Slide 1

Diagnosis of a unit-wide disturbance caused by saturation in a manipulated variable

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APC 2004, Vancouver   April 26-28th 2004

Slide 2

Layout of the presentation

Unit-wide disturbances
  ➢ The challenges of the case study
Detection and diagnosis
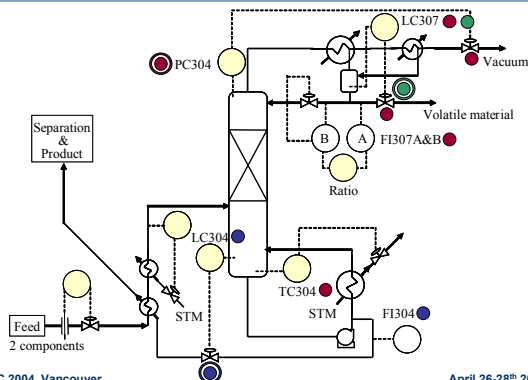 ➢ Process signal spectroscopy
  ➢ Oscillation analysis
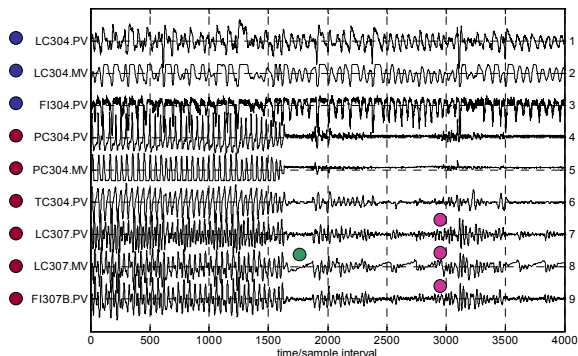 ➢ Wavelet analysis
  ➢ Saturation analysis
Conclusions

The case study in this talk is courtesy of Mitsui Chemical Company, Omuta, Japan

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Slide 3

Unit-wide disturbances

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Slide 4

Unit-wide disturbances

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Unit-wide disturbances

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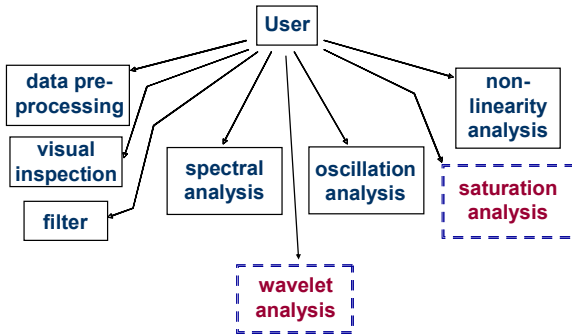

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Unit-wide disturbances

Challenges of the case study
  ➢ Characterize the disturbances
  ➢ Determine how widespread they are
  ➢ Find the causes
  ➢ Ultimately it all has to be automated

Approaches used
  ➢ Spectral and oscillation analysis
  ➢ Wavelet tools from Yamatake and Mitsui
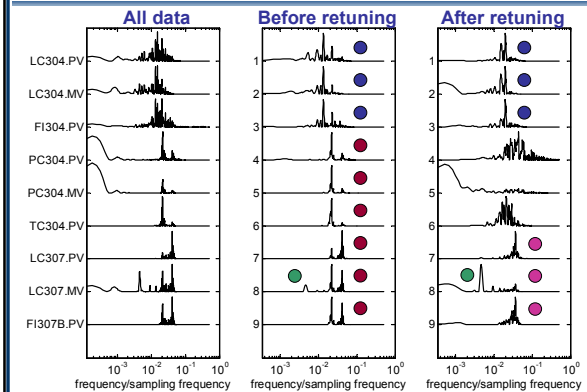 ➢ Non-linearity analysis (*not in the talk*)
  ➢ Saturation analysis

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Unit-wide disturbances

```
                    User
        ┌──────┬─────┼─────┬──────┐
data pre-                          non-
processing                         linearity
                                   analysis
visual        spectral   oscillation
inspection    analysis    analysis    saturation
                                       analysis
filter

              wavelet
              analysis
```

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Detection and diagnosis

Process signal spectroscopy

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Process signal spectroscopy

Spectral analysis

> Power spectrum is the squares of amplitudes of the discrete Fourier transform (DFT);
> The data set changed when pressure loop was retuned;
> The DFTs have to be done before and after retuning;
> A spectral peak at, say, 0.02 on the frequency axis is a sine wave with period of 1/0.02 = 50 samples per cycle.

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Process signal spectroscopy

All data   Before retuning   After retuning

LC304.PV
LC304.MV
FI304.PV
PC304.PV
PC304.MV
TC304.PV
LC307.PV
LC307.MV
FI307B.PV

10^{-3} 10^{-2} 10^{-1} 10^{0}
frequency/sampling frequency

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Detection and diagnosis

Oscillation analysis

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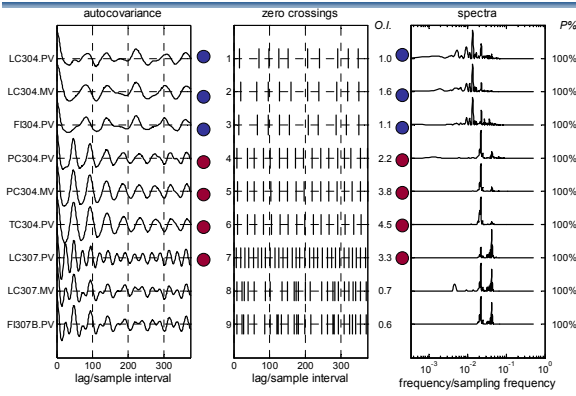

Oscillation analysis

Plant-wide oscillation detection

> Regular zero-crossings suggest an oscillation;
> Noisy time domain has spurious zero crossings;
> Use detection of zero crossings of autocovariance functions – autocovariance is much smoother:

$$ACF(\tau) = \frac{1}{N-(\tau+1)} \sum_{i=\tau+1}^{N} y(i) \times y(i-\tau)$$
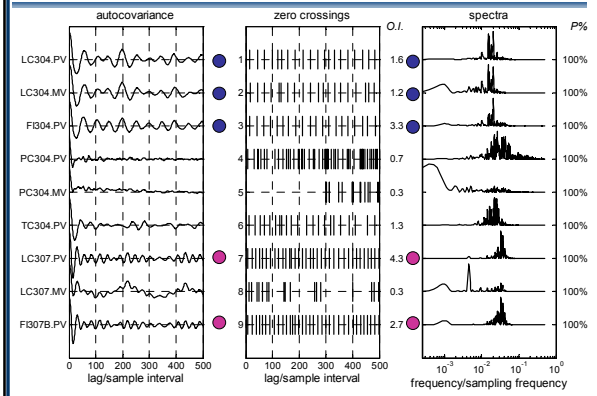
where y is mean – centered and scaled

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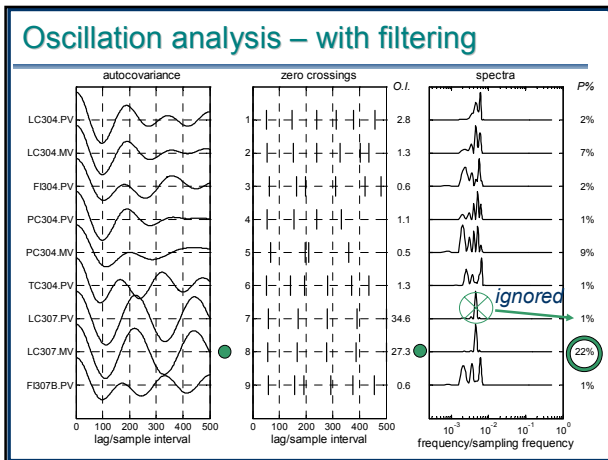

Oscillation analysis – before tuning

Oscillation analysis – after tuning

Oscillation analysis – with filtering

Summary so far

Pressure control loop was retuned at sample 1800

Before retuning
> There were two main groups, Tags 1-3 and 4-9

After retuning
> Tags 4-9 were different before and after retuning;
> Tags 1-3 looked not much different after retuning;
> After retuning, tags 7-9 were different from 4-6;
> Tag 8 had a new (?) oscillation after retuning

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Detection and diagnosis

Wavelet analysis

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Wavelet analysis

Wavelet analysis
> Has a high visual impact
> Shows the before and after cases together
> Quantifies the similarities

The wavelet transform
> Decompose $f(x)$ over localized basis functions with different resolutions
> Plot coefficients as colours on a 2-D position versus resolution grid

$$f(x) = a_0\phi(x) + a_1 W(x) + a_2 W(2x) + a_3 W(2x-1)$$
$$+ ... + a_{2^j + k} W(2^j x - k) + ...$$

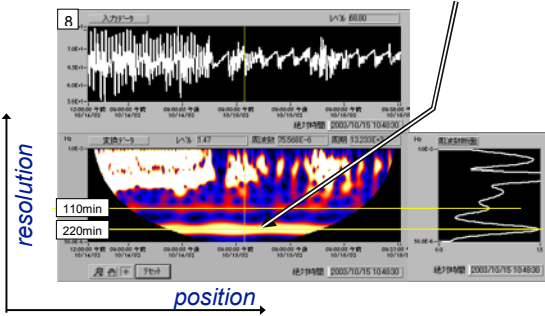**APC 2004, Vancouver**   **April 26-28th 2004**

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Wavelet analysis - example

Tag 8 with the "new" oscillation at 220 mins per cycle
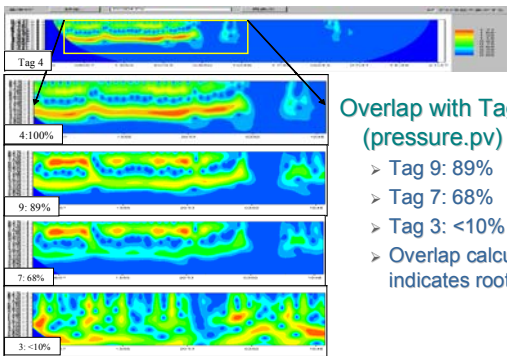- Wavelets show it is not new, it was there all the time

- resolution
- position
- 110min
- 220min

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Wavelet analysis

resolution

position

Slide 21
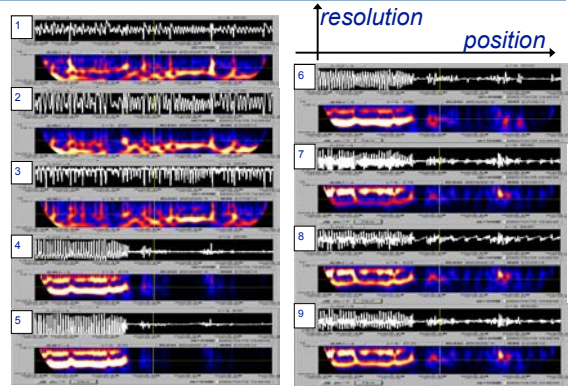
Wavelet analysis

Overlap with Tag 4 (pressure.pv)
- Tag 9: 89%
- Tag 7: 68%
- Tag 3: <10%
- Overlap calculation indicates root cause

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Detection and diagnosis

Saturation analysis

Slide 23
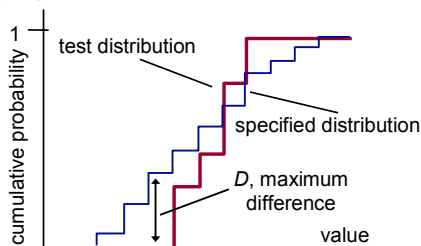
Saturation analysis

Based on Kolmogorov-Smirnov test
- Robust, non-parametric
- Tests is test data match a specified distribution
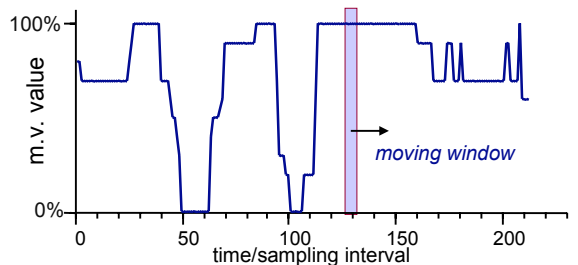- Sampling distribution of D is known

- cumulative probability
- test distribution
- specified distribution
- D, maximum difference
- value

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Saturation analysis

Test the distribution of values in a moving window
- If similar to **[100 100 100 100 100]** – fully open
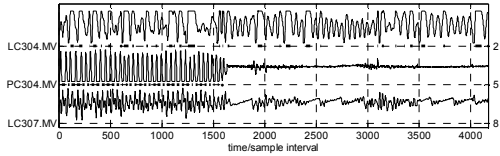- If similar to **[0 0 0 0 0]** – fully closed

- m.v. value
- moving window
- time/sampling interval

Saturation analysis

— *indicates saturation*

close-up, before retuning

before and after retuning

Saturation analysis
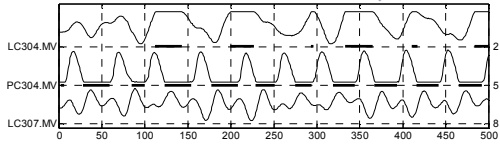
A new finding
  - A healthy valve caused oscillation
  - Oscillation + non-linearity ≠ faulty valve

Conclusions

Conclusions

  - A suite of data analysis tools was presented
  - They work on different aspects of data;
  - Wavelet analysis enhanced and reinforced the findings;
  - Saturation was automatically detected;
  - The case study was solved by the tools;
  - The root cause was a tuning problem driving a pressure loop into saturation.

Acknowledgements

  - Mitsui Chemicals and Yamatake Corporation;
  - Mr Takashi Shigemasa, Toshiba IT and Control System Corporation;
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END