Brüel & Kjær Vibro

Application Note

Case study – High technology and effective maintenance ensures high productivity

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Figure 1. The "TU" diesel engine.

Française de Mécanique has always been one step ahead of the competition, and has numerous awards to show for it. But it was no less of a challenge for two of Française de Mécanique's technicians to learn condition monitoring diagnostics, invest in an off-line monitoring system, and then turn it into a profit, all within the first year.

Française de Mécanique of France (FM) manufactures both diesel and gasoline engines, ranging in size from small, economical 954cm3 engines to 3 l 250 hp fuel-injected, turbo-charged workhorses. They have made over 17 million engines over a period of 23 years for cars such as Rover, Lada Diesel, Peugeot, Citroën and Renault. Cars with their engines have won the Formula 3 and the Paris-Dakar and been car-of-the-year.

The FM factory was founded in 1969 in the Nord/Pas-de-Calais area, as a joint venture between Peugeot and Renault to combine their talents and resources to develop and manufacture automobile engines. Since that time, it has grown to over 4700 employees and produces 4000 to 5000 engines a day. With a turnover of $1.5 billion, this makes FM one of the top 100 French companies.

The automobile industry has to be extremely reactive to product demands to remain competitive. Once an order is received, FM can manufacture and deliver engines and parts within 3 to 4 days. A flexible manufacturing process, using specialized machines and automation, is essential to achieve this kind of production.
Figure 3 shows the Saturne (Renault Automation) system, for example, which takes only 5 seconds to change tools for working on different parts. Moreover, this machine has a multi-spindle head, so it can perform one or more machining operations on the same part.

Figure 2. Française de Mécanique.

Automation was also adopted because it allows a wide variety of different engines to be manufactured, in any sequence, and at a moment's notice, by making a simple program change. It also improves product quality, working conditions and safety, as well as productivity. In fact, the Peugeot "TU" engine assembly is one of the worlds most fully automated processes; 65 to 70% on average, and up to 94% for cylinder head manufacture.

Maintaining a sophisticated plant such as FM is a demanding job. To deal with this task, each production department (i.e. the foundry and the individual engine manufacturing/assembly lines) has its own maintenance service which includes; a maintenance section, which supervises the entire department, and several task

groups, which are dedicated to different production units. The task groups consist of trouble shooting teams and a predictive maintenance unit under which the condition monitoring technicians work. This maintenance organisation, they feel, best suits their needs; partly because it is flexible enough to allow them to continuously refine the maintenance activities to achieve optimal performance.

All the maintenance departments use what is called the STIMI system (Système de Traitement de l'Information pour la Maintenance des Installations) for optimising maintenance. The database contains information on all machines and parts, spare parts

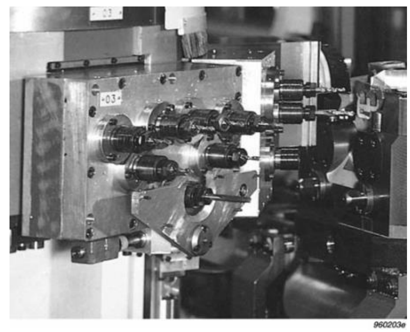


Figure 3. The Saturne system.

available, historical information on every problem experienced by each of the machines, and the solutions that were adopted. The system also keeps a record of the personnel and material costs of repairs, as well as the cost of implementing predictive maintenance programmes.

All the engine manufacturing facilities and the foundry have their own condition monitoring sections. Monitoring in the North and South “TU” engine building sis being done by two experienced maintenance technicians who took courses so they can manage the monitoring system themselves, including diagnosis.

The monitoring purpose for their section is:

- To extend the time between overhauls for bearings and gears
- To ensure precision machining is not affected by vibrations
- To trouble-shoot and diagnose specific machine problems

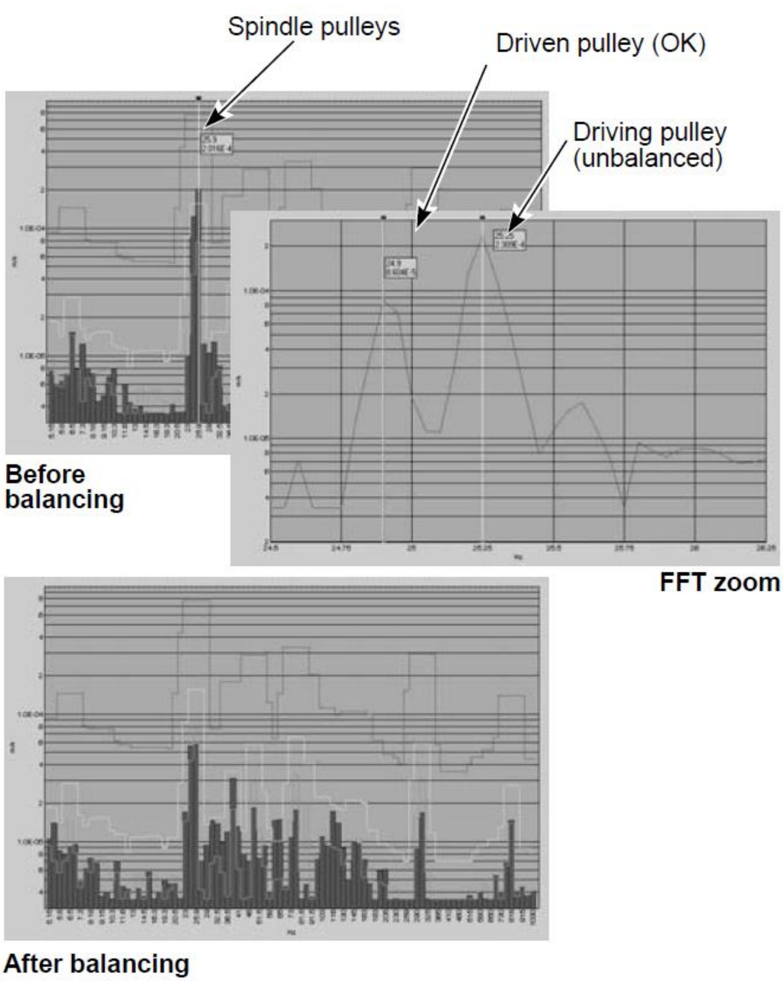


Figure 4. CPB and zoom spectrum of the cam grinder.

Monitoring in the "TU" engine department is basically limited to the machining area only, and focuses on the bearings and gears for a wide variety of machines, including CNC machines (e.g. the Saturne system), conveyors, parts washing machines, ovens, lathes, milling machines, etc. Bearing faults are a crucial machine element to monitor because of the quality control aspect of the work. A cam shaft, for example, has to be machined within a 1.5 micron tolerance, so even the smallest bearing defect could generate enough vibration to upset the machining process, and result in the part being scrapped.

Because it was not practical to monitor the machines continuously under infinitely varying loads, it was obvious that an off-line monitoring system was better suited to the task. The Brüel & Kjær Vibro off-line monitoring system fulfilled the requirements for the job, so all the engine manufacturing facilities and the foundry (with the exception of the J engine group) are now using the system.
Although the machines that are monitored are complicated, a very simple monitoring strategy is used.

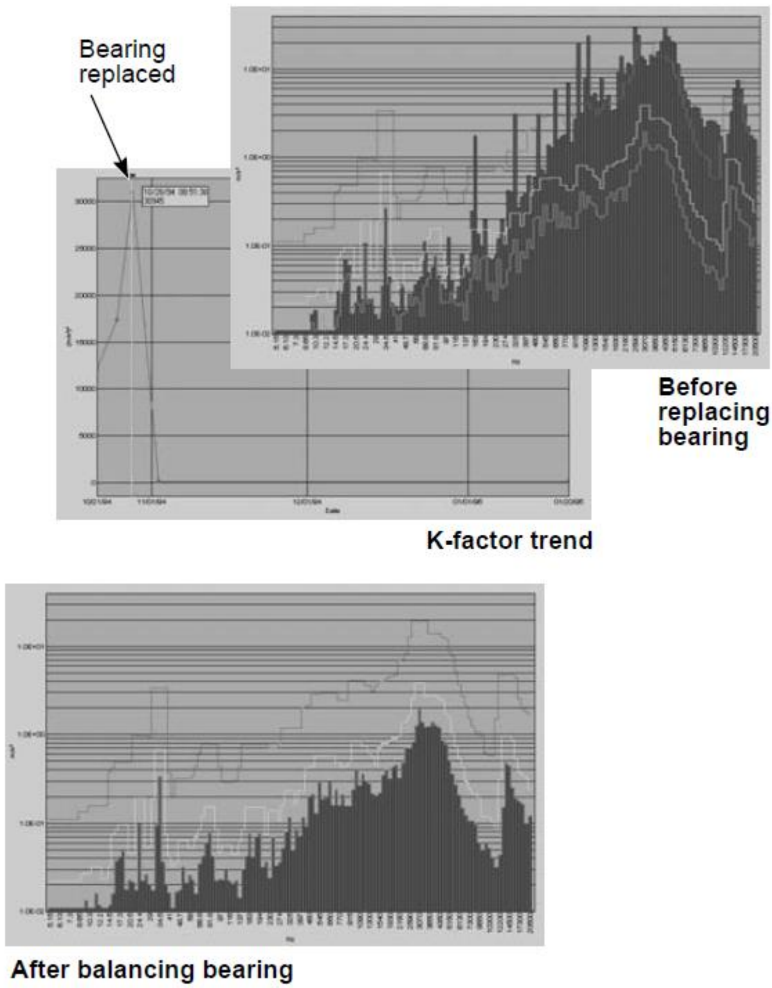
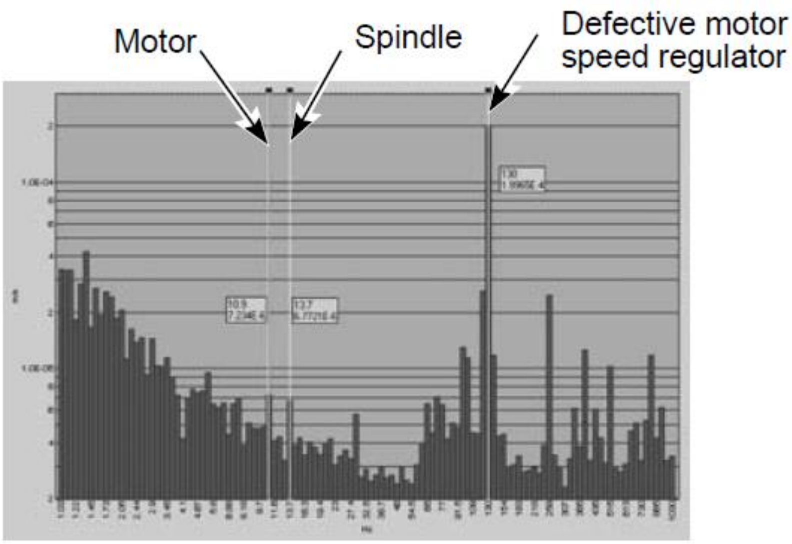
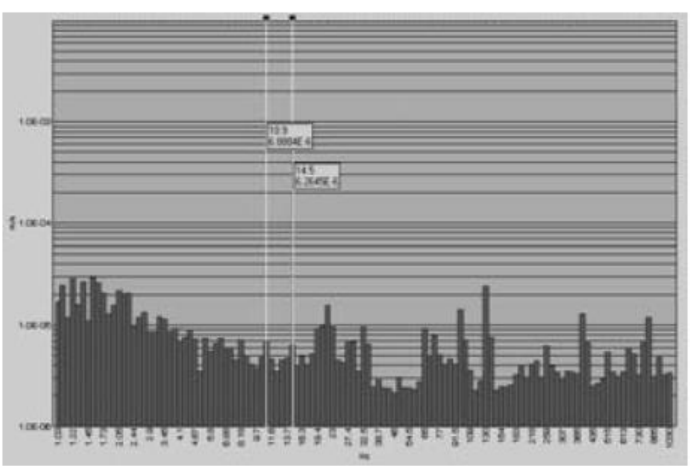


Figure 5. CPB and K-factor trend plots of parts-drying machine.

Firstly, the number of measurement points per machine are minimised. For example, a single measurement point is used on a multi-spindle head since all the important bearing frequencies are easily distinguishable here for setting alarms and performing diagnostics. Secondly, only simple measurements are used where possible. A narrow-band Constant Percentage Bandwidth (CPB) measurement is extensively used to monitor the general machine condition, and the K-factor measurement (RMS of a bandpass multiplied by the peak) is a simple, yet effective, way of detecting and following rolling-element bearing faults since it amplifies even the smallest of changes. To make life even simpler, as mentioned before, monitoring is only done on idle machines (i.e. while they are not cutting parts, which is a seldom occurrence!) Altogether, there are around 1000 measurement points covered at intervals between 1 and 3 months.



Before replacing speed regulator



After replacing speed regulator

Figure 6. CPB plots of cam grinder.

Looking at the Data Collector used in the North "TU" building, there was a cost-saving in bearings alone of almost $21000 over a period of a year. This saving was caused by avoiding unnecessary machine overhauls (in the past, many machines were overhauled three or more times a year). This figure does not even include labour savings, or lost production savings due to downtime, etc., but it is still enough for the system to effectively pay itself off within the first year.

Projected material savings for the same Data Collector next year are expected to top $45300. The Data Collector used in the South "TU" building detected a vibration fault that, as is described in the case story below, saved $21122 within the first nine months of use. The potential savings for the entire company can be even more impressive if you consider the results obtained with the other five Data Collectors.

The two technicians have detected and diagnosed several faults over the year or so since they have been using the monitoring system, some of which are described below:

Using CPB, an imbalance condition was detected while monitoring two identically sized pulleys that were running at the same speed. But it was difficult to say for sure if the fault lay with one or other of the pulleys, or if the fault lay with both. Using a little deduction, it was assumed the driving pulley would be more worn since the belt momentarily slips at each start-up. This gives a slightly smaller diameter, and thus a faster speed. Using the Data Collectors measurement zoom function, it was possible to isolate the two pulley speed frequencies on a plot and see which one was higher. As seen in Figure 4, the driving pulley was out of balance.

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In Figure 5, a K-factor trend plot shows the gradual deterioration of a bearing up to the time when it was changed, and then the amplitude drop with the new bearing in place. The CPB plots shown indicate the same problem before replacement (increase in upper frequencies) and after (reduction in upper frequencies). The sudden appearance of vibrations in the milling machine prevented the cam shafts from being machined to within tolerance. Looking at the high-resolution CPB plot (see Figure 6), a 130 Hz peak was present that did not correspond to any of the components that there was data on (i.e. spindle, drive belts and motor). Using the process of elimination, it was determined that the source of vibration was the motor's speed regulator. This was immediately replaced, and the problem disappeared without undue production downtime. This saved $21122 since it was not necessary to dismantle the machine for suspected repair.

One of the multi-spindle machines exhibited increased 2nd and 4th harmonics that led the technicians to believe there was mechanical looseness (see Figure 7). Taking apart the spindle head, a loose bolt was discovered. This was re-tightened, the spindle head reassembled, and new measurements taken.
But the 2nd harmonic was still high. It was hard to believe there a problem with the measurement, so the spindle head was opened again and it was discovered that a bearing was also loose. After this was corrected, the problem disappeared.

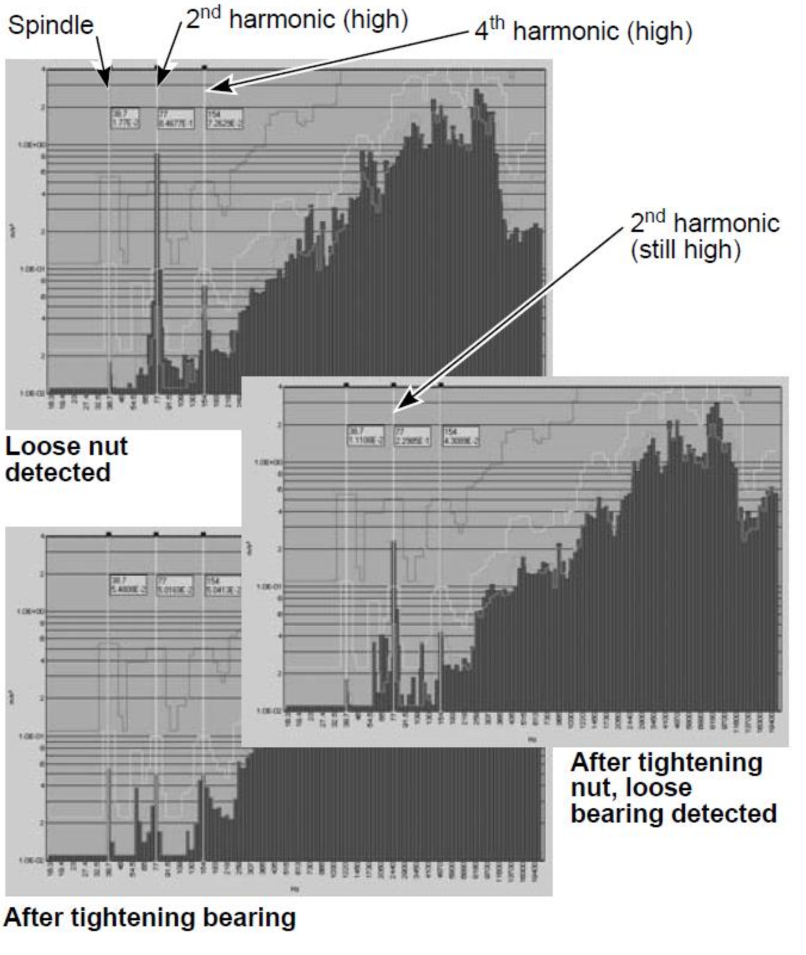

Figure 7. CPB plots showing mechanical looseness on multi-spindle lathe.

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Even though a simple monitoring strategy is used with the off-line system, it has proved to be very effective for the application. This, coupled with the ease-of-use and versatility of the off-line system, allowed the system to pay itself off within the first year of use. FM is satisfied with the fault detection and diagnostic capability of the system and plan on extending the monitoring they do next year.

After presenting the initial results of the off-line monitoring system to Renault and Peugeot, the technicians were asked by management in the FM maintenance unit to set up training courses for other Data Collector users.

Brüel & Kjær Vibro GmbH
Leydheckerstrasse 10
64293 Darmstadt
Germany
Phone: +49 6151 428 0
Fax: +49 6151 428 1000
info@bkvibro.com
www.bkvibro.com

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