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Fault Diagnosis System of Machine Using Neural Networks and Its Application

Toshiyuki ASAKURA*, Takashi KOBAYASHI*,
Shoji HAYASHI* and Baojie XU**

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This paper describes a method on machine fault diagnosis system using neural networks. As fault diagnosing signal, the sound signal of machine can be used, in which the data is obtained as the power spectrum density through FFT analyzer. First, the structure of fault diagnosis system is shown. Next, in the neural networks, both the normal and abnormal conditions of machine can be learned by back-propagation method and the fault diagnosis system of a machine may be constructed. Finally, through simulation experiments, it was verified that the failure of machine was diagnosed based on the spectrum of sound signal including noise. Also, it was certified that, using the real data of sound signal, the fault diagnosis system proposed here can be applied to the practical machine.

1. Introduction

Among many problems in industries, the most important function is for each machine systems to work in the normal conditions. In order to maintain a normal running condition of a machine system, a fault prediction and diagnosis system are necessary, especially for those such as electrical generators which run continuously for long time. The failures should be detected as soon as possible when failures occur, because if these machine run at abnormal condition continuously, it may result in havy loss and even loss of human lives. Up to date, though many kinds of diagnosis method (1) have been developed, much of them have been based on traditional method of establishing mathematical model, analysing variety of parameter and judging the operating condition of machine system. But, because of the complication of machine system, the uncertainty of running condition and many nonlinear factors, it is very difficult in most cases to establish mathematical model of machine structure and to know the operating conditions of the machine, and also even impossible in some cases to detect failures occured when it is running. So that, many researchers are recently attracted in untraditional approaches. (2)

This study describes a methed of fault diagnosis based on machine fault diagnosis system using neural networks. In this method, the characteristics of machine system with fault will be identified by neural

* Dept. of Mechanical Engineering
** Dept. of Mech. Engi., Beijing Institute of Mech. Industry, Beijing, China

networks without the need of mathematical model. The real data can be obtained as a time-series data and then transformed to the power spectral density through FFT analyzer. The normal and abnormal conditions of a machine can be learned by a back-propagation method. Moreover, the fault diagnosis system can be constructed using neural networks. As an application to the practical machine, this diagnosis system is applied to the wood-slicer machine. A lot of data can be obtained as the sound signals, including the normal and abnormal conditions. Through the result of diagnosis, it can be shown that this fault diagnosis system is valid and has the possibility of wide applications.

2. Structure of fault diagnosis system

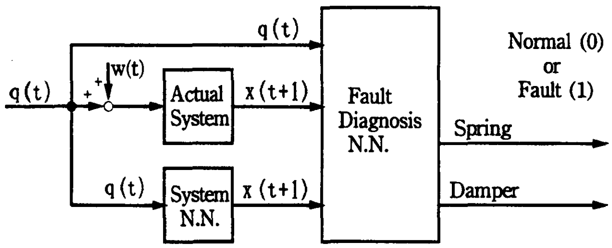


Fig.1 Structure of fault diagnosis system

In this section, we outline a general architecture for designing fault diagnosis system. The idea of this procedure is illustrated in Fig.1. This system has two neural networks(N.N.); one is N.N. for system identification as shown in Fig.2, which consists of input layer 4, middle layer 20 and output layer 1, and the other for fault diagnosis as shown in Fig.3, which consists of input 3, middle layer 40 and output layer 2. The N.N. for system identification learns the normal state of the motion and the output data of actual system is compared with the output of the identified neural network. If the fault occures in the actual system, the difference generates between the actual system and N.N. system. This difference can be detected by the fault diagnosis N.N. system and the part of the fault may be specified. Here, the teaching signal of fault diagnosis N.N. is set as 0 for normal and 1 for the fault.

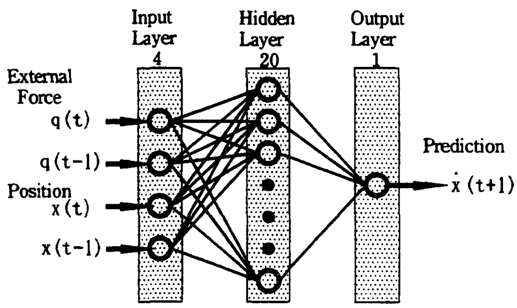


Fig.2 Neural Network for Identification

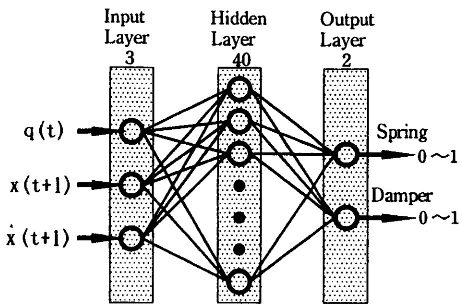
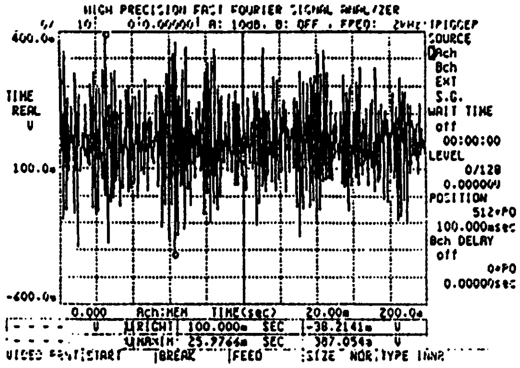


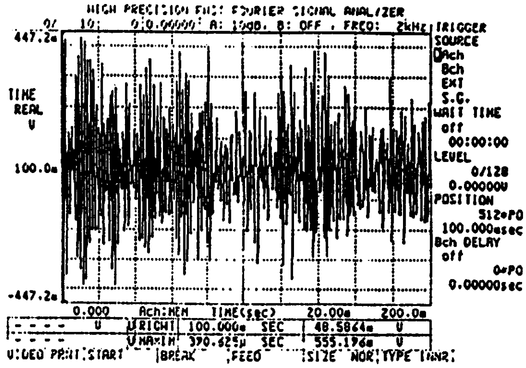
Fig.3 Neural Network for Fault Diagnosis

3. Fault diagnosis by sound signal

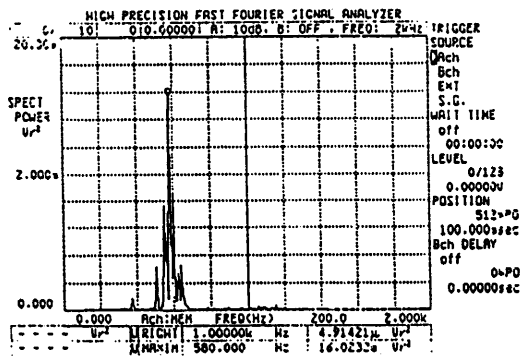
For the machine fault diagnosis, the oldest and most wide used method is perhaps hearing sound of machine by the human ear. Obviously, this method is neither objective nor precise, but it implies that the sound signal ejected from running machine includes the information of operating conditions and failures.



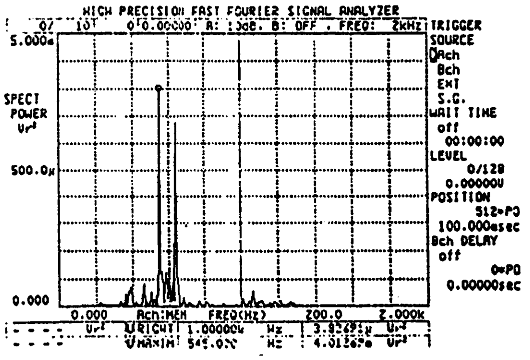
(a) Normal



(c) Abnormal



(b) Normal



(d) Abnormal

Fig.4 Sound signal of machine

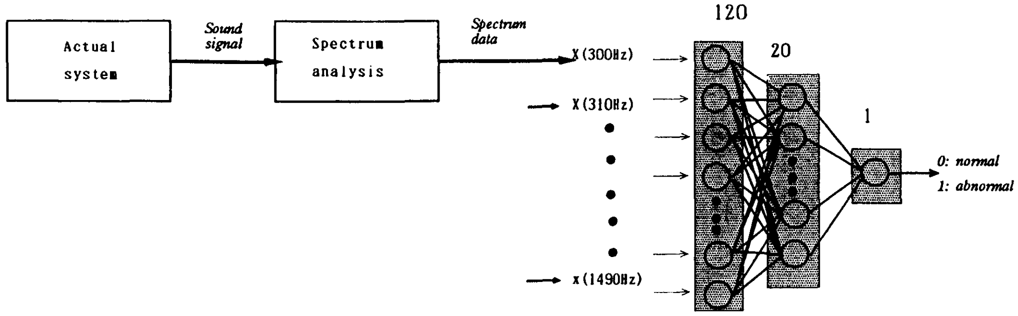
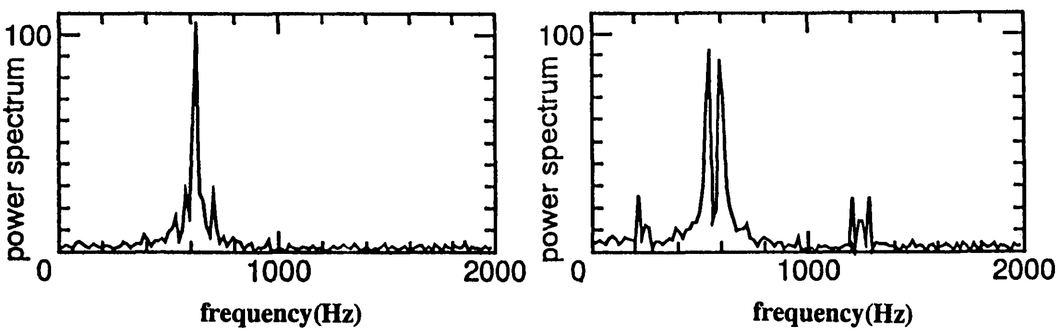


Fig.3 Fault diagnosis system based on spectral data

shows the ability of diagnosing failures from spectrum of sound signal. The learning and diagnosing results are showed in Table 1. If the output of neural networks is less than 0.4, it means normal condition, and if bigger than 0.7, it means abnormal condition. By these results, the possibility of application of the machine. fault diagnosis system are verified. Next, to examine the effect of noise levels, a group of simulated data including noise with different levels are put into the fault diagnosis neural networks. Though the diagnosis shows the right decision up to S/N=1, the diagnosis give an wrong result, when S/N=0.4.



(a) Normal condition (b) Abnormal condition

Fig.4 Simulated spectrum of sound signal

Table 1 Results of fault diagnosis

Signal	a Normal	b Normal	c Normal	d Abnormal	e Abnormal	f Abnormal
Output of NN	0.088	0.088	0.087	0.912	0.915	0.919
Result of Learning	Normal	Normal		Abnormal	Abnormal	
Result of Diagnosis			Normal			Abnormal

6. Application to the Machine

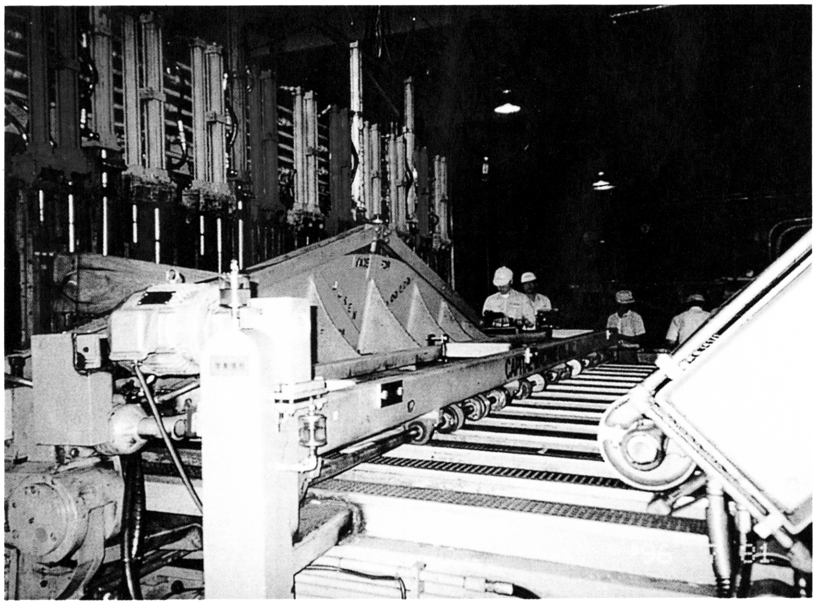


Photo 1 Outline of wood- slicer machine

Based on the simulation experiment, the fault diagnosis system of Fig.3 is applied to the wood- slicer machine. The outline of wood- slicer machine is shown in Photo 1. This machine shaves a thin board from a lumber, in which the length of cutter is about 3m. The speed of slicer is about 60 times/min. The materials are logs of pine, cryptomeria and oak etc. The sound generates when the machine slices a wood. The sound changes when the cutting conditionds are abnormal.

The measurement system is showed in Fig 5. The construction of this system consists of sound meter, FFT analyzer and computer with a diagnosis system. By this system, we can obtain the machine sound signal under every operating conditions including normal and abnormal conditions. Next, the sound signal is transformed to the form of power spectrum, and then the power spectrum data is put into the neural

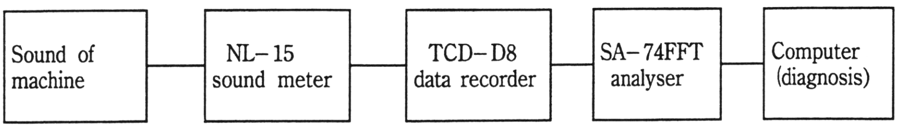
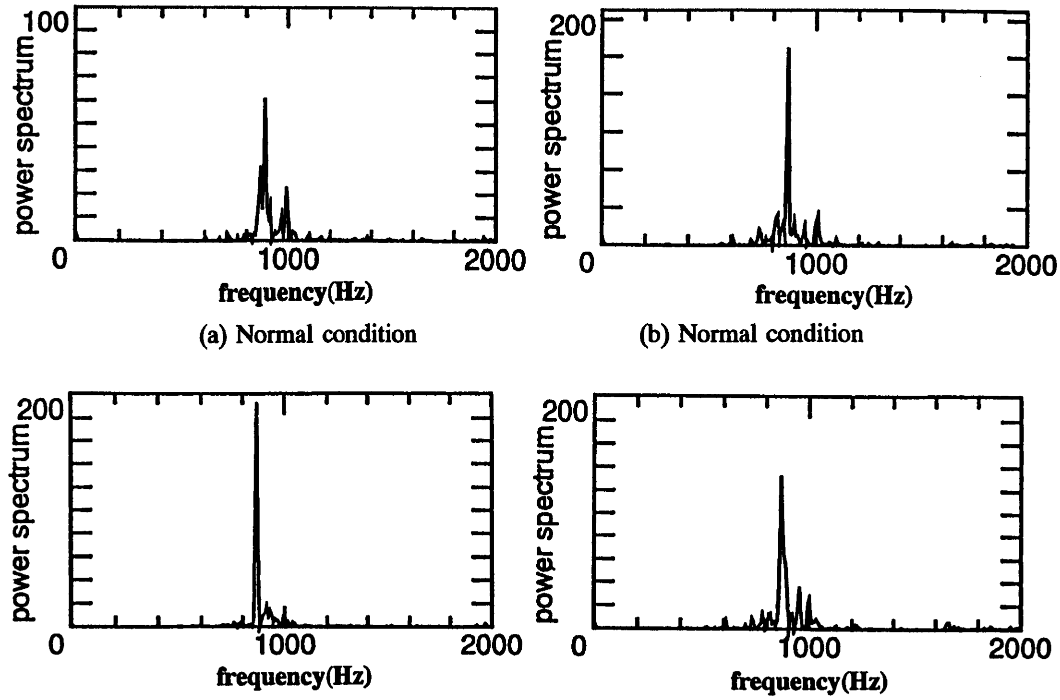


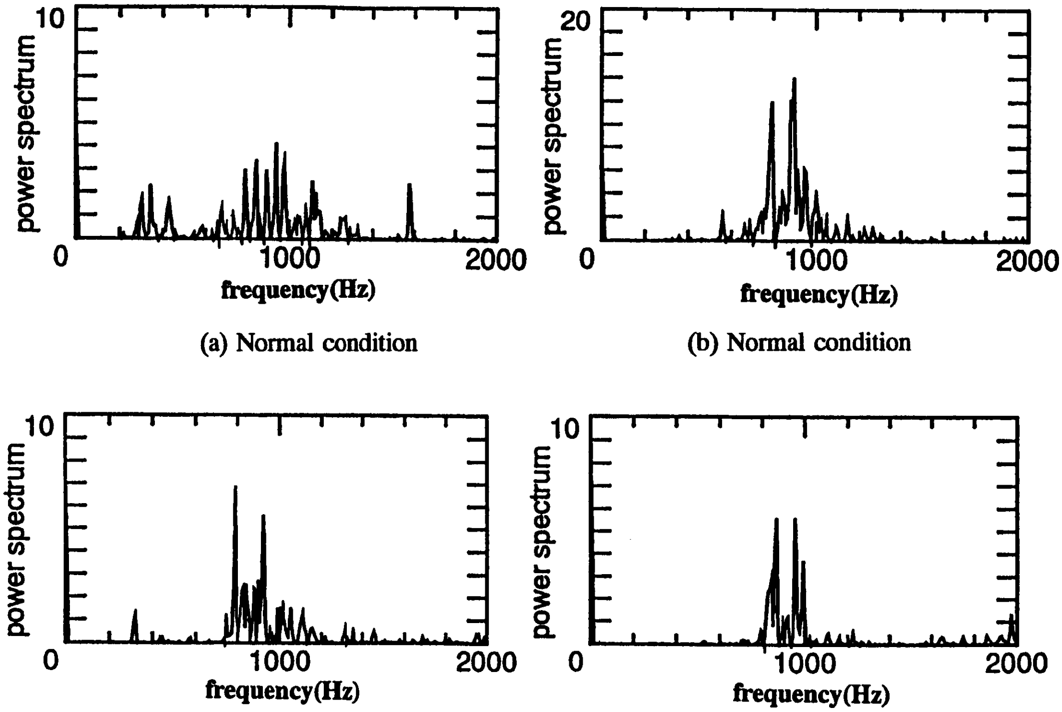
Fig.5 Costruction of measurement system



(a) Normal condition (b) Normal condition

(c) Abnormal condition (d) Abnormal condition

Fig.6 Spectrum of sound signal for learning



(a) Normal condition (b) Normal condition

(c) Abnormal condition (d) Abnormal condition

Fig.7 Spectrum of sound signal for diagnosis networks. Using the neural networks showed in Fig.3, the typical four normal and four abnormal spectrum data may be learned by neural networks, in order to determine the unified coefficients of neural networks. After learning, this neural networks can be used to examine whether unlearning spectrum data is normal or abnormal.

Table 2 Results of fault diagnosis

Signal No.	Operating condition	Output of NN	Result of diagnosis	Signal No.	Operating condition	Output of NN	Result of diagnosis
1	Normal	0.1563	Normal	11	Normal	0.1014	Normal
2	Normal	0.1234	Normal	12	Normal	0.0745	Normal
3	Normal	0.0955	Normal	13	Normal	0.0947	Normal
4	Normal	0.3012	Normal	14	Normal	0.0125	Normal
5	Normal	0.4124	Normal	15	Normal	0.3827	Normal
6	Normal	0.1542	Normal	16	Abnormal	0.7006	Abnormal
7	Normal	0.0845	Normal	17	Abnormal	0.7451	Abnormal
8	Normal	0.1332	Normal	18	Abnormal	0.8564	Abnormal
9	Normal	0.3526	Normal	19	Abnormal	0.9189	Abnormal
10	Normal	0.6854	Uncertain	20	Abnormal	0.8547	Abnormal

Spectrum data used for learning are showed in Fig.6, and the learning time is about 50 sec in the case that the mean square error becomes less than 0.01. Using N.N. system with unified coefficients determined here, the fault diagnoses for spectrum data in Fig.7 are performed, and the results of diagnosing are showed in Table 2. If the output of neural networks is less than 0.4, it means normal condition. On the other hand, if bigger than 0.7, it means abnormal condition. From these results of Table 2, the accuracy of fault diagnosis is about 90%, and at result, the validity of the machine fault diagnosis system are verified.

7. Conclusion

In this paper, a machine fault diagnosis system using neural networks has been proposed using spectrum analysis. Through simulation experiments, the possibility of diagnosing failures from spectrum of sound signal including noise was verified and the application to the wood-slicer machine was demonstrated. The real data of sound signals was acquired including normal and abnormal states and the useful diagnosis results are obtained through the application to the fault diagnosis system proposed here. However, for the practical application at the real condition, the following problems remain yet to be considered:

(1) More data with faults information are needed for learning of neural networks to raise fault diagnosis capacity of the system. Every kind of faults should be considered.

(2) For the machine system using uncontinuous processing method like the wood-slicer machine, it is

necessary that the sound measurement system should include signal trigger control, to certify the trigger time which is simultaneous with the processing movement of the machine.

(3) When running, the conditions of machine system are very complicated and too much kinds of faults, Then, the informations concerning with signals of vibration, temperature, pressure etc. may be needed. [4]

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