



**ZRÍNYI MIKLÓS NEMZETVÉDELMI EGYETEM
BOLYAI JÁNOS KATONAI MŰSZAKI KAR
Katonai Műszaki Doktori Iskola**

Alapítva: 2002 évben

**MIKLÓS ZRÍNYI NATIONAL DEFENSE UNIVERSITY
BOLYAI JÁNOS TECHNICAL MILITARY FACULTY
TECHNICAL MILITARY PhD COUNCIL**

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**VIBRATION DIAGNOSTICS AND RESEARCH
INTO MILITARY TECHNOLOGICAL
APPLICATIONS**

PhD theses

**Scientific supervisor:
Dr. Jenő Sipos PhD**

2010. BUDAPEST

1. THE SCIENTIFIC PROBLEM AND ITS CURRENT RELEVANCE OF THE SUBJECT

Servicing and maintenance assume an increasing significance in every area of life. The need to ensure continuity of production and extend the useful lifetime of high-value equipment has generated a new strategic philosophy that has spread from high-technology industrial production to the operation of military equipment.

Since Hungary joined NATO, it has had to modernise in many areas of military equipment and acquire new types of weaponry. As part of this process, the Hungarian Air Force put JAS-39 Gripen EBS HU fighter aircraft into service in 2006. Now that it has rearmed with such world-class equipment, it must develop new maintenance methods to keep the aircraft in service. This thesis investigates the theoretical and practical issues of the application of vibration diagnostics, a technology which has proved most effective in servicing and maintenance. The relevance of the subject stems from the increasing complication of military equipment and the high maintenance costs associated with it. Maintenance costs can only be reduced by the application of advanced diagnostic methods.

Vibration diagnostics is an area of engineering which has become a central part of the author's work. The author has taught state-dependent maintenance and technical diagnostics in the Donát Bánki Faculty of Mechanical Engineering and Security Technology in Óbuda, and its predecessor college, for two decades. Vibration diagnostics delivers considerable economic benefits for machinery operation. Vibration measurement can show up mechanical problems and harmful effects which act on the parts throughout the operating period of the machine. Identifying and eliminating these can significantly extend the lifetime of the machine, and forecasting faults can assure continuity of production.

Besides teaching, the author has worked as a vibration diagnostics expert in every area of industry in Hungary for fifteen years. The purpose of the current research was to put at the service of the Hungarian Defence Force (MDF) the theoretical and practical experience acquired from making measurements on several hundred machines, writing several thousand engineering reports and analysing several tens of thousands of vibration spectra.

2. RESEARCH OBJECTIVES

- To review the most common machinery faults and their characteristic spectrograms, and vibration diagnostic measurement methods.
- To present the author's measurements related to basic machine faults.
- To develop a universal demonstration device which offers advantage in the teaching of vibration diagnostics than what is presently available.
- To verify the practical applicability of the motion-animation method through test-bench experiments.
- To verify the determinability of technical state by the motion animation method through diagnostic measurements performed on real equipment.
- To develop a motion animation simulation model and measurement method to display the operational vibrations in JAS 39-EBS Gripen fighter aircraft and to determine the technical state of the power unit.

3. RESEARCH METHODS

- Review of literature on maintenance and vibration diagnostics.
- Application of fifteen years' vibration-measurement experience in measuring vibration and performing balancing and shaft adjustment on several hundred items of industrial plant.
- Survey of the teaching of maintenance and vibration diagnostics and the use of demonstration devices in Hungarian higher educational establishments.
- Development and production of the WibroShoW modular vibration diagnostics test bench.
- Setup of a simplified model of an aircraft on the test bench, performance of motion animation simulation experiments and discussion of results.
- Motion animation tests and experiments on industrial plant to solve real technical problems.
- Participation in JAS-39 Gripen fighter aircraft power unit tests and vibration measurements at the 59th Kecskemét Szentgyörgyi Dezső Air Base of the HDF.
- Vibration measurement on MiG-29 B fighter aircraft to prove demonstrability of power unit faults by vibration spectra.

4. CONTENTS OF THESIS, BRIEF SUMMARY OF RESEARCH

The thesis consists of five chapters. **Chapter 1** covers the basic task of servicing, the technical state of mechanical systems and the factors governing the change of technical state. It presents and analyses traditional maintenance strategies and philosophies and those which are being applied nowadays. It introduces the concept of technical diagnostics, the main diagnostic information media and how they operate.

Chapter two surveys the characteristics of periodic mechanical vibrations and reviews the practically-applied vibration measurement methods which the author has found from his experience to be most important. A description of the vibration measurement instrumentation chain is followed by a discussion of those practical measurement methods which can be used most effectively for diagnosing faults in real machinery.

Chapter 3 covers the application of vibration diagnostics methods and the development of the WibroShoW vibration diagnostics test bench. The first section draws on the author's practical experience to summarise the objective and subjective machinery data required for measurements on machinery and present the rules of setting measurement points. This is followed by a presentation of the characteristic vibration spectra of practically-occurring machine faults, based on the author's own measurement results. The second section describes the background, design criteria, structure and modules of the WibroShow vibration diagnostics test bench and the advantages it offers. The broad variability and scope of use of the test pad is explained.

Chapter 4 starts with a discussion of the theoretical foundations of the motion-animation vibration diagnostics method, followed by descriptions of the testing procedure, the required instruments and software and the measurement setup developed for the experiments. A review of the circumstances and results of the measurements is followed by an analysis of the information gained from the motion animation test. Findings and conclusions are derived from the spatial animation provided by the software. A case study demonstrates the practical applicability of the method.

Chapter 5 explores the applicability of motion animation to military equipment. It presents a power unit test and vibration examination of a JAS 39 Gripen fighter aircraft, the present measurement method and an alternative method for increasing the information content of vibration measurement. The motion animation method proposed and designed by the present author uses animation to display the real vibrations of the power unit in a moving three-dimensional diagram, providing additional information for the planning of state-dependent maintenance of fighter aircraft.

5. SUMMARY OF CONCLUSIONS

In line with the stated objectives, one of the main observations gained in the course of the research work is that diagnostic and servicing work calls for highly-trained mechanical and diagnostic engineers who have appropriate practical experience.

To this end, the present author has made advances in vibration diagnostics demonstration aids and extended the scope of application and development of diagnostic methods into what was for him a new area.

This has resulted in a new product capable of modelling a wide range of faults and thus developing further the knowledge and outlook of several generations of engineers.

Vibration measurement methods used in practical vibration diagnostics tests of machinery are presented via industrial and test-bench measurement results. These lead to the conclusion that practically-applied methods are suitable for forecasting mechanical faults, hidden bearing failures (which develop under the surface) and deterioration of lubrication state.

The air force is a fundamental component of military operations in modern warfare. The final outcome of combat tasks to be performed by the air force largely depend on the availability of military equipment. The fighter aircraft in service with the air force will only be effective against the enemy if it is supported by state-of-the-art technologies. The increasingly complex equipment involves considerable expenditure not only on procurement, but also on maintenance. The motion animation vibration measurement method, whose practical applicability has been proven by experiments and real equipment, enables these servicing costs to be reduced. With appropriate preparation, involving the development of a system of symptoms corresponding to base state and faults, the method will therefore be appropriate for use in the state-dependent maintenance of JAS-39 EBS HU fighter aircraft.

6. NEW SCIENTIFIC RESULTS, THESES

1. Development of the WibroShoW modular vibration diagnostics test bench, and use in modernising of teaching methods for vibration diagnostics in Hungary.
 - a. Measurements and purpose-constructed equipment which show that the WibroShoW may be used as an experimental model and demonstration aid. Proof that it is portable and suitable for display of machine faults, machine adjustment methods and comprehensive diagnostic methods.

- b. Ease of dismantling and assembly showing that parts in good and bad technical states may be exchanged quickly. The modular system permits differences between technical states, and the faults themselves, to be displayed either together or in a variable order.
 - c. Proof that the vibration diagnostics tests and motion animation experiments which may be performed on the WibroShoW test bench may be applied in industry and military technology. Results on the equipment have shown that the test bench has broad potential for further development.
2. Proof that real spatial movements of rotating machines may be displayed by motion animation methods, which are therefore suitable for assessing the technical state of mechanical and military equipment and tracking changes of state.
- a) Using the three-disc module developed for the WibroShoW test bench, it has been proven that motion animation is capable of clearly tracking changes in rotary speed, operation at resonant frequency and change of state caused by deliberate unbalancing of the disc.
 - b) The measurement results provided by the motion animation method, i.e. the 3D display of displacement of test parts, prove that the method is capable of detecting problems in fighter aircraft power units (e.g. loss of balance), thus preventing operational failure or air accident.
3. Development of a motion animation model of the JAS-39 Gripen RM 12B power unit, permitting the display and analysis, using on-site vibration measurement results, of the motion of the main components of the power unit and therefore changes in the technical state of the power unit.
- a) On-site vibration measurements on a MIG-29B fighter aircraft proving that amplitudes in the vibration spectrum indicate faults in the power unit and transmission, permitting identification of fault frequencies at which a motion animation test should be performed.
 - b) Identification of measurement points and directions in the RM 12B power unit required to permit state changes to be displayed in the motion animation model.
 - c) Proof that by 3D display of motion, the animation permits the location, direction and severity of a fault to be immediately analysed and documented.

7. POTENTIAL APPLICATION OF RESEARCH RESULTS, PROPOSALS

- The WibroShow developed, constructed and perfected during the research is recommended for use in all engineering higher education institutions in Hungary, because it facilitates teaching, and the theoretical relationship of vibration diagnostics may be demonstrated via practical examples.
- The WibroShoW test bench is used in Óbuda University in the teaching of maintenance and vibration diagnostics.
- The WibroShoW may serve as a model for those engineering higher education institutions in Hungary which teach vibration diagnostics. On request, the vibration measurement test bench may be manufactured for them.
- The author offers his services for the teaching of the practical application of advanced diagnostic methods and instruments, using the WibroShoW test bench, to departments of ZMNE teaching servicing.
- The test bench may be used in the training of staff in various areas of HDF who are involved in vibration measurement and maintenance.
- The test bench could usefully be employed in diagnostic courses in industry. Demand for the test bench is already apparent in this area, because a request for a quotation for manufacture has already been received from SKF Svéd Golyóscsapágy ZRt.
- In addition to diagnostic tests of aircraft power units, motion animation experiments may be of use in all areas of the HDF which use rotating machines.
- The motion animation model of the Gripen RM 12 power unit was designed for use in the 59th Kecskemét Szentgyörgyi Dezső Flight Base of the Hungarian Defence Force, and its use is recommended to be incorporated into the state-dependent maintenance system of JAS-39 Gripen fighter aircraft after the practical details of motion animation and the characterisation of symptoms indicating the base state and various faults.

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Curriculum vitae

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- Postgraduation – engineer - economist

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- Mechanical engineer

1982–1986 Bánki Donát Technical Collage, Budapest

- Mechanical engineer

Languages: English, middle level C, Russian, basic level C

Practice in the institution of higher education

Motor-vehicle diagnostic

Fuel Technic of Automotive

Service technique and maintenance

Modern diagnostic methods

Maintenance

Technical diagnostic

Practice in the business life; 24 years in business

1986–1990 Mátraaljai Szénbányák Thorez Gépüzem, Visonta :

Technological group leader

From March 1996. – Mc. Method Bt. (Owner, managing director) conditional monitoring

Professional activity in public life:

1993- Member of Mechanical Scientific Association,

1994-1995 Member of Maintenance Management

1992-től Member of Teachers of Maintenance in Higher Education

Professional awards: GTE Technical Literature Award

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Industrial contacts:

Yearly visits: AUDI Hungária Kft. Győr, Porsche Hungária Kft. Budapest Fáy u.

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