Ultrasound Solutions

Commercial Document DC.QUAL.007

Online4US Tires Leak Detection Case Study

02	GEL 2015-05-19	Removed confidential info	ADG
01	GEL 2015-04-30	Original version	JPE
Ver.	**Author**	**Nature of modification**	**Verified**

Online4US System Case Study: Tire leak detection

1. Introduction

The aim of this system is to detect a possible leak on a retreaded aircraft tire:
the goal is to avoid the possibility to deliver a leaking tire to a customer.

After testing the feasibility of using ultrasound detection with a SDT270 portable ultrasound detector, the Quality Assurance Department designed a whole leak detection system based on the SDT Online4US system (in short: O4US), a fixed ultrasound measuring system supporting multiple sensors

2. Short description

The tire is put under pressure, and rotated on its axis;
the 04US system detects ultrasound coming from the tire surface: any leak will generate ultrasound;
if a leak is passing in front of the O4US sensors, they will measure a temporary signal increase.
For operator safety [(1)] and to protect against factory noise [(2)] the system is mounted inside a closed chamber:

Photo 1 : Front view of the closed chamber.
The pneumatically operated door is open.
One sees the O4US four sensors
mounted inside a metal cone.

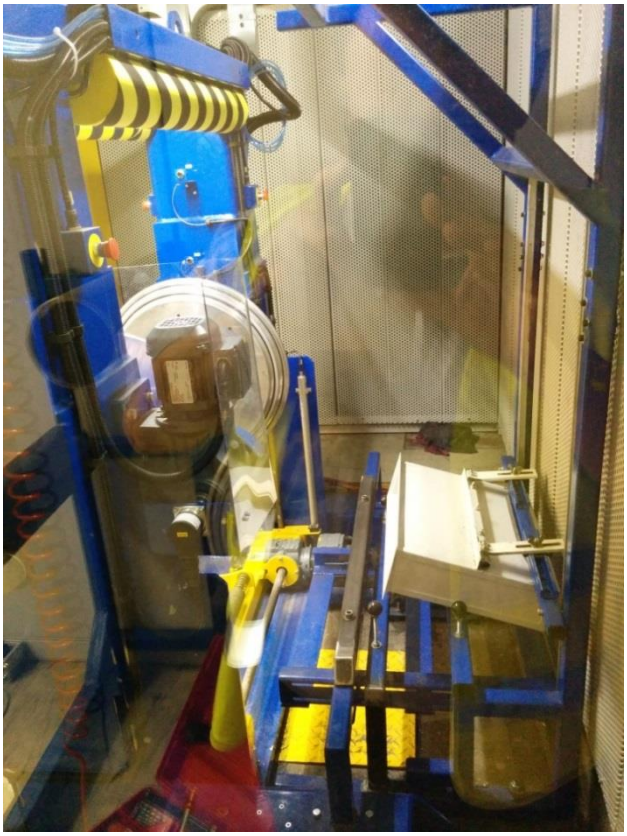


Photo 2 : Side view inside the chamber.

[(1)] because airplane tires are tested here under a pressure of up to 8 bars
[(2)] because air guns are employed at multiple places in the factory

3. The Programmable Logic Controller (in short : PLC)

Photo 3 : Electrical cabinet

Photo 4 : PLC Front panel touch screen

The Quality Assurance Department has installed a standard PLC in an electrical cabinet.

The PLC can be operated locally (it has a touch screen) or remotely (it has an Ethernet connection).

The PLC controls the whole system: O4US, pneumatic valves, electrical motors:

- it opens and closes the chamber door
- it instructs the operator to put the tires
- it controls the pneumatic system that put the tire in position,
  and that put the tire under pressure, or off pressure
- it starts and stops the motor
- it instructs the O4US to start and stop the measurements

- it receives measurements and diagnostics from the O4US
  (it communicates with the O4US in a redundant manner:
  by isolated 24V digital input/outputs and by a serial communication line)
- to signal the position of the leak for further repair, the PLC controls
  the painting a mark on a leaking tire
- the PLC can be operated remotely, and reports results/statistics to a central factory computer

4. The SDT Online4US system

4.1. Architecture

The SDT Online4US is a modular system used to measure the intensity of several ultrasounds signals.
In this application the system consists of :

- A set of 4 aerial ultrasound sensors that are mounted inside a cone (see §7. Appendix Design Notes); each sensor is equipped with a Preamplifier, and connected by a standard shielded twisted pair cable (STP, 2 pairs, 10 meters length) to the O4US central processor.
- The O4US processor : it processes the signals, makes the measurements and transmits calculations and test results to a PLC (Programmable Logic Controller) programmed by the Customer

4.2. O4US Leak detection algorithm

When the tire is rotated, an eventual leak that is passing in front of the sensor(s)
generates a temporary increase of the sensor signal.

The algorithm computes the RMS signal (with a user-configurable RMS time-constant);
a leak is signaled if this number is higher than the average ambient noise level
(plus a user-parametrable threshold).

More precisely, 3 test results are possible:

- Green : tire is good (no leak)
- Red : tire has a leak (its position is marked by a painted mark)
- Yellow : a possible problem has been detected: the operator shall analyze the machine, the environment, the pressure, make eventually a second test, call Quality Assurance, …

4.3. O4US Self-test, redundancy

- A small SDT ultrasound source (SDT200mW emitter) is powered by an external power supply that is switched on or off under control of the PLC.

  As the O4US transmits all measurements from all sensors to the PLC,
  the PLC can check that *all sensors signals levels are comparable to reference values that have been recorded during installation*
  when the ultrasound emitter is on, as well as when the emitter is off (average noise level).

- The O4US uses four (4) sensors, but two (2) of them are sufficient for the largest tire:
  the system is redundant : in case of a failure (of a sensor or of its electronics):
  - The failure will be *immediately* detected by the discrepancy between the sensors signals.
  - An elementary parameter change (disabling the faulty sensor) will permit the system to continue normal production while waiting service repair.

5. Practical results

Photo 5 : Reference aircraft tires

Photo 6 : regular production tires

- The Quality Assurance Department has selected a set of reference tires (smallest to the largest size)
    - some tires with a small leak,
    - other tires with a large leak, and
    - other tires without leak,

  that were regularly tested during a start-up phase.
- Test results on the reference set are excellent :
    - All leaks (small and big) are detected
    - All non-leaking tires are correctly classified as “non-leaking”

6. Summary and conclusions

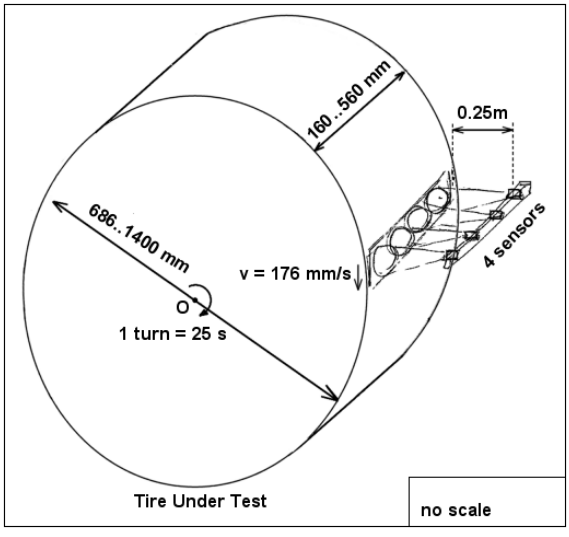
- After testing the feasibility of using ultrasound detection with a SDT270 portable ultrasound detector, the Quality Assurance Department designed a whole leak detection system based on the SDT Online4US system, a fixed ultrasound measuring system supporting multiple sensors.
- The aim of the system is to detect a leak on a tire that will be used on an airplane.
  The goal is to avoid the possibility to deliver a leaking tire to a customer.
  The Quality Assurance Department manages the SDT O4US measurements by following well-known statistical methods. Numbers are confidential, but the goal is clear:
  from a Quality Assurance point of view, the tire manufacturer wants to decrease to the extreme the probability of delivering a leaking tire to any of its customers.
- Project is successful: in view of the good results obtained at first with a portable SDT270, then with a prototype fixed system, then during several month in full production with a first SDT Online4US system, a second 04US system has now been installed: both are working well; installation of the same system is under evaluation for all facilities in the group.

7. Appendix: Design notes: sensor type, sensor mounting and positioning, tire pressure

1) Sensor type: Open – or closed aerial ultrasound sensors?
   - Open sensors have a higher sensitivity (6 dB more than closed sensors).
   - Closed sensors are more robust and are easily cleaned
     It is felt that a very big punctual leak could destroy an open sensor;
     also cleaning the sensors from time to time might be beneficial
     because some dust is floating in the air (coming from rubber tire machining) :
     closed sensors have been chosen.

2) Sensors mounting inside a cone:
   - The inverter driving the motor generates ultrasound noise,
     the motor generates ultrasound friction noise.
     Additional ambient noise is also present and varying over time.
     We measure ambient noise during the whole rotation of the tire and we compute the average.
   - The leak is emitting ultrasound in a directional manner ; the direction is relatively constant over time with reference to the tire surface, however, this direction is determined by interferences of waves generated by each point of the leak surface … whose geometry is unknown: in practice the direction of the US waves emitted by the leak leaking surface is fixed, but … random
   - Mounting sensors inside a cone can then help
     - decreasing ambient noise perceived by the sensors
     - increasing the leak signal by collimating (focusing) it towards the sensors
     - locating the leak, without needing the intelligence of a human operator

3) Sensor positioning:



Tire diameter : 686 through 1400 mm
Tire width : 160 through 560 mm
4 sensors

Despite various tire diameters and width,
it is not needed to move the sensors:
sensors have been positioned
in order to accommodate the largest tires,
and work also for the smallest tires.

Figure 1 : Tire with 4 sensors and the sensitive area

4) Influence of tire pressure (2, 4, or 8 bar) on SNR (Signal to Noise Ratio) in presence of a small leak:
   - Increasing pressure from 2 bar to 4 bar increases the SNR by 2 to 3 dB,
   - Increasing pressure from 2 bar to 8 bar increases the SNR by 5 to 6 dB

A pressure of eight (8) bar has been chosen (because 8 bar is ok for these airplane tires).