Quebec quandary solved by Fourier transform

CASE HISTORY

By Michel Ruel and John Gerry

Power spectral density analysis software hits the spot at a paper mill.

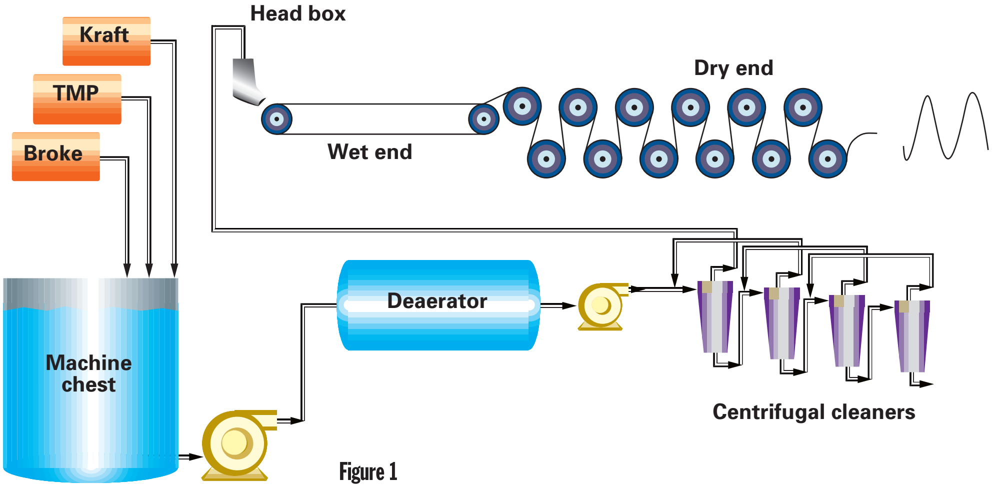

Figure 1

Process plants are reaping large benefits from the widely available analysis tool power spectral density analysis (PSDA). PSDA uses a mathematical technique, the Fourier transform, to analyze process controller signals. A Fourier analysis can determine the amplitude, frequency, phase, and a host of other functions for each sinusoidal component of a given waveform. Specifically, mysterious and hard-to-trace process cycling problems can be located and brought to specification more quickly and, thus, efficiently.

Stumped at hundreds of dollars per minute

The production from a newsprint paper machine in a Quebec, Canada, paper mill was out of specification and had to be rejected. The lost revenue and expense was pushing a million dollars per day. A 16-minute cycle in the basis weight, humidity, and dry weight was causing unacceptable product variability. The cycle did not seem to be present at the wet end of the paper machine. A graphic of the process is shown in Figure 1.

The paper machine receives pulp in three forms: kraft pulp, thermomechanical pulp (TMP), and broke pulp.

Terminology and definitions

CO	**controller output**
PSDA	**power spectral density analysis**
PV	**process variable**
TMP	**thermomechanical pulp**
basis weight	**the weight of a ream (500 sheets) of paper, reported in Canada as grams per square meter of paper**
dry weight	**the dry weight of the paper from the oven**
humidity	**the ratio of water weight in the paper to the total weight of the paper**
kraft pulp	**pulp derived from wood chips using heat and chemicals**
thermo-mechanical pulp	**pulp manufactured by grinding stripped logs into chips and exposing them to high-pressure steam**

The broke is obtained from rejected product that has been sent to a beater where it is mixed with water and reduced to pulp. All the paper machines in the mill are fed with the same kraft pulp and TMP. The broke pulp is different on each machine, and, in fact, each machine's broke pulp is derived from its own out-of-spec paper.

Thirty-six hours into the problem, it remained unsolved. In the face of this serious situation, the production superintendent created a special task force comprising the most experienced engineers and technicians in the mill. Even retired personnel with experience on this particular paper machine were brought in. Two topnotch papermakers from competitive mills were also hired in an exhaustive attempt to arrive at a quick solution. Manufacturers of the wires, felts, and dryers sent people to help the team.

Two weeks of traditional troubleshooting ensued unsuccessfully. During that time the following steps were taken: Every suspected loop was put in manual mode for one hour. Each pump, roll, bearing, and all mechanical parts were checked. The set points for all the critical loops were changed (one at a time). Operation changes and human factors were considered. Each of the three types of pulp was removed one at a time for one hour.

At this point, the task force decided it needed a brand-new perspective. Outside help with a novel, fresh tool was brought onboard.

What's your sine?

Data was collected from the process at a point before the paper machine using a data acquisition package and trending software. This data, displayed below in Figure 2, was taken from the machine chest. The process variable (PV) measured is the pulp level in the machine chest. The graphic for the PV closed-loop time response is the top graph and the bottom graph is the controller output (CO). The CO is the set point for the three pulp flow loops.

From the time response, it was hard to reach any conclusions. It appeared to be noisy process response data only.

Using this time data, software was used to perform a power spectral density calculation. A

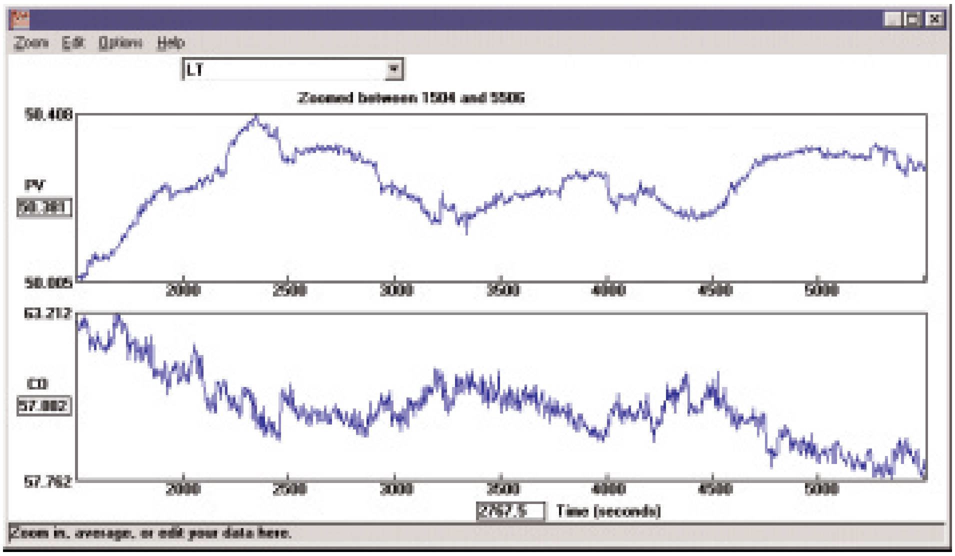

Figure 2. The closed-loop time response for the machine chest level control

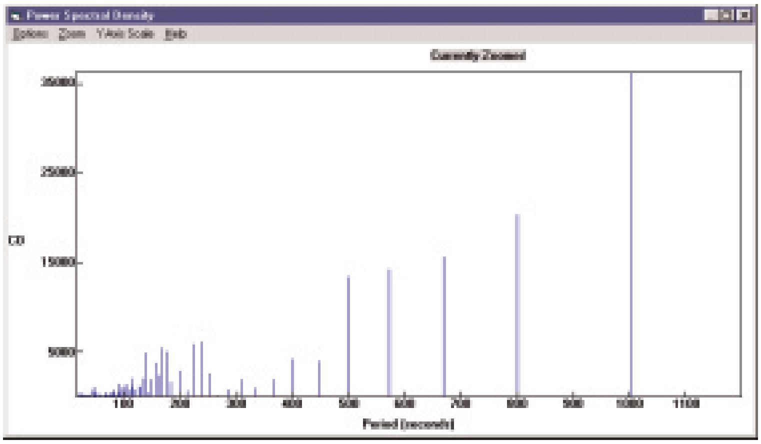

Figure 3. The power spectral density analysis of the controller output

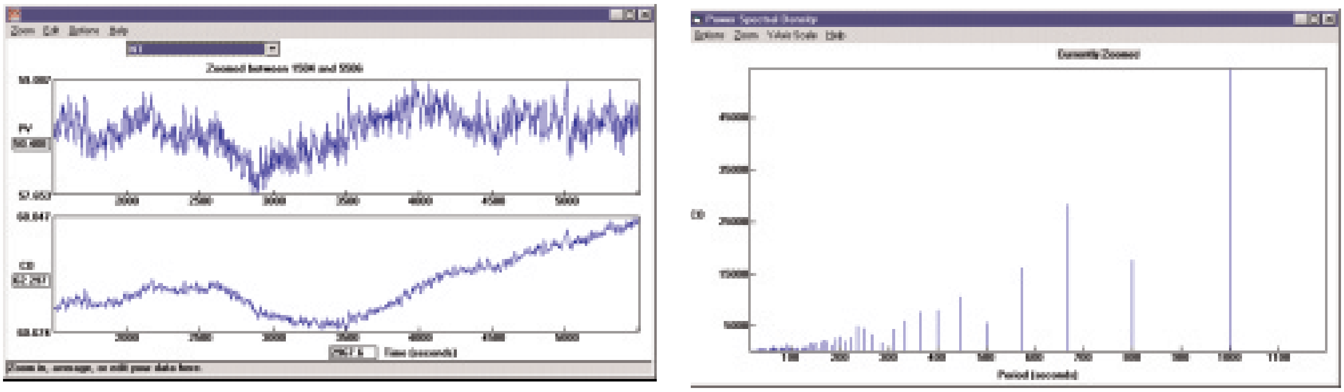

Figure 4. The pulp consistency controller data and the PSDA interpretation

power spectrum displays the frequency content of a signal. If the signal is a sine wave, only one frequency is present. If the signal is white noise, all frequencies are present.

The latter condition is the desired state for a successful and continuous process with no cycling. Using PSDA, each frequency component is found, and any dominant frequencies are highlighted. In the spectrum pictured in Figure 3, the horizontal axis is the period or inverse frequency (1/frequency).

Voila! C'est le probleme

In Figure 3, notice the large spike at 1,000 seconds (16.5 minutes). This corresponded exactly to the cycle seen in the rest of the mill.

As a check, data was collected from the pulp consistency loop at the output of the machine chest. The results are shown in Figure 4. The left graph shows the closed-loop time response of the consistency (PV) and the output of the consistency controller (CO). Again, it is difficult to reach any conclusions from this time response data. Running a power spectral density calculation on the CO, however, again shows a large spike at 1,000 seconds (see Figure 4, right).

These two power spectral density graphs clearly show a problem cycling at 16 minutes. From this, the engineers concluded that the cycling problem was located before the paper machine.

Homing in on the culprit

Since the mill had three other paper machines that did not have 16-minute cycle problems, it was decided to check the broke pulp circuit by temporarily shutting it off.

During the initial troubleshooting, the broke circuit was shut off, but only for 60 minutes. It had not been long enough. This sort of human error is often seen in such situations. Without advanced tools like PSDA, variability sources are difficult to spot over such a long period.

After two hours, the process cycling had disappeared. The source of the problem was found! Product was now within acceptable limits, and the only mystery remaining was the specific default within the broke circuit.

Guilty as charged

With the quandary now narrowly defined, clues from bygone days and experiences fell quickly into place. One member of the task force recalled that the problem roughly coincided with a faulty mixer in the broke chest. To temporarily compensate for the loss of a mixer, an old circulating pump was used to move the stock around in the tank with pumping action.

The pump had been designed to pump low-consistency stock. But the recycled stock was high consistency. As the pump circulated the pulp, the consistency became thicker in the area of the pump intake, and the flow was gradually reduced to almost nothing. At the same time and at the opposite end of the chest, the pulp was becoming diluted and more able to flow. As the thick pulp mixed with the thin, the circulating pump gradually was able to pump more. The overall effect was a 16-minute pumping and not-pumping cycle.

To confirm this scenario, the circulating pump was stopped, and the broke pulp was again introduced at the paper machine. No cycling was present in the system. Later, the pump was restarted. The cycling reappeared.

Technique has other applications

Process loops have a significant impact on final product variability not only in paper mills but in other industries.

Advanced tools like PSDA can quickly identify the source of cycle problems. The techniques are powerful and easy to implement. By knowing the cycle's period, problems relating to vibration, loop tuning, loop interaction, and the mechanics are readily solved. **IT**

Caught in the Web

For online information relating to paper production and the pulp and paper industry, connect to these two Web sites: www.aifq.qc.ca/english/industry/fabric.html and www.tappi.org/.

Behind the byline

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