis and learning. Through several experiments, it is proved that the engine fault diagnostic system (EFDS) can effectively identify the working status of engine it studies, find out and confirm fault area and character and further find out the reasons that generate certain faults. The theory and technology used in the study of engine fault intelligent diagnostic system provide a new way to build a better intelligent EFDS.

Aero-engine is the heart of aircraft, flight delays of civil aircraft and grounding incidents of military aircraft often occur due to engine failure. The serious harm and maintenance costs caused by the faults have been widely recognized. The case is especially true in the new machine in development and test. Therefore, Wang’s paper puts forward the research topic of engine condition monitoring and fault diagnosis in order to predict the occurrence of failures based on monitored parameters, with the purpose of making correct diagnoses to failures, ensuring the safety of flight and/or ground test, saving maintenance costs and testing costs, and improving the efficiency of maintenance and/or ground test. In combination with the characteristics of engine performance failures diagnosis and the distributed control network for field test, this paper proposes a three-level systematic fusion structure for engine test, by which optimization can be made hierarchically. Through the research of the method of space-time registration for multi-sensor data and the application of technology such as spline interpolation, filtering reconstruction, clock synchronization, and frame acquisition synchronization, Liu’s [4] paper proposes a new method of system synchronization integration based on the model of frame synchronization. Using the basic theory of a variety of improved BP network, radial basis function network, probabilistic neural network, self-organizing feature map (SOFM) network and Elman regression neural network, his paper makes a comparative study about the reliability and accuracy of failure diagnoses in different ways of normalization and in different noise conditions. Through the research of diagnosis method of vector machine support, it has been found that the method has the limitation that it does not correctly identify the distinction between two fault samples with strong linear correlation. Li’s [5] paper proposes the concept of classification rate. The diagnostic decision rule has been improved and a new diagnosis method for data fusion failure based on vector machine support has formed. This method can improve the reliability and accuracy of failure diagnosis. By researching information fusion fault diagnosis method based on D-S evidence theory, it has been found that when making fusion diagnosis of the same failure case, the credibility value of diagnostic output of two evidence samples with two different diagnostic algorithms is different, even conflicting sometimes. Chen’s [6] paper, therefore, puts forward the concept of off rate to improve the diagnostic decision rules and algorithms and to further enhance the accuracy of fusion diagnosis. This paper integrates the method to extract the fault characteristics by five layers of wavelet decomposition with the way to make fault diagnosis by probabilistic neural network and therefore opens up the application of wavelet probabilistic neural network in the engine vibration fault diagnosis with satisfactory results.

Huang’s paper [7] aimed to analysis the reasons of BP neural network appeared shortages, and then proposed improved algorithm of BP neural network and a new method for time series prediction. On this basis, BP neural network optimization problems were discussed. Finally, the theoretical research production of BP neural network for prediction of Heilongjiang province agriculture machinery total power and processing parameters optimization of inertia separation chamber of stripper combine harvester with air suction.

Analysis indicated the reasons of BP neural network algorithm appeared problems and poor extrapolation results of time series forecasting when use BP neural network. Wang’s study put forward an improved BP neural network algorithm. It was proposed that each weight corresponds to an improved learning rate of BP algorithm. This algorithm made the negative gradient direction information was more fully utilized, while the learning rate achieved necessary changes. It overcome the fluctuation and oscillation when BP neural network close to the optimal solution, and significantly improved the calculated accuracy; also the latter iterative calculation continued the learning rate of previous iterative calculation, which can improve the learning rate. In
addition, the improved BP algorithm was independent of the initial learning rate, which avoided the difficulties of learning rate selection. A new prediction method of BP neural network based time series was presented in Wang’s research [8]. The prediction shortcomings of BP neural network were indicated, according to the structural features of BP neural network time series prediction, based on Z transform theory, a new activate function was given. And in the BP neural network, as activation function was \( y = \alpha - \beta x \) was the reason of equivalent to the activation function. Secondly, \( y = x \) was derived as the activation function of BP algorithm and the model formula. Finally, through examples calculation, it was showed that with the growth trend for time series prediction, the extrapolation results were not good when unipolar S-function as the activation function, but the extrapolation results were better when \( y = x \) as the activation function. In addition, the extrapolation results were not affected by data processing interval when \( y = x \) as the activation function, while the extrapolation results were influenced by the processing interval a lot when unipolar S-function as the activation function. And the \( y = x \) as the activation function can overcome the shortcomings of prediction problems of unipolar Sigmoid function as the activation.

III. THE BP NEURAL NETWORK AND ALGORITHM

Since 1982 American California Engineering institute physicist J. Hopfield proposed Hopfield neural networks models, Artificial neural networks theory and applied research has been attracted more and more attentions. Artificial neural networks can carries on the different information processing, such as artificial intelligence, secure communications, network optimization, military information, pattern recognition, etc. Using the domain is widespread, including biology, computer science, management science, sociology as well as economic. Neural network was successfully applied in these areas are greatly dependent on system’s dynamic characteristic. The stability is one of neural network very important dynamic characteristics. The stability is a key feature in designing a practical application system. Known to us, neural networks is unstable system in theory which is impossible to be carried in practical application.

BP neural network is one of the most mature and widely used artificial neural network models. As it has the advantages of simple structure, easy to operate, good self-learning capability, effectively solve the approximation problems of nonlinear objective function, etc. which has been widely used in pattern recognition, signal processing, automatic control, prediction, image recognition, function approximation, system simulation and other disciplines and fields. However, BP algorithm also has many deficiencies. For example, the selection of initial learning rate is difficult, the rate of convergence is slow, the volatile appears when close to the optimal solution, and sometimes there is oscillation. It is ineffective extrapolated with growth trend of time series prediction problems. Therefore, it has not only of theoretical significance, but also important application value in further BP neural network systematic study of these issues. It is proved that as long as the hidden nodes of three-layer BP neural network are enough, it has the capacity to simulate any complex nonlinear mapping, so the BP neural network has strong ability of the fitting ability. However, in practice, sometimes people not only care about the fitting effect of neural networks, but also very concerned about the value of the input, which can lead the output to achieve maximum or minimum. This problem is actually based on the optimization problem of BP neural network, by now, the research on this issue has not yet be reported. Although some literatures are referred to as BP neural network optimization, but they are focus on the weights, learning rate and network structure optimization of BP neural network, according to the relationship between BP neural network input and output, and to choose a better output value, which is actually not really optimization, but a simulation, it is to choose an optimal solution from simulation results. Therefore, it has not only of theoretical significance, but also important application value in exploration of real BP neural network optimization method.

Here the use of the BP neural network model with multi-input and single-output as building performance evaluation, the topology is shown in Figure 1.

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data to determine, you can also experience the value of the formula (4) the decision.

\[ n = \log_2 m \]  \hspace{1cm} (4)

Hidden node output is calculated as follows:

\[ h_j = f \left( \sum_{i=1}^{m} w_{ji} x_i - \theta_j \right) \]  \hspace{1cm} (5)

where \( \theta_j \) is defined as the threshold value for hidden node.

The output of the output node is calculated as follows:

\[ f \left( \sum_{i=1}^{m} w_{ji} x_i - \theta_j \right) = f \left( f \left( \theta_j \right) \right) \]  \hspace{1cm} (6)

Where in 0 is an output node threshold.

IV. THE EXHAUST VALVE EXPERIMENT RESULT

A group of Stellite 12 valves were set in an automobile engine for purpose of the test. After the automobile was driven about 100 thousand kilometers, the specimens tested were taken out, and measured the wear depth of valve seat, and cut the worn surface along transverse section and analyzed topography of the surface and subsurface with S.E.M. A lot of wear tests and experimental analysis have been done for comparing the fatigue characteristics in the intensity wear test with that in actual engine test. Only some typical SEM photographs are presented in the paper for the discussion.

A orn surface topography of exhaust valve in an actual engine can be observed that some plastic deformation characteristics and corrosion products presented on the worn surface. A micro-analysis verified that the corrosion products manly come from two respects:

1. The material deformed suffers from high temperature corrosion of exhaust gas from cylinder.
2. unburned matters in fuel deposited in the worn surface.

V. CONCLUSIONS

In this paper, the author studies on analysis of abnormal sound of automobile engine based on BP neural network. BP neural network is one of the most mature and widely used artificial neural network models. As it has the advantages of simple structure, easy to operate, good self-learning capability, effectively solve the approximation problems of nonlinear objective function, etc., which has been widely used in pattern recognition, signal processing, automatic control, prediction, image recognition, function approximation, system simulation and other disciplines and fields. The analytical model based on the introduction of the method, discussed in detail that the methods of their classification as well as lack of implementation are proposed. Additionally, introduce the knowledge-based method of fault diagnosis then based on signal processing methods to conduct a detailed classification analysis, and combination of the above-mentioned theory a real example is given, which based on neural network expert system for fault diagnosis. Furthermore, the use of fault diagnosis methods and virtual instrument combining virtual instrumentation based on the introduction Engine Fault self-diagnosis systems; on the other hand, introduce the basic components of engine remote diagnosis system, analysis the structure of the remote diagnosis center, focus on the fault Reasoning System, both the two sides are based on the fault diagnosis technology and modern network technology.

REFERENCES


