



## USING ACOUSTIC EMISSION IN HYDRAULIC MACHINERY DIAGNOSTICS

David VARNER – Michal ČERNÝ – Jan MAREČEK – František BAUER  
Department of Engineering and Automobile Transport, Faculty of Agronomy, Mendel  
University, Brno, Czech Republic. E-mail: info@davar.cz

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**Summary:** Presented paper describes status evaluation of a hydraulic pump used in an aircraft construction. Acoustic emission (AE) signals have been monitored both for new and used hydraulic pump. Two significant parameters have been taken into account: RMS and values of PSD function for individual AE events. The AE monitoring method has proven significant changes of RMS and minor changes of PSD function between the new and the used hydraulic pump.

**Key words:** acoustic emission, AE, hydraulic pump

### INTRODUCTION

New and used hydraulic pump has been subject to several diagnostic procedures. The non-destructive methods used included pressure tests, flow test, and acoustic emission. This paper deals with acoustic emission method only. The method has been extensively used in aircraft construction/component testing. Acoustic emission was used to determine wear-off of hydraulic pump. The experiment was to prove any significant differences between AE parameters (RMS and PSD) for new and used hydraulic pump.

### MATERIAL AND METHODS

#### Acoustic Emission Method

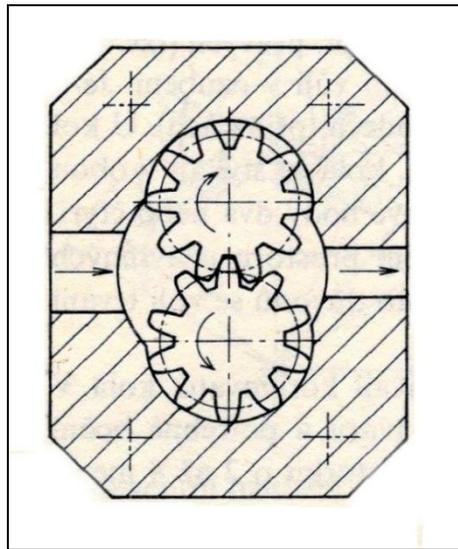
Acoustic emissions are the stress waves produced by the sudden internal stress redistribution of the materials caused by the changes in the internal structure. Possible causes of the internal-structure changes are crack initiation and growth, crack opening and closure, dislocation movement, twinning, and phase transformation in monolithic materials and fiber breakage and fiber-matrix debonding in composites. Most of the sources of AEs are damage-related; thus, the detection and monitoring of these emissions are commonly used to predict material failure.

In technical diagnostics, AE method has been used to monitor rotational part status (friction and cavitation of bearings/gears), detection of micro-cracks, pressure vessel defects, tubing system defects, aircraft structure evaluation/testing, and bridge status diagnostics. Acoustic emission technique has proven useful in fatigue testing and destruction experiments. Major advantages of AE include continuous monitoring of the object, time savings, and forecast abilities of the concept. On the other hand, AE wave source is not always obvious, as the emitted energy may result from several phenomena inside of the part. Further variable factors include shape of the object, surface area, material structure, and homogeneity level. [2]

#### Hydraulic Pump Layout

The following picture shows simplified cross-section of hydraulic pump.

Basic components of a conventional hydraulic pump assembly include pair of gears in pump housing. Working space of the pump is represented by inter-tooth cavities.



**Figure 1** Simplified cross-section of hydraulic pump with inter-tooth cavities and flow directions.

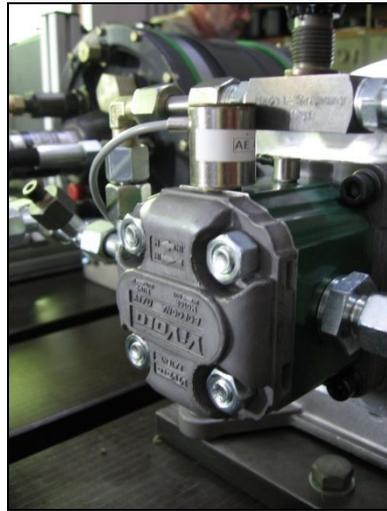
The cavities have volume limited by radial/axial gear faces and tooth contact faces. The fluid is sucked into inlet chamber by under-pressure caused by cyclic increase of inlet chamber volume. This happens when individual teeth part from each other, opening the chamber for fluid. Then, the fluid travels around the gear circumference into the outlet chamber. Outlet chamber is isolated by the teeth forming multiple-stage labyrinth seal. Hydraulic pumps are being widely used due to their high performance, long service-time and low costs. By a constant development, they have reached perfection with respect to high working pressures, excellent volume effectiveness, and reduced noise emission. [4]

### Acoustic Emission in the Hydraulic Pump

Acoustic emission may occur due to contact of pump teeth and irregular fluid flow in inter-tooth cavities. Contact of individual teeth and AE event count depend on pump rotation (rpm). As the internal parts of the pump get worn-off, the inter-tooth cavities are filled irregularly, with variable volume curve. Then, short-time variations of pressure and velocity occur in the fluid transported along the pump circumference. Under extreme conditions, even cavitation may be registered that might influence smoothness of the pump operation. During acoustic emission monitoring, these situations result in increase of AE event number and/or robustness.

### Experiment Setup

The pump was XV1P/0.9 Al alloy type made by Rerosa. Acoustic emission monitoring was performed on the 3<sup>rd</sup> of June, 2008 using the Dakel XEDO 2008 analyzer and Dakel AE piezoelectric sensor. Acoustic emission has been monitored for new and used hydraulic pump. The calibration of the system has been made using pentest (Hsu - Nielsen AE source). The sensor was glued onto upper face of pump housing using a Loctite second-bond glue (see Figure 2).



**Figure 2** Piezoelectric sensor on the pump housing.

AE signals generated during the pump operation have been captured and analyzed using the XEDO box with the AE 3.0 slot (both manufactured by the DAKEL ZD Rpety Company). XEDO represents state-of-art multi-channel system for AE signal analysis. XEDO. The slot covers frequency range of 80 – 550 kHz. Data from XEDO have been sent via Ethernet adapter to control PC. Dakel Daemon software was used to monitor the AE signal parameters.



**Figure 3** Control PC with Dakel Daemon software and hydraulic circuit with the pump.

### Acoustic Emission Parameters

Two significant AE signal parameters have been taken into account during the experiment: RMS values and PSD function maximum values. They are described as follows: RMS (Root Mean Square) indicates so called "effective" value or "robustness" of the signal. RMS indicates quantity properties of the acoustic emission events (amount of energy). RMS is measured in Volts. PSD (Power Spectral Density) of the AE events indicates distribution of energy transmitted over the frequency spectrum. PSD graphs show one or more peaks. Transformation of the signal from time to frequency domain had been performed using the Hanning window. PSD is measured in mW/Hz or dBm/Hz for logarithmic scale.

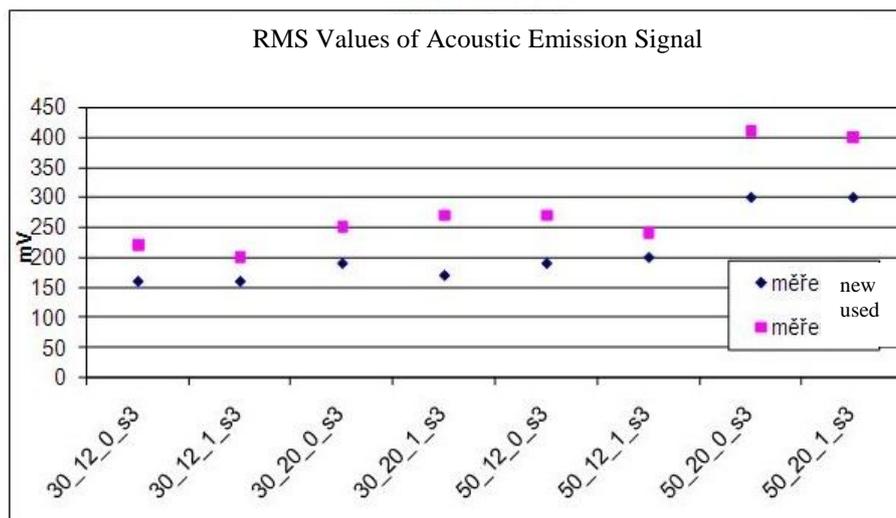
## Acoustic Emission Monitoring

Comparison method has been used for the acoustic emission monitoring. The AE signal has been acquired for new and used XV1P/0.9 hydraulic pump in an oil-filled hydraulic circuit. The experiment setup featured 8 operation modes with 2 rpm modes (1800/3000 rpm), 2 typical pressure levels (12/20 MPa), and auxiliary by-pass line simulating medium leak (0/1).

AE sensor calibration and XEDO analyzer setup has been performed using Pen Test with 0,5 mm lead H2 and certified adapter. First, new hydraulic pump was tested. Afterwards, this pump was removed from the circuit and replaced with a used pump of the same type. The acoustic emission monitoring lasted 1 minute for each pump and for each operation mode (see table above).

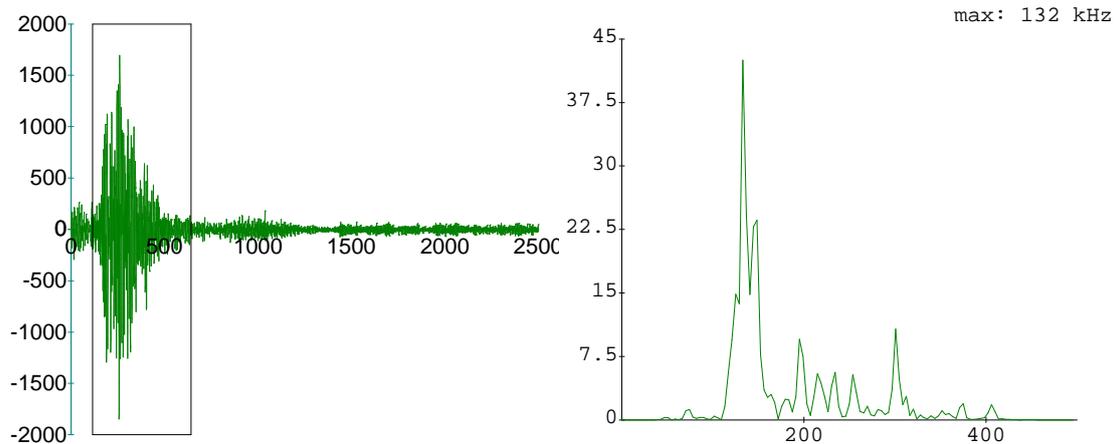
## RESULTS AND DISCUSSION

During testing of new/used XV1P/0.9 hydraulic pump, RMS and PSD values have been registered and evaluated. In all operation modes, used pump showed significant increase of RMS compared to new hydraulic pump - 25 to 58%, see figure 4.



**Figure 4** RMS values for acoustic emission signal for new and used hydraulic pump for various operation modes. S3 indicates sensor no. 3.

Maximum values of PSD function reside in 120 kHz – 320 kHz range. With used hydraulic pump, more robust values have been registered for higher frequencies. However, there was no significant shift of maximum value range compared to new pump.



**Figure 5** Example of typical PSD graph (configuration 30\_12\_1, used pump)

## CONCLUSIONS

Hydraulic pump status has been evaluated using acoustic emission method. Used pump showed significant increase of AE signal RMS compared to new hydraulic pump in all operation modes. PSD function showed no major differences to be used as reference. Therefore, we recommend to further explore possibility of using AE signal RMS as status evaluation parameter.

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