Acta Mechanica Slovaca 13 (4): 54-59, 2009
DOI: 10.2478/v10147-010-0037-x

Aircraft Safety Enhancement with Vibrodiagnostic Implementation

Ján PIĽA (SK) jan.pila@tuke.sk
Aurel SLOBODA jr. (SK) aurel.sloboda@hotmail.com
Aurel SLOBODA (SK) aurel.sloboda@tuke.sk
Zuzana HAJDUOVÁ (SK) zuzana.hajduova@tuke.sk

ABSTRACT
The subject of the paper is methodology of aircraft hydraulic pump and helicopter gearbox testing by means of vibrodiagnostic tools. By vibrodiagnostics methods it is possible to detect mechanical changes occurring within aircraft hydraulic pumps and gearboxes, remove its causes and prevent large system failures and equipment malfunctions before they occur. Vibrodiagnostics as a part of routine aircraft preventive maintenance of power machines greatly reduces expenses of maintenance, increases safety and reliability of the system while at the same time extends system long-lived.

KEY WORDS
hydraulic pump, vibrations, spectral analysis, aircraft maintenance.

INTRODUCTION
Current aircraft maintenance practice requires a large number of parts to be monitored and replaced at fixed intervals. This constitutes an expensive procedure that adds considerably to the aircraft operational and support costs.
The operation of technical processes requires increasingly advanced supervision and fault diagnostics to improve reliability and safety. This paper gives an introduction to the field of fault detection and diagnostics and has short methods classification (Fig. 1). Growth of complexity and functional importance of aircraft power systems leads to high losses at the equipment refusals. Not all operational conditions and degradation impacts of particular system elements can be revealed theoretically or by using simulation methods. To gather real information about particular system elements, there is need to provide experimental measure-ments. They gave us real views and through their application we are able precisely determine immediate behavior of monitored object [2]. Monitoring and diagnostics based on prediction maintenance are leading tools at present time.

MATERIAL AND METHODS
First object of our experiment was the aircraft emergency hydraulic pump NP 27T that gets to its operation when main hydraulics system failures or hydraulic pressure drops to 16,5 MPa. Experimental measurements were accomplished on the testing rig, where vibration parameters were the main subject of monitoring.
As the second object of our experiment was a helicopter transmission system. To determine the helicopter gearbox failure root cause we performed vibration analysis.
A vibration measuring instrument can separate the frequencies and quantifies the amplitude. It converts the physical motion into an electrical signal that can be further processed and displayed along a frequency axis. It provides us with the "big picture" of vibration by identifying the specific causes with the frequency and judging acceptability with the amplitude.

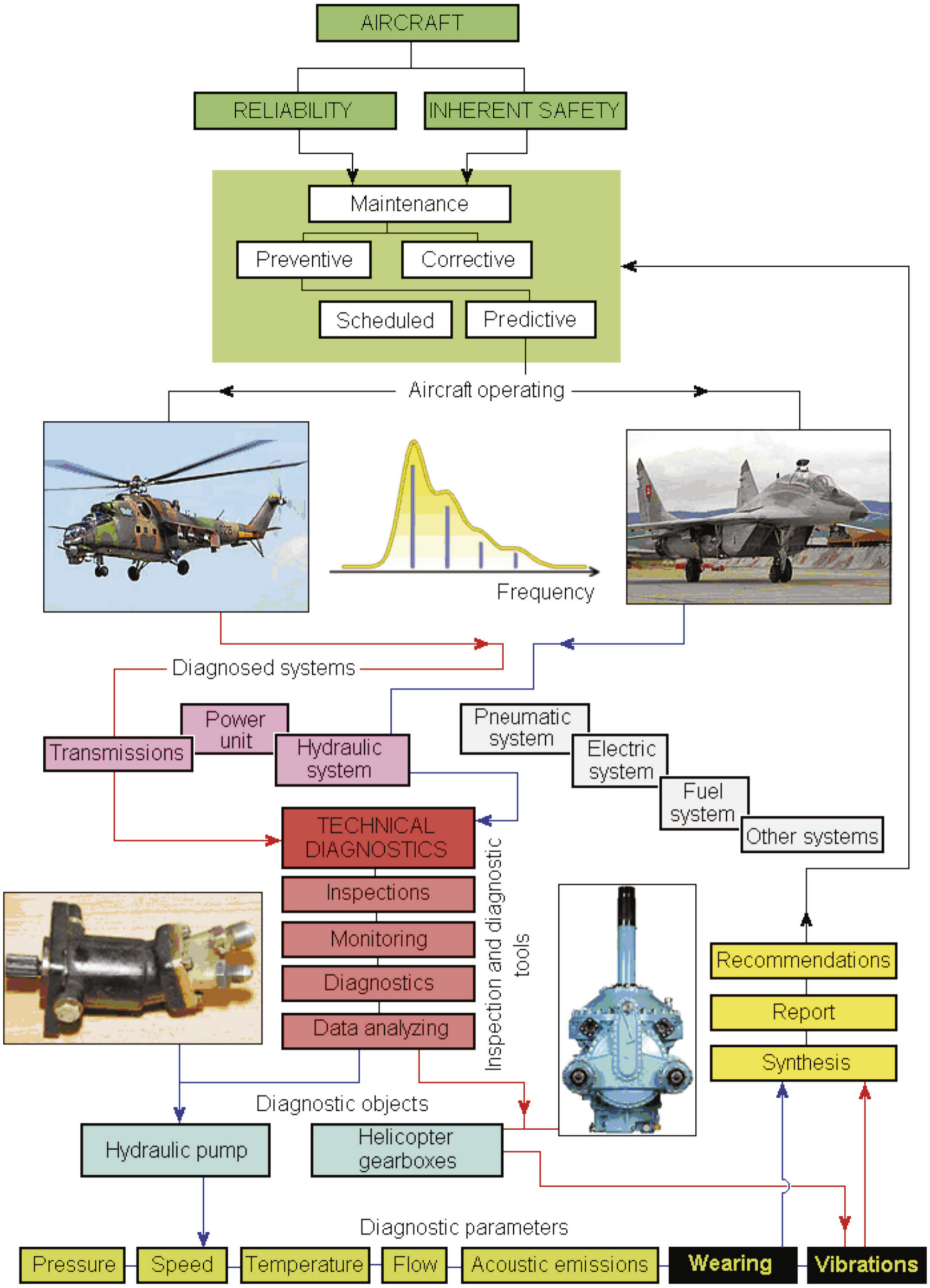

Fig. 1: *Aircraft monitoring and diagnostics based on predictive maintenance.*

HYDRAULIC PUMP NP 27T DIAGNOSTICS

Aircraft hydraulic pump NP-27T is a low-volume piston pump system for emergency use powered by electric motor (Fig. 2, 3). For the purpose of aircraft safety enhancement four hydraulic pumps were tested on the special rig.

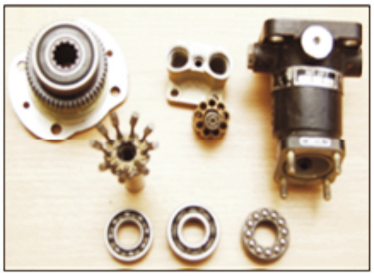

Fig. 2: *Main parts of hydraulic pump.*

Fig. 3: *Three axis transducer location.*

During the test the real pump operational conditions were applied to obtain real outcomes, i.e. hydraulic fluid stream was varied by using of restrictor valve. In mode of nominal revolutions the main kinematics couples (piston and cylinder) were tested for wear as a result of their mechanical action and surface interactions. Tribology and acoustic results of measurements are not the subject of the article.

There is an assumption that process of kinematic couple wearing (piston, cylinder) is the most characteristic in axis x and z in envelope acceleration spectra where were the highest amplitude values since this is in conjunction with piston couple kinematics (Fig. 4). This phenomenon could be explained by existing of centrifugal forces together with radial piston movements that make the highest stress of the kinematic couples [6].

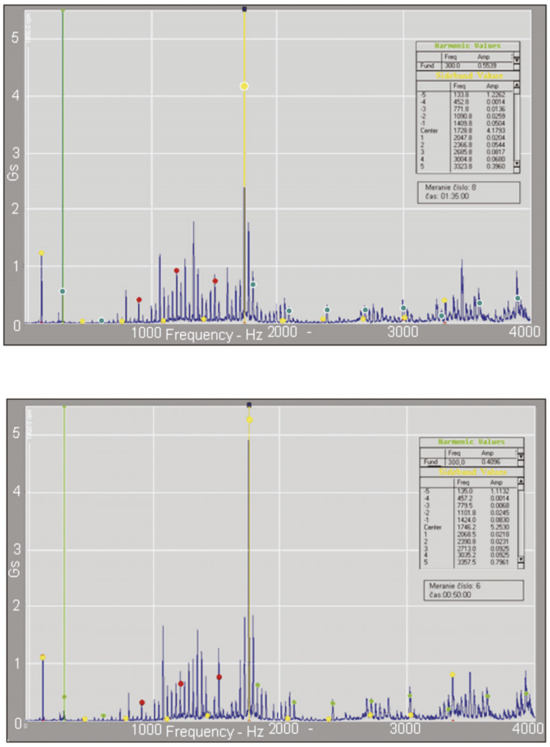

Fig. 4: *Acceleration vibration spectra in the axis x, z.*

HELICOPTER GEARBOX DIAGNOSTICS

Helicopter gearboxes are critical systems, where in flight any malfunctions can lead to catastrophic results. Helicopter's transmission system is a complex of gears, shafts and bearings which are potential source of degradation and accidental failures [1]. If any failure of transmission system occurs, the lift, thrust and helicopter controllability is seriously reduced and flight mostly finish with catastrophe.

Helicopter gearboxes as a part of transmission system are suitable objects for vibrodiagnostic application. Particular gearbox's components are highly stressed and generate unique vibration spectra useless for failure signals identification and normal or abnormal operation determination [3].

Helicopter gearbox diagnostics is considerably complicated since measurements must be accomplished under special conditions (measurements during helicopter hovering or on the ground with a load mass on the helicopter board). Measurements must not reduce safety or to disturb helicopter operational mission [4].

Vibrodiagnostic measurements were accomplished under Mi-24 helicopter operation in helicopter flight nominal mode with load of 2500 kg and 95 % main rotor revolutions. The angle of a collective control stick was 6 °C.

Measurements were realized by means of analyzer Microlog CMVA55 and three transducers located on the main gearbox body in such way to get vibration signal from thee axis. Spectra analyzing were performed in program PRISM for 4.

On the Fig. 5a are vibration spectra of a new gearbox (after gearbox general overhaul) and on the Fig. 5b a vibration spectra of worn-out gearbox (before gearbox general overhaul) where high level of gearbox degradation is presented [5].

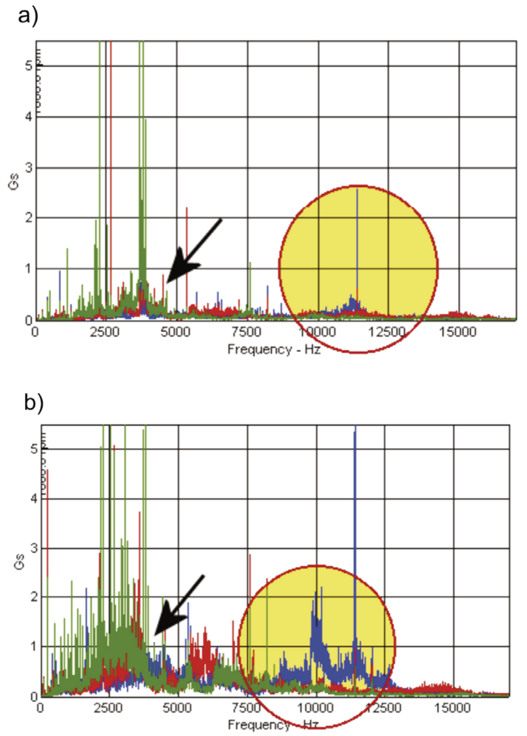

Fig. 5: *Vibration spectra of helicopter transmission system a) vibration spectra of a new gearbox, b) vibration spectra of worn-out gearbox.*

During the meshing process, energy is transferred from the driving gear onto the driven gear to establish acceleration or a deceleration of the driven shaft according to the relation

$$f_2 = f_1 \frac{N_1}{N_2},$$

where N_1 and N_2 are the number of teeth in the driving respectively the driven gear, and f_1 and f_2 are the respective shaft rotation frequencies in both gears.

In this process, two teeth of both gears make contact in several stages. At making contact and taking off two impacts occur, which will always be measured in the vibration response of a gearbox. This gear-meshing frequency can be computed as

$$f_{gearmesh} = N f_r,$$

where N is the number of teeth in the gear and f_r is the rotating frequency of the shaft connected to the gear. If a fault develops inside the gear (e.g. on the contact surface of a tooth), the generated impacts will be more severe: more energy will be dissipated and radiated in the meshing process. Because of asymmetric loading effects, severe modulations of the gearmesh-frequency (usually with the shaft rotation frequency) will show up. Alternatively, the gearmesh-process may excite the machine structure more severely, possibly leading to stronger modulation of machine resonances with the gearmesh-frequency.

CONCLUSION

This paper has partially reviewed vibration-based hydraulic pump and helicopter health and diagnostics methods. Machinery failure prevention was shown to be an important component of the maintenance activity for most engineering systems, especially in aerospace. Due to specific continuous vibrations induced by the pump pistons and helicopters rotors are particularly exposed to operations-induced fatigue damage, and their failure prevention increasingly relies on vibrations, health, and usage monitoring systems.

Real machinery diagnostics require vibration monitoring based on systematic measurements. Predictive maintenance in aircraft operation is a new and progressive philosophy based mainly on vibrodiagnostic spectra analyzing. It has large utilization not only for hydraulic pump and helicopter gearbox implementation but for all another airframe and engine systems.

For effective vibration monitoring and diagnostics utilization in process of technical service is important for information to be extracted from obtained vibration spectra. Quantity and quality of extracted vibration spectra and their analyzing is an important assumption for correct diagnose and prognosis of aircraft system condition. The need exists to develop an on-board, continuous vibration diagnostic system to detect and to prognosticate faults in these components prior to failure.

REFERENCES

[1] Bušmarin P.P., Dementev G.A., Mechaničeskie peredači vertoletov, Mašinostrojenie, Moskva, 1983.

[2] Jacková J., Spoľahlivosť, meracích podmienok, meracích miest a ich najvhodnejia voľba pri diagnostike strojov, Bezpečnosť práce no. 7, EPOS Bratislava, 2008, 5 p., ISSN 1325-4078.

[3] Neštrák D., Piľa J., Aerodynamika, konstrukce a systémy vrtulníků, Učební texty dle nařízení komise (ES) 2042/2003 Part 66: Studijní modul 12.1, Akademické nakladatelství CERM, Brno, 2006, 454 p., ISBN 80-7204-484-2.

[4] Piľa J., Sloboda A. jr., Niektoré možnosti využitia diagnostických parametrov pre proaktívnu údržbu lietadiel, DIS 2004, Košice, 2004, p. 4, ISBN 80-232-0237-5.

[5] Piľa J., Sloboda A. jr., Vibrodiagnostika planétového prevodu vrtuľníkovho reduktora VR-24, Bezpečnosť - kvalita - spoľahlivosť, 2. Medzinárodná vedecká konferencia, KBaKP SjF TU Košice 2005, Košice, 2005, p. 5, ISBN 80-8073-258-2.

[6] Sloboda A. jr., Beník J., Využitie vibrodiagnostiky u hydrogenerátora NP - 27T, Bezpečnosť - kvalita - spoľahlivosť, 2. Medzinárodná vedecká konferencia, KBaKP SjF TU Košice 2005, Košice, 2005, p. 4, ISBN 80-8073-258-2.