A complex diagnostic system for the MiG-29's airframe and power plant*

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Abstract

A complex diagnostic system for the MiG-29's airframe and power plant has been presented in the paper. Functional, vibroacoustic, tribological, flaw-detection-based, and thermographic subsystems as well as the diagnostic-data-processing subsystem have been distinguished. The above-mentioned subsystems can operate either as components of the whole system or autonomously, which provides high flexibility of the diagnostic system on the one hand, and reductions in both labour demand and the system's complexity on the other.

1. Introduction

Research into diagnostic systems for airframes and power plants of aircraft have been carried out in the Air Force Institute of Technology since the early 1970s. Four diagnostic methods have been systematically developed, i.e. functional, vibroacoustic, tribological and flaw-detection-based ones. Quite recently efforts to implement thermographic methods have been initiated.

Development of diagnostic methods has been conditioned by technological level of available measuring devices and recorders. It has also been featured with considerable independence and a limited range of exchange of diagnostic information obtained with different methods.

Analyses carried out in Air Force Institute of Technology, both of literature-sourced data and operational experience, have enabled design and development of a model of a complex diagnostic system which automates the processes of examining and inferring in the fields of evaluating the health/maintenance status, fault location and health/maintenance-status forecast (in particular, of the engine and the airframe as subsystems mostly affecting reliability and safety of the aircraft and the pilot). All the efforts have given grounds for starting research works on complex diagnostic systems for the Su-22 and the MiG-29, partially financed by the Polish State Committee for Scientific Research (KBN).

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2. Fundamental diagnostic methods

At present, the following methods are used to diagnose products of aeronautical engineering:

- a functional method,
- a vibro-acoustic method,
- a tribological method,
- a flaw-detection-based method, and
- a thermographic method.

The functional method of diagnosing uses diagnostic signals gained in the course of operation of the object under examination. The signals are collected via monitoring systems which first of all are used to evaluate the object's performance and operation of additional measuring systems. Then they are recorded by computer-based diagnostic systems. All the results are stored in the data base.

The vibro-acoustic method makes use of vibration signals (velocity, acceleration of signals etc.) gained during the object's performance. The signals are recorded and processed by suitable testing systems, and results are stored in the data base.

The tribological method has been based on information collected when the object is out of operation. A sample of the working liquid (e.g. oil) is taken immediately after shutting down the engine or switching the system off. The wear products contained in the sample are examined with the field set of test equipment in the air base and/or with special laboratory equipment in the Air Force Institute of Technology. The range of tests depends on the current state of the object. If the wear is normal, the sample is investigated only in the air base. If, however, it is increased, more intensive or proves that pre-failure level has been reached - in the Air Force Institute of Technology . All results are stored in the data base.

The flaw-detection-based method is grounded on non-destructive testing of components of the aircraft engine and airframe while the object is out of operation. The number of components under examination depends on reliability characteristics shown by the object at the moment. Information is gained with specialised equipment. Results are stored in the data base.

The thermographic method consists in analysing thermal pictures of the examined object, ones received with the IR devices. Both continuous and discrete spectra are used. Requirements on quality of the thermal pictures greatly affect the cost of the equipment in use.

According to principles that underlie the diagnostics, received information (signal) is processed into the diagnosis, the genesis and the forecast of health/maintenance status of the object. The information processing consist in comparing signals gained in the course of one test to those collected from all previously made tests (expressed in the form of diagnostic standards or thresholds).

3. The idea of the complex diagnostic system

The above mentioned diagnostic methods can be used independently of each other. By assumption, each of them has been designed for a specific purpose. Owing to many analyses it has been found that information flow among all these methods is possible; therefore, they can be integrated to form an information-processing system. It is also necessary to increase power of the set of methods to provide some new diagnostic quality.

The complex diagnostic system for an aircraft should include subsystems to provide the following capabilities:

- functional diagnostics,
- vibro-acoustic diagnostics,
- flaw-detection-based diagnostics,
- tribological diagnostics,
- thermographic diagnostics, and
- data-processing management and diagnostic inference.

Solving the problems of diagnosing a highly engineered object (e.g. an aircraft) requires the following items to be developed:

- a model of an object being diagnosed and its components (modules),
- models of engineering means of diagnosing,
- models of operations to process diagnostic information gained with different methods.

All these models should take account of both different levels of detail of representing the object and its components (e.g. engine-rotor-blade) and variety of methods engaged.

Engineering accomplishment of a complex diagnostic system for an aircraft requires modern digital measuring systems and a microprocessor controller with „flexible” software to make it possible to develope the system as diagnostic information is collected in the course of operating of the object.

The following methods of diagnostic information processing can be distinguished:

- procedural methods,

- systems with knowledge bases,
- neural network systems.

Systems with knowledge bases and neural network systems seem to be the most promising ones. Diagnostic systems with knoledge bases consist of:

- a knowledge base (general and specialized knowledge),
- inference unit to draw conclusions on the health/maintenance status of the object under examination on the grounds of diagnostic data and base-included knowledge;
- interfaces – the user's ones and those of the external data bases.

One of the most important components of a diagnostic system with a knowledge base (expert system) is software. It should include:

- diagnostic software;
- list of spare parts and special tools;
- technical documentation;
- training software.

It is assumed that the complex diagnostic system is an open system that provides the user with capability to include new diagnostic methods and diagnostic-information processing methods.

4. The complex diagnostic system for the MiG-29's airframe and power plant

The idea of the complex diagnostic system for both an airframe and a power plant, i.e.one discussed in the previous paragraph, has been applied to develop a diagnostic system for the MiG-29. This project is carried out in the Air Force Institute of Technology within the purposeful project (with research and development, and implementation works included) grant-aided by the Air Force & Air Defence Command and the Committee for Scietific Research.

The project includes:

- analyses and simulations to investigate dependences of check parameters on the health/maintenace status using the MiG-29's diagnostic model.

  The diagnostic model is a hierarchical set of partial models of functional blocks and units to provide the user with capability to represent objects under examination with the required accuracy. Analyses and simulations result in generating a set of parameters and diagnostic signals necessary to evaluate the health/maintenance status for fault location and to forecast pre-failure states,

- design and development of a test kit for the complex diagnostic system KSD-MIG29 with a preliminary design of the system’s software,
- experimental work on dependences of check parameters on the health/maintenance status of the MiG-29’s systems and components, with the test kit for the KSD-MIG29 applied.

  Tests of the KSD-MIG29 system were continued with, among other items of equipment, a system developed at AFIT to simulate diagnostic parameters and signals that feature aircraft systems,
- implementation of the KSD-MIG29 complex diagnostic system in an air base.

  Giving training in maintenance and operational use of the KSD-MIG29 to technical staff to diagnose the MiG-29’s airframe and power plant is a fundamental requirement to implement the system,
- controlled operation of the KSD-MIG29 system to:
  - support the technical staff in the field of operating all the advanced monitoring/measuring subsystems included into the KSD-MIG29,
  - update and analyse – by the system’s originators – the diagnostic data base and evaluation of the extent to which the user’s expectations are satisfied from the point of view of accomplishing the MiG-29’s operational tasks,

The KSD-MIG29 complex diagnostic system (Fig. 1), consists of both hardware and software. The hardware includes:

- a set of general-purpose and specialised sensors of functional signals,
- electronic signals-processing modules,
- a set of vibration sensors with preamplifiers and specialised wiring,
- a set for eddy-current inspection,
- a set for supersonic inspection,
- a set for magnetic inspection,
- a set for colour inspection,
- a set for thermographic diagnosing,
- a set of devices, materials and standards for tribological diagnostics,
- a set of equipment for thermographic diagnostics.

The software includes programs that enable the signals measuring and processing (Fig.2) and their archiving (Fig. 3).

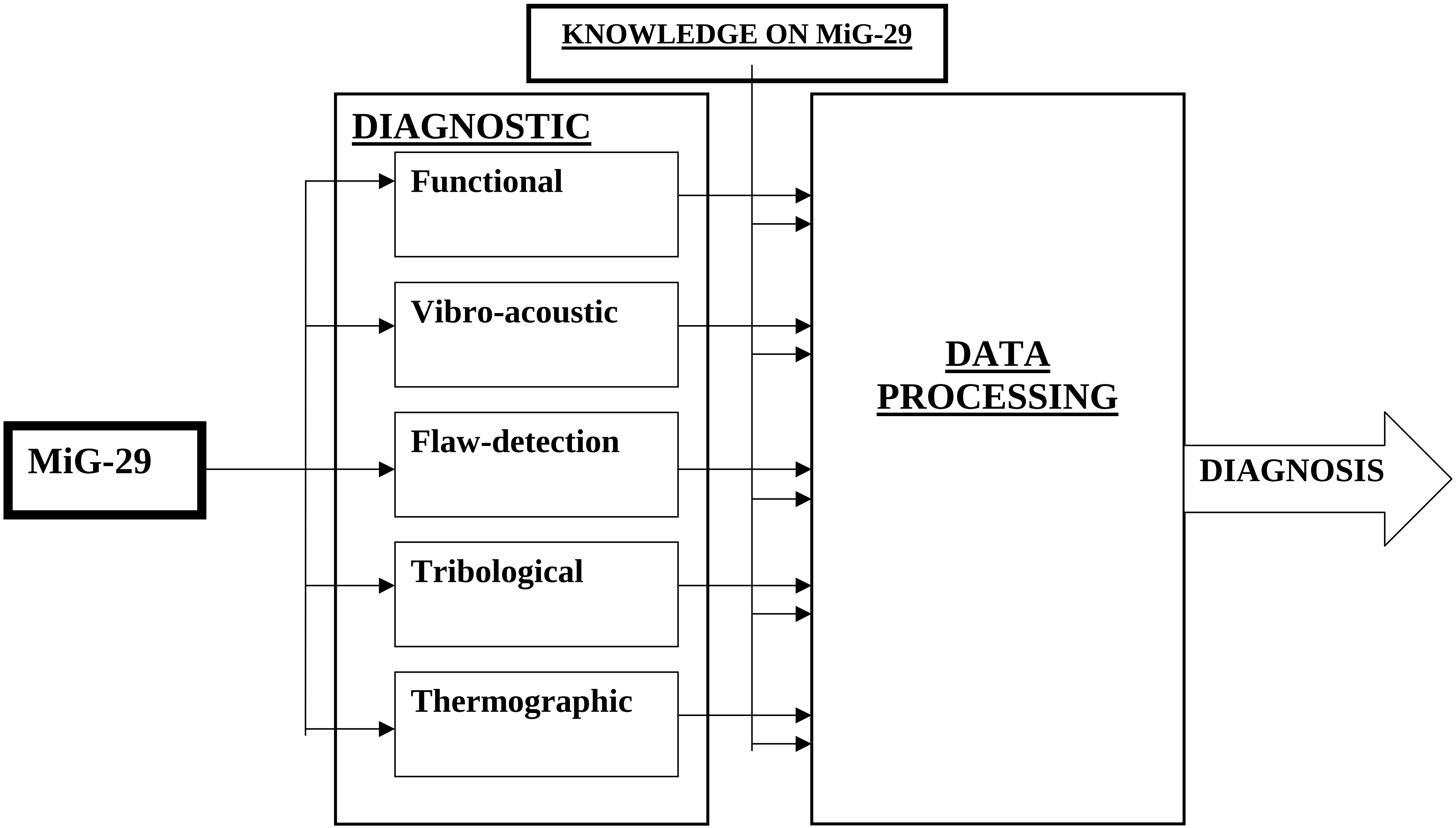

Fig. 1 Functional diagram of the complex diagnostic system for the MiG-29.

Fig.2 Control display of the software for parameters acquistition and analysis (functional diagnostics)

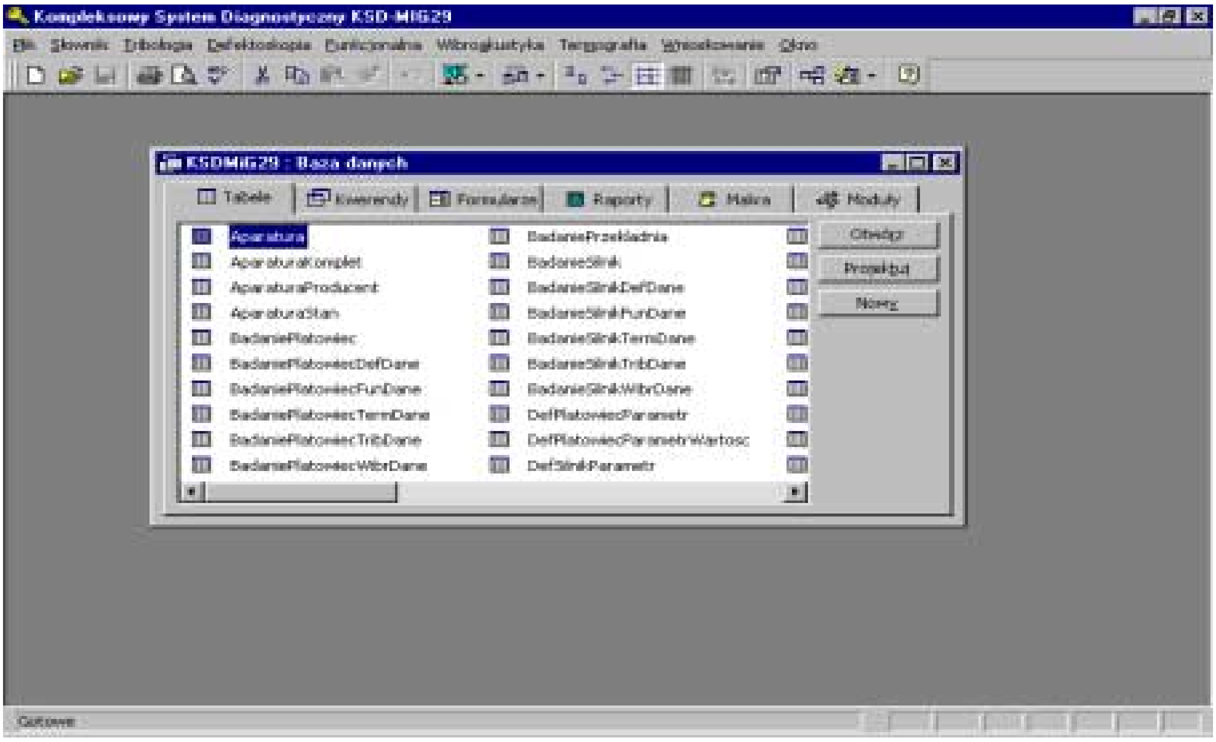

Fig. 3 Diagnostic data base of the KSD-MIG29 system.

5. Conclusions

1. There is no solitary general-purpose diagnostic method capable of determining the health/maintenance status of the aircraft under examination.
2. It is necessary to include the complex diagnostic system into the process of operating products of aeronautical engineering to make ivestigation and inferring in the fields of the health/maintenance status evaluation, the fault location, and the health/maintenace-status forecasting proceed automatically.
3. Advanced measuring instruments and computer-aided tools enable complex analysis of diagnostic data gained with different methods complementary to one another and well-correlated, to detect pre-failure states and start preventive treatment.

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