MOSYCOUSIS

Intelligent Monitoring System based on Acoustic Emissions Sensing for Plant Condition Monitoring and Preventative Maintenance
Introduction
MOSYCOUSIS project overview

Industrial production failures

Replacement costs, man-hour resources and downtime losses.

Operating risk reduction
Plant failures minimizations
Equipment reliability
Production maximization

Predictive maintenance.
MOSYCOUSIS project overview

Support Predictive maintenance

Main value

Allowing convenient scheduling of corrective maintenance, and to prevent unexpected equipment failures.

Requirements

Earlier information and reliable diagnosis

Current solutions

Manual procedure
Expensive devices
Simple diagnosis algorithms
User experience

expectations

Automatic procedure
Low-cost devices
High diagnosis analysis
Untrained users
maintenance
Flexible & Modular
Task 1.1 – Collecting demands

- Commercial solutions

**Ultraprobe, electrical, mechanical or leak detection by ultrasound level**

The Ultraprobe senses high frequency sounds produced by operating equipment, leaks and electrical discharges. It then electronically translates these signals down into the audible range so that a user can hear these sounds through a headset and see them as intensity increments on the Ultraprobe "gun's" LED meter.

<table>
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<tr>
<th>Indicators</th>
<th>dB in time, Acoustic level in frequency</th>
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<tbody>
<tr>
<td>Others</td>
<td>from 20KHz to 100KHz, response in &lt; 10 miliseconds, Trisonic Scanning Module.</td>
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Ultrasonic Ultraprobe 100: € 1400.00
Ultrasonic Ultraprobe 9000: € 5500.00
MOSYCOUSIS project overview

- Advanced diagnosis algorithms
- Energy autonomous system
- Application adaptability
- Wireless communication
- Location in non-accessible places
- Compact system
- Full Acoustic Emissions analysis
- Application adaptability
- Optimum electronic design
- Expert System
Targeted customers

Development of a professional, effective, safe, and accurate mechanical equipment monitoring system for industrial machinery in manufacturing plants.

Main applications
- Gearboxes and shafts
- Slow speed bearings and gearboxes

Secondary applications
- Split and planetary gearboxes
- Alternative and reciprocating machinery

Electrical motors, gearboxes, pumps, yaw control and blowers.
Consortium structure

8 Beneficiaries / 5 countries

2 beneficiaries in Romania
2 in Ireland
2 in Spain
1 in Estonia
1 in Poland

5 Industrial enterprises
3 Research Centers or Universities

2 years project duration:

from October the 1st 2011 to October the 31st 2013
Acoustic emissions data analysis
AE data analysis
– Fault Characterization with AE signals

Analysis of Acoustic Emission Signals WP2

“STATIC” EXPERIMENTS:

Experimental Setup:
- Fatigue testing machine
- Tensile test machine

Experiments:
- Micro-Hardness Test
  Characterization of materials
- Spherical Indentation Test (AE)
  Failure Mechanisms in Surface
- Three Point Bending (AE)
  Fatigue Crack Initiation and Propagation
- Fatigue Test in Gear Teeth

SIMULATION:

Experimental Setup:
- FEM software

Experiments:
- Different conditions (fault size) evaluated.

DYNAMIC EXPERIMENTS:

Experimental Setup:
- Gearbox test bench

Experiments:
- Different gears conditions
AE data analysis
– Fault Characterization with AE signals

Static Analysis of Acoustic Emission Signals

• Long term testing were conducted to identify the relation between the degradation procedure and AE signal characteristics.

Laboratory Set-up for the fatigue cycle testing in F114 Gears
AE data analysis
– Fault Characterization with AE signals

Static Analysis of Acoustic Emission Signals

• Generally, in fracture process, the acoustic activity of a material can be classified in three phases: crack initiation, crack incubation, and crack propagation.

• AE Event

Theoretical response

Experimental response

Threshold

AE data analysis
– Fault Characterization with AE signals

Finite Elements Models Simulations

• Simulations with a gear finite element 2D model
• Identify the relation of the AE signals with:
  – Geometrical aspects of the gear.
  – Size of the fault.
  – The position of measurement.

Evolution and propagation of the AE wave

FEM crack and mesh representations
AE data analysis
– Fault Characterization with AE signals

Report of the fault modeling system, acoustic emissions FEM simulations

FEM SIMULATIONS
Study of acquired AE signal

AE signature Vs Fault Size:

Increasing amplitude of the AE signal.
Dynamic Experiments

- Experimental tests were performed with different types of machinery in order to extract AE information and fault patterns in applications under laboratory conditions.
Review of WP2 – Fault condition characterization and Acoustic signal response

Report of the feature extraction.

DYNAMIC EXPERIMENTS: Time Domain Analysis

The AE signals are highly influenced by the speed conditions of the test [2].

- \( v = 150, 250 \) and \( 450 \text{rpm} \)
- (sensor: VS150-M)
- (time: 1 revolution)

Review of WP2 – Fault condition characterization and Acoustic signal response

Healthy Gearbox

Faulty Gearbox
Diagnosis Algorithm
Sensor description
Sensor General Operation

MOSYCOUSIS DEVICE

Local/Remote Wireless Network

Expert System

Central Server

MOSYCOUSIS CONCEPT

AE Sensor

Signal Conditioning

A/D

Mechanical/Electromagnetic Energy Harvesting

Local CPU

Digital I/O

Analog I/O

Local Device

Power & Data Transfer

Energy Harvesting & Storage

Power Mgmt

DC Bus

Frequencial Feature Extractor

Prediagnosis and Thresholds

Temporal Feature Extractor

Signal Processing

ZigBee // GPRS Interface

Data Buffer

Alarm Detection

Full Data Analysis

Security Decisions

Life Expectancy
Sensor structure

- **Signal Processing Unit Module**
  - Local digital signal processor, ADC, Signal conditioning,…

- **AE Transducer Module**
  - AE Sensors

- **Interfaces Module**
  - Wireless and Cabled modules

- **Power Management Module**
  - Energy Storage and Management
ACQ Board

AE conditioning board

Signal Processing Unit Module
AE Transducer module
Interfaces Module
Power Management Module

BAND PASS FILTER
100Khz TO 400Khz

Sampling frequency: 2Mhz
Main Board

- Signal Processing Unit Module
- AF Transducer module
- Interfaces Module
- Power Management Module

LQFP-144 MCU
Signal Processing Unit

Processor core
- Low power family
- 1.8V-3.3V
- Sleep, stop and standby mode
- 32 bits processor

Peripherals:
1. USB 2.0
2. DIGITAL I/O
3. SERIAL COM.
4. HIGH SPEED ADC
Algorithm Explanation

AE signal acquisition considerations:

- 20,000 Samples @2MHz, 12 bits resolution.
- 10 ms of signal.
**Review of WP2 – Fault condition characterization and Acoustic signal response**

**MOSYTRON as the resulting machine health indicator**

**Machine Health Condition**

**Stage 1: From 00 to 20 %:**
- Status: Good Condition.
- Periodic inspection of sensor’s alarm.

**Stage 2: From 21 to 50 %:**
- Status: Initial Degradation.
- Common maintenance actions.

**Stage 3: From 51 to 85 %:**
- Status: Continuing degradation.
- Carry out Expert system full analysis.

**Stage 4: From 86 to 100%:**
- Status: Severe failure.
- Mechanical components replacement.

*Non dependent of the laboratory test conditions!*
Zigbee Board

Zigbee- uC SPI protocol communication.
Totally turned off if is not transmitting.
Zigbee transceiver

Local communication

WSU concept

Features: Module
- 2.4GHz IEEE802.15.4, JenNet and ZigBee PRO compatible
- Sleep current (with active sleep timer) 2.6μA
- JN5148-001-M00/03 up to 1km range (Ext antenna)
  - M00: integral antenna 18x32mm
  - M03: uFI connector 18x30mm
  - TX power +2.5dBm
  - Receiver sensitivity -95dBm
  - TX current 15mA
  - RX current 17.5mA
  - 2.3-3.6V operation
Energy Harvesting Board

- Signal Processing Unit Module
- AE Transducer Module
- Interfaces Module
- Power Management Module
- Vibration
- TEG
- 24Vdc
- S-caps
- SOLAR
MOSYCOUSIS Sensor Integration
Mechanical Design
Mechanical Design

24 Aux. input

EH inputs

USB 2.0
Added Features

- Local communication
- WSU concept
- Power and Data transfer
- Expert System
- Wireless
- Wired
Comms network and expert system

Graphical User Interface
Default view in ES user interface
Comms network and expert system

Sensor status window
Industrial Validation
AE data analysis  
– Industrial Validation

General Set-Up Description

- Methodology:
  - Initial Analysis: Retrieve AE data from the machines under different working scenarios.
  - Continuing monitoring: Long term experiment in order to test the real functionality of the sensor.
AE data analysis
– Industrial Validation

Set-Up in CGI facility

Compressor model ASEA

Compressor model Sabroe
**AE data analysis**

– Industrial Validation

**Initial Analysis in Sabroe**

**Time vs. Frequency domain AE signal**

AE temporal form in SABROE Pos1 vs Pos2

**FFT in SABROE Pos1 vs Pos2**

- Pos 1 Motor
- Pos 2 Motor D

**Mosytron Value in the Motorside**

- Pos 1 Motor
- Pos 2 Motor D