ICAS-98-6,6,4

A98-31687

THE NEURAL DIAGNOSTIC METHOD AND A COMPLEX SYSTEM OF DIAGNOSING AIRFRAME AND POWERPLANT *

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Summary

It has been noted that four diagnostic methods in use up to now as autonomous means to monitor technical condition and to forecast further performance of devices can and should be utilized in a complex way. The methods represent: functional diagnostics - to analyse automatic systems, vibroacoustic diagnostics - to analyse rotating components and flows, diagnostics based on analysis of wear products - to examine tribological kinematic pairs, and diagnostics based on flaw detection techniques - to examine cracks in structural members. Complexity of utilizing the methods enables many and various pieces of output information to be interconnected.

Sets of data and interconnections for all four methods have been described. The interconnections enable complex diagnostic information to be obtained due to immediate data processing capability, which in turn is possible owing to capabilities of the neural networks. Such an approach significantly reduces numbers of necessary signals and measuring points.

*) The paper has been prepared under the research project No 148-127/C-T00/97 partially funded by the Committee for Scientific Research

Introduction

Maintenance of complex devices/systems calls for complex diagnostic systems that enable the systems to be thoroughly examined with several diagnostic methods, i.e. with functional and vibroacoustic ones as well as those based on analysis of wear products and various flaw detection techniques. The diagnostic inspection understood in such a way could be carried out according to two variants:

- diagnostic efforts are made using one method only, e.g. a functional diagnostic method, to be then verified and completed with other methods, e.g. with vibroacoustic one and that based on analysis of wear products. This variant is widely used in the course of examining the bearing system of an aero-engine. For example, inspections of the bearing system of the engine based on the quite frequently measured 'time of the engine run-out' (i.e. time between shutting off the fuel and complete stoppage of the engine) are completed and verified with analysis of spectrum of vibration of bearing pairs to be then authenticated with analysis of wear products contained in the bearing lubricating oil. Diagnostic methods in use with this variant stay autonomous;
- diagnostic efforts are made with two or more methods simultaneously. Such being the case, the diagnostic signals generated by the device/system can be correlated within one method and between

various methods. Correlating the signals between various methods results in additional diagnostic information on the current condition of the object. A set **k** of diagnostic signals can be established, where: **k-1** - inputs, and the k-th diagnostic signal is an output. Interrelations between all the signals within this set can be investigated with neural networks.

A complex diagnostic system

Promising effects have been produced with complex diagnostic systems based on four fundamental, well-developed diagnostic methods, i.e. on functional and vibroacoustic ones as well as those based on analysis of wear products and various flaw detection techniques.

A functional diagnostic method has been based on collecting diagnostic signals generated in the course of the system's functioning. A set of diagnostic signals is established taking account of reliability characteristics of the device/system under investigation. Diagnostic signals acquisition is carried out using some monitoring units (applied to system evaluation in some specific order) and some additional, specialized testing (measuring) systems, both fitted for diagnosing purposes. The signals are recorded with computer-based diagnostic systems. A suitable computer analysis of diagnostic signals enables the system's operating conditions to be monitored according to principles of automatic control engineering, and then - according to principles that underlie diagnostics - the maintenance status (health) of the system of interest to be determined and forecasted. All results are collected in the data base.

A vibroacoustic diagnostic method has been based on signals acquired in the course of the system's functioning. The number of signals results from the system's reliability and safety characteristics. Acquisition of signals is accomplished by means of special monitoring systems (to show pre-failure and failure states) and measuring systems to evaluate the maintenance status (health) of the system under examination. The signals are recorded and processed by means of special testing systems (i.e. analysers, measuring instruments, instrumentation amplifiers, etc). All results are stored in the data base.

The diagnostic method based on analysis of wear products utilizes information collected when the system is out of operation. (after turning it off and bringing to a standstill). A sample of a working liquid (e.g. oil) drawn from a lubrication, cooling or hydraulic system is the information carrier. What is examined are the wear products contained in a standard sample of a working liquid. Findings, i.e. compositions, concentrations, granulations and colours of wear products are stored in the data base.

Diagnostic methods based on flaw detection techniques use data collected with non-destructive testing procedures when the system is out of operation. Images of some selected structural members exposed to heavy loads and high temperatures, ones gained with, e.g. optical, ultrasonic or eddy-current techniques are data carriers in this case. Analysis of information is carried out with methods of recognizing changes in compared images. Again, all information gained is stored in the data base.

Autonomous utilization of the above-mentioned diagnostic methods often presents many difficulties, in particular when the signals - carriers of information on the maintenance status (health) of the system (module) approach diagnostic threshold. Additional verifications are carried out then, also some other undertakings such as the system rinsing, oil change, etc., very expensive ones, no doubt about that. All such actions can be limited by means of applying a complex diagnostic system. Fig. 1 shows a schematic diagram of the complex diagnostic system.

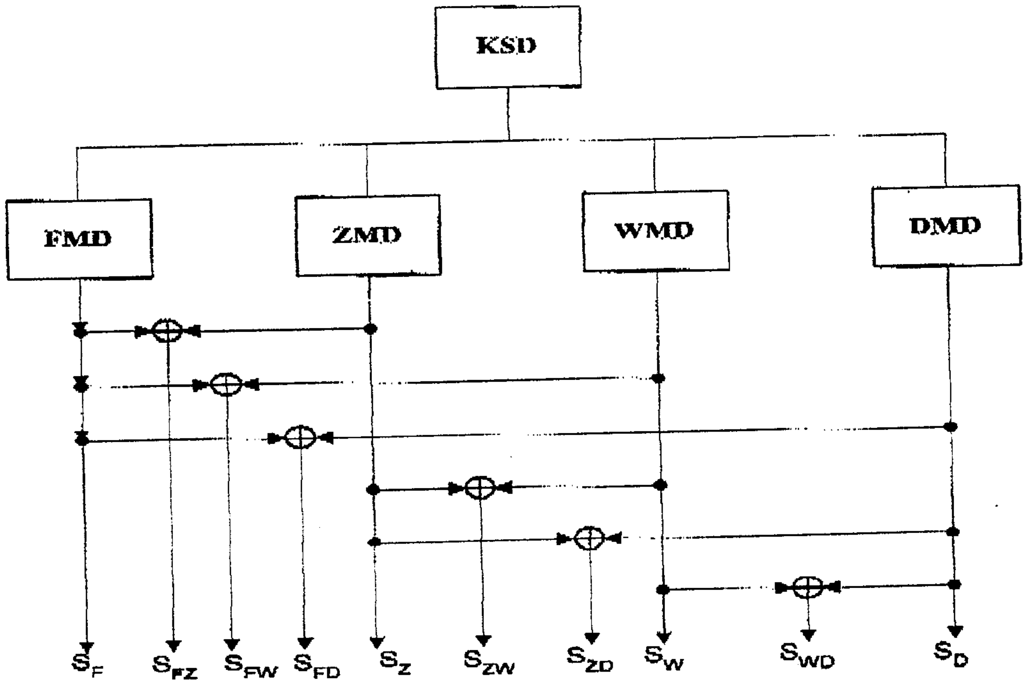

Fig. 1. A complex diagnostic system (KSD) based on the following diagnostic methods: a functional one (FMD), one based on wear product analysis (ZMD), a vibroacoustic one (WMD), and one based on flaw detection techniques (DMD). S_F, S_Z, S_W, S_D - signals of the above-mentioned diagnostic methods, respectively. S_{FZ}, S_{FW}, S_{FD}, S_{ZW}, S_{ZD}, S_{WD} - signals resulting from correlating the S_F, S_Z, S_W, S_D. →•→ - information node, ⊕ - correlator.

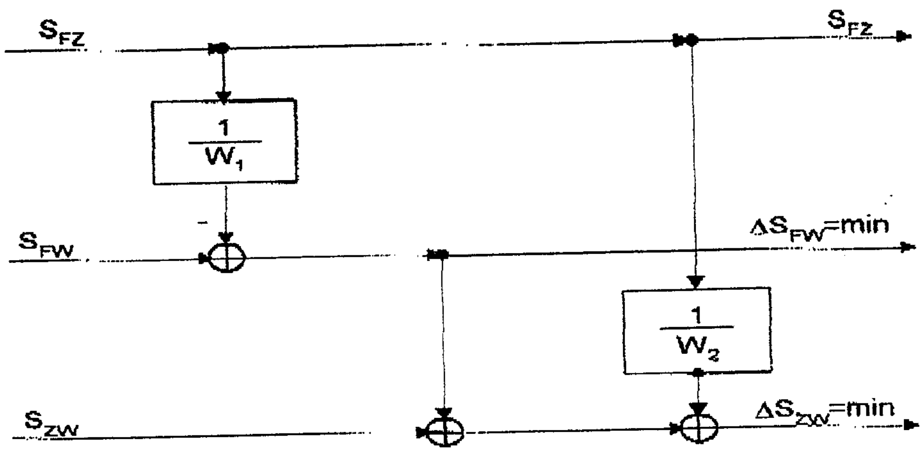

Fig. 2. A neural network to diagnose the bearing system with the functional/wear-products-analysis/vibroacoustic methods. S_{FZ}, S_{FW}, S_{ZW} - correlated signals. $1/W_1$, $1/W_2$ - inverses of spectral transmmittances, W_1, W_2 - spectral transmittances.

It is evident that correlating four signals S_F, S_Z, S_W, S_D results in gaining additional six signals, i.e. S_{FZ}, S_{FW}, S_{FD}, S_{ZW}, S_{ZD}, S_{WD} which give new diagnostic capabilities resulting from already known interdependences between correlated signals.

The neural method of signals processing

Modern diagnostics of devices/systems (aircraft) should be based on diagnostic parameters. Therefore, an essential problem arises of processing diagnostic signals into sets of diagnostic parameters. One of possible means of processing the diagnostic signals into diagnostic parameters is the neural network method. The neural network is both the technique and the system to process diagnostic signals (providing a device/system with many input signals and only one output signal is dealt with) into diagnostic parameters using:

- knowledge fed into the network,
- knowledge exchanged between individual neurons of the network,
- knowledge of the neural network functioning.

Fig. 2 shows an exemplary neural network. Parameters of transmittances W_1 and W_2 after operations executed within the neural network become diagnostic parameters. The transmittances W_1 and W_2 are new abstract diagnostic models of the jet engine's bearing system under investigation. They relate signals of different physical natures of a homogeneous process of the bearing system wear.

Conclusions

The complex-diagnostics method given consideration in the paper enables the aircraft airframe, hydraulic systems and power plant to be operated according to their technical condition. It has been proved that the method makes earlier detection of aircraft inefficiencies possible. Moreover, the numbers of inefficiencies observed not earlier but in the course of flight have been evidently reduced. Therefore, maintenance and overhaul procedures can be scheduled in an optimum way as far as time and economy are concerned (all works are performed at home airfields).

Acknowledgement

The Authors wish to thank Mrs Małgorzata Mercik for the English form of the paper.

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