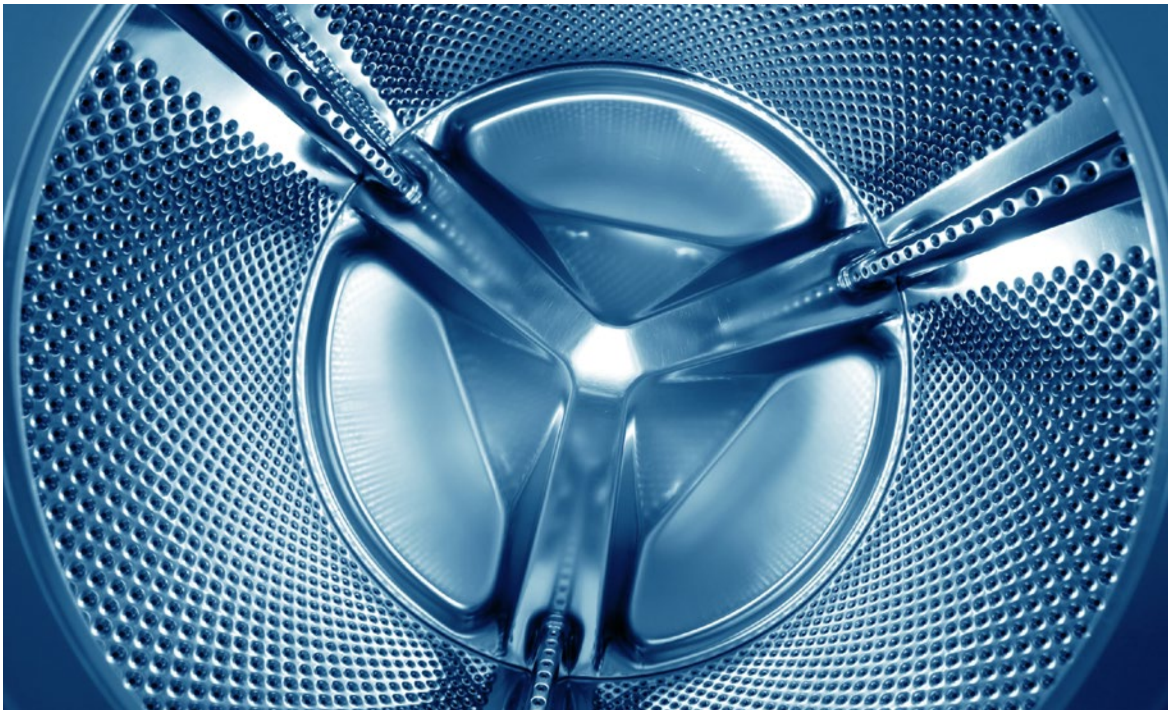


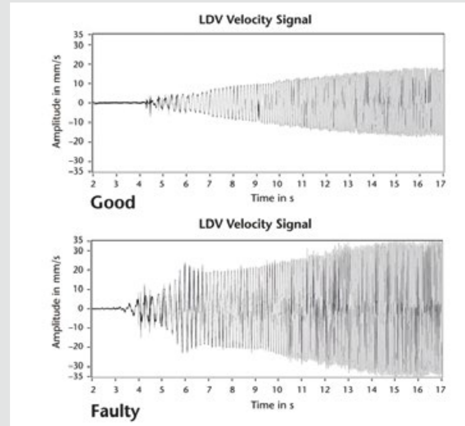
A Clean Solution

Automated Quality Control of Washing Machines

Application Note

1
The MUSA test station handles three washing machines at the same time

2
LDV pointing at the washing machine tub (center)



3
Velocity time signals for a good (above) and faulty (below) washing machine

Fully-automatic Noise and Vibration Test Stations Garantuee Quality for Premium Washing Machines

Thanks to a close collaboration with the world's largest manufacturing companies over more than 45 years, the Loccioni Group has gained a leading role in the implementation of automated quality control and testing systems in laboratories and production lines. MUSA (Measurement Unit in Sound-proof Area) is a turn-key, completely automated testing solution for washers, integrating noise & vibration tests that are usually performed in R&D laboratories.

A complete (100 %) test on the finished products is an appropriate method to assure a high standard of quality because statistical tests on a random selection of samples cannot guarantee the quality of the full production run. It is well known that vibration tests enable discrimination between good and faulty products and hence the analysis of the vibration signals can be used for quality control of household appliances. The technology of the Laser Doppler vibrometers (LDV) is widely used for quality control in-line or close to line where non-contact measurements are essential.

MUSA – the System

This paper presents an industrial solution for the in-line monitoring of washing machines, where the use of LDV and microphones allow an objective vibro-acoustic quality inspection of the product thus detecting specific mechanical defects. The system mainly comprises a sound-proof cabinet to reduce the external noise by about 35 dB, containing three stations running simultaneously (figure 1):

- 3 IVS Industrial Vibration Sensors (one per station), pointing at the tub of the washing machine in a radial direction with respect to the axis of the motor (figure 2)
- 3 microphones (one per station) positioned on the rear part of the washing machine, facing the motor.

When the three washing machines arrive in the sound-proof cabinet, they stop in front of each station and the cabinet doors close. Each washing machine is driven to the spinning phase and the signals coming from the LDV and the microphones are acquired simultaneously, both during the run-up and the steady state (figure 3).
The core of the system is the signal processing software which:

- Calculates the machine's RPM directly from the LDV signal (figure 4)
- De-noises the velocity signal (not described here in detail)
- Analyzes the LDV and microphone signals during the transient state in the time-frequency-domain (STFT, figure 5)
- Analyzes the LDV and microphone signals during the steady state in the frequency domain (figure 6)

Certain features are calculated both in the run-up and steady state phases. The selected features are compared with fixed thresholds in order to decide the status of the machine and these values are related to the specific model of the machine under test. In particular, the sum of the energy in specific frequency bands is extracted and correlated to the specific defect, e.g. the defect related to the electrical motor. As shown in figure 7 (left), the main frequency peak in the spectrum is related to the RPM of the washing machine. In fact, it is around 20 Hz, which corresponds to the speed of the tub (1,200 RPM). The faulty machine shows additional frequencies around 280 Hz and 560 Hz (figure 7, right). It can be easily demonstrated that these frequencies are related to the motor (the fundamental and the second order harmonic). It is known that the ratio between the RPM of the motor and washing machine RPM is 13.5. It therefore follows: RPM motor = 13.5 x 1,200 = 16,200, or 270 Hz.

Results

The software has been developed in the LabVIEW® programming language. Using the LDV, the MUSA system is able to detect the following defects:

- Unscrewed or damaged pulleys
- Unscrewed counterweight
- Defective belt (dirty, damaged or incorrectly positioned on the pulley)
- Defective bearings
- Defective/missing spring connecting the drum to the cabinet
- Drum unbalance
- Defective motor

The microphone mostly allows the operator to distinguish those defects that create noise but are not big enough to generate vibratory effects on the machine, such as a ground wire touching the pulley, missing material (e.g. a screw) inside the tub, etc.

Conclusion

The described solution shows how the developed data analysis system, composed of appropriate sensors, a data acquisition system and pattern recognition algorithms, can be successfully applied to mechanical defect diagnostics for washing machines in the production line. Particular features have been extracted in order to replace the subjectivity of human inspection testing with an objective assessment of product quality. In particular, laser Doppler vibrometers can be used to detect the vast majority of mechanical defects in washing machines.

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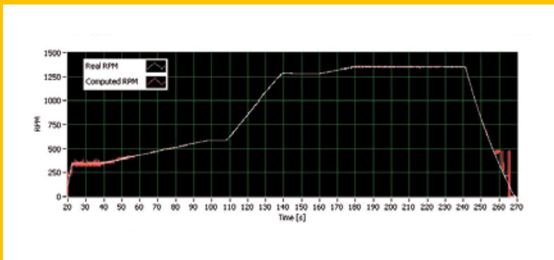
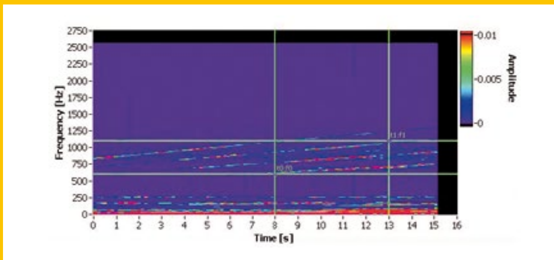
Source: Polytec InFocus

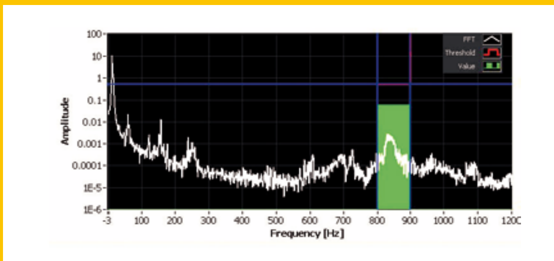
4
Washing machine RPM computed from the LDV



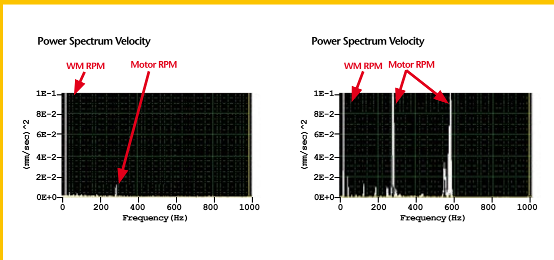
5
Velocity signal STFT of a good washing machine during run-up



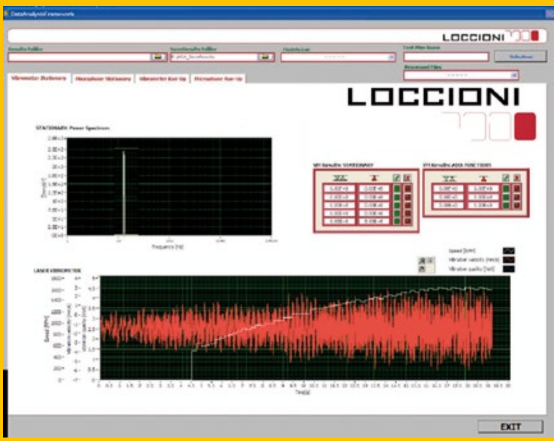
6
Velocity signal FFT for a good washing machine during steady state phase



7
Power spectrum of the velocity time signals for a good (left) and faulty (right) washing machine



8
Front panel of the vibration test system



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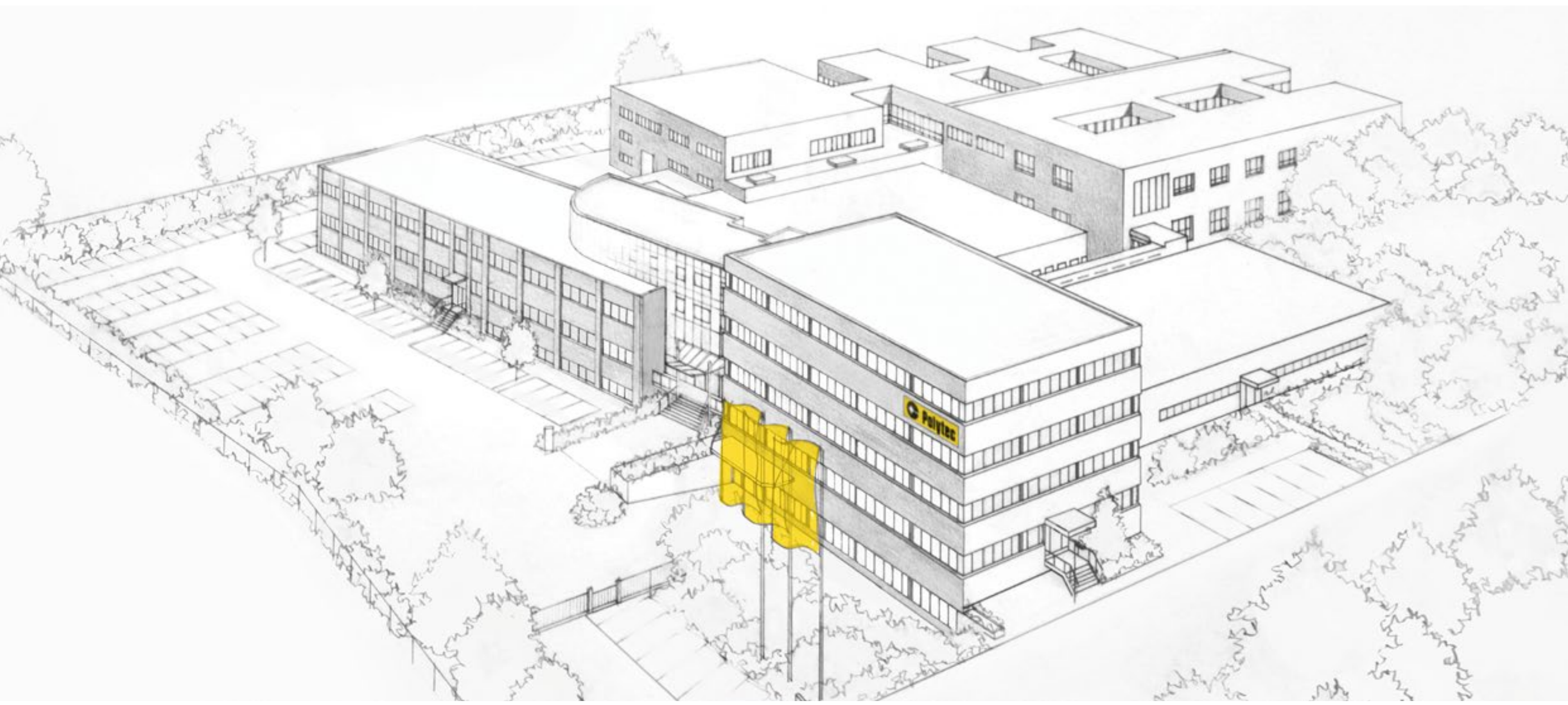

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