Brüel & Kjær Vibro

Application Note

Positive monitoring results achieved with new CM system

Alcoa World Alumina Australia is the world's largest producer of alumina, and one of the country's largest overall exporters, currently earning Australia more than $2 billion per year. Alcoa operates two bauxite mines and three alumina refineries in Western Australia (WA), with a combined rated annual capacity of 7.3 million tonnes of alumina. This accounts for around 18% of the western world's demand. In addition to their mining activities, Alcoa has also achieved international recognition for its record in land care and environmental management.

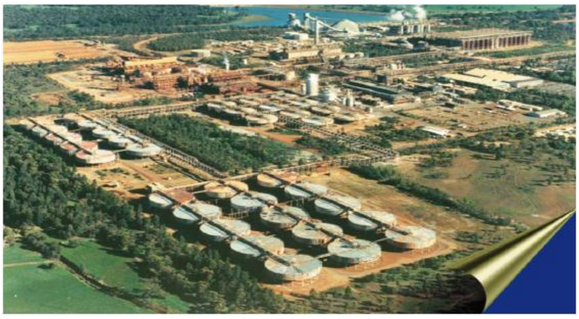


Figure 1. Alcoa World Alumina Australia's Pinjarra alumina refinery.

The Pinjarra alumina refinery, located 90km south of Perth, is Alcoa's biggest refinery worldwide. Pinjarra was the second of Alcoa's refineries in Western Australia, and began operations in 1972 at an initial annual production rate of 210,000 tonnes. This grew over the years to the more than 3.2 million tonnes now produced each year. The Pinjarra plant has been retrofitted for a new, patented process for alumina refining that resulted in a 165,000 tonne per year capacity expansion. This expansion project is one of several that the company has implemented to meet the increasing demand for alumina products; the market for aluminium alone has increased 17.6% since 1997.

Maintenance and monitoring strategy

The primary maintenance strategy at Pinjarra has been to decrease maintenance costs by increasing time between outages and minimising their impact upon plant production. For many years a basic monitoring system had been operating with varying degrees of success, but system problems identified the need to implement an effective machine diagnosis monitoring system to supplement the safety monitoring system already installed, and to help better manage critical machine assets at the powerhouse.

The Pinjarra powerhouse, located at the refinery site, was targeted as the first area to implement the diagnostic monitoring system. The operational expectations were such that the impact of an equipment failure within the powerhouse had a major impact upon the refinery's ability to sustain production.

The important requirements for the new diagnostic monitoring system were an on-line safety and diagnostic monitoring capabilities and an off-line monitoring capability. The system had to be modular in design, flexible to allow for expansion, yet easy to use. It had to be open to accept data from a wide range of field transducers as well as from other systems, such as the process DCS (distributed control system). The system should effectively monitor, store, analyse and trend the following types of data: vibration, operational process values, performance and oil analysis data.

Alcoa's strict procedure for vendor selection criteria was used for evaluating a wide range of systems and from these the Compass system was selected. The Compass system installed is schematically illustrated in Figure 2.

Condition monitoring team

The monitoring group responsible for implementing and running the system included the powerhouse mechanical maintenance fitter Frank Brunner, mechanical engineer John Butler, electrical engineer Dick Turner, operations crew Gabe Feenstra and powerhouse supervisor Cliff Merwood.

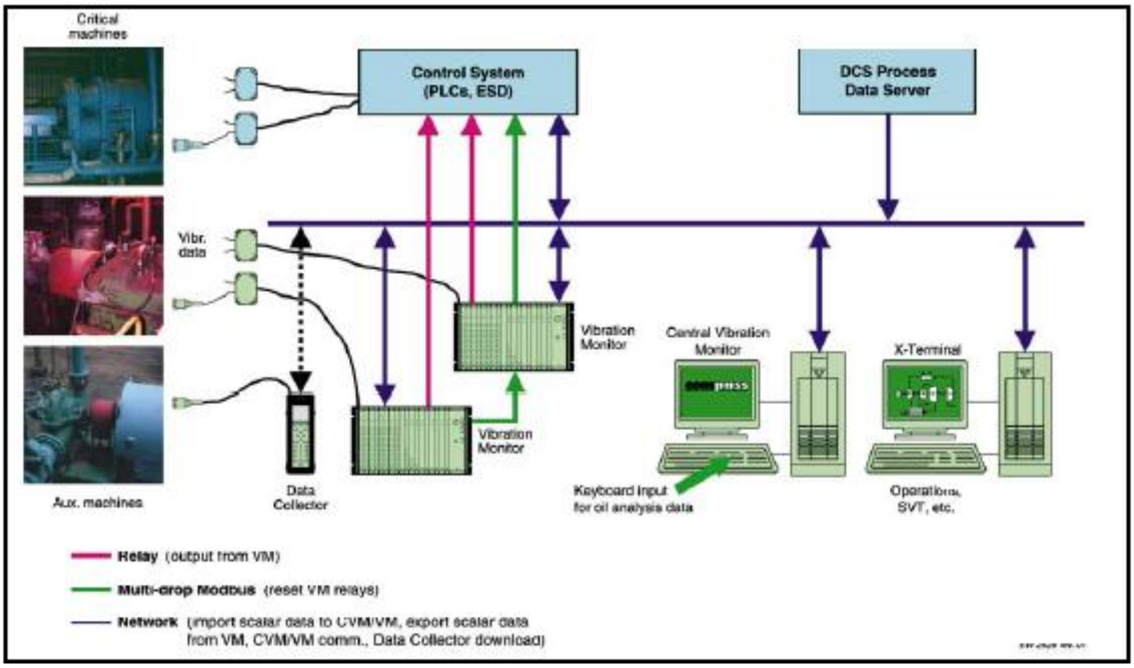


Figure 2. The Compass monitoring system configuration, where the upper components represent the DCS and the lower components the Compass system.

Because most of these people had little experience in diagnostic monitoring systems and techniques, Graham Forrester, from consultant company SVT-Engineering Consultants, was brought in to oversee installing and configuring the system. His brief also included training personnel in using the monitoring system and developing in-house expertise. Training was in fact crucial, and covered all aspects of setting up, operating and managing the system, as well as basic machinery and advanced analysis techniques. SVT continues to provide an on-going, on-site and remote diagnostic monitoring expertise when needed.

Machines monitored

The Pinjarra powerhouse has three 20 MW steam turbine generator sets and one 35 MW steam turbine generator set, with six boilers that are fired on gas from the North West Shelf. Refinery conditions dictate the load on these units but, with connection to the Western Power (utility) grid system, the site is able to import as well as export power as required, within the limitations of Alcoa's agreement. The powerhouse also contains all normal auxiliary equipment in a power plant, *viz.* compressed air, condensate, cooling water and boiler-feed water systems.

An overview of the monitoring strategy for the machines monitored in the powerhouse is shown in Table 1. Most of the process measurements are imported on-line measurements from the DCS.

Qty.	Machine group		Vibr.	Process	Oil analy.	Perf. Mon.	Strategy
4	Turbo-generators	Steam-turbine	X	X	X	X	M, C (1xD)
		Generator	X	X	X	X	M,C
5	Boiler-feed pumps	Motor (2)	X	X	X	X	M, C (1xD)
		Steam-turbine	X	X	X	X	M,C
		Pump	X	X	X	X	M, C (1xD)
6	Forced-draft fans	Motor-driven	X		X		D
3	Induced-draft fans	Motor-driven	X		X		D
4	Compressors	Motor-driven	X		X		D
4	Cooling-tower fans	Motor-driven	X		X		D
9	Pumps	Motor-driven	X		X		D

Table 1. Overview of monitoring strategy for the Pinjarra powerhouse machine groups

D = Data-collector (predictive, off-line monitoring)
M = Multiplexed on-line channels (predictive monitoring)
C = Continuous on-line channels (protective monitoring)

Vibration monitoring

In general, the vibration monitoring carried out is similar across the range of different machines:

- X/Y relative shaft displacement at bearings.
- Vibration at bearings.
- Differential expansion of casing.
- Axial thrust on turbine bearing no.1.
- Accelerometer measurement of absolute vibration of casing.

Oil analysis results

Data from the oil analysis system is received from Alcoa’s own testing laboratory and is imported into the Compass database using FTP (file transfer protocol). This data is then trended along with vibration levels to provide a more accurate assessment of the machines’ condition.

Process and performance monitoring

The Compass performance monitoring software has been installed using the thermodynamic expertise provided by KEMA, Brüel & Kjær, Vibro’s performance monitoring consultant in this project and others.

	Generator	Boiler-feed pump	Turbine
Imported process data	Current Voltage Megawatts Megavars Power factor Stator air out temp. Stator H_2O Stator air in temp. Stator temp. (3x) Exciter current Exciter voltage Cooling water in Cooling water out	Flow Discharge press. Suction press.	Hydraulic oil press. Governor oil press. Actuator position Turbine speed Steam inlet flow Steam inlet temp. Steam inlet press. Steam 1st stage press. Steam 1st stage temp. Steam flow Steam outlet press. Steam outlet temp.
Calculated performance parameters	Efficiency factor Steam tonnage/MW	Efficiency factor	Inlet enthalpy 1st stage enthalpy Outlet enthalpy Turbine power Overall efficiency

Table 2. Performance monitoring of machines at the Pinjarra powerhouse

Although no case stories have been published, it is widely agreed that the system has played an important role for the maintenance and monitoring group to learn more ‘intimately’ about the machine’s performance and condition from both an operation and maintenance point of view. Important information can be gathered on the dynamic condition of a pump’s impeller or a steam turbine’s blades for the given operating conditions, and this can then be correlated directly with vibration data to allow specific faults to be diagnosed earlier and more reliably. Although the performance monitoring capability provided by Compass is comprehensive enough for operational purposes, it is still only used for predictive maintenance purposes, and is in no way intended to replace the safety or control capability which comes with the machines’ own protection systems.

The performance-monitoring portion of Compass was easy to implement since there were no extra sensors or monitoring system hardware required to be installed. All the process data needed for the thermodynamic calculations done in Compass is automatically imported from the DCS via FTP using DTF files (data transfer files).

Expert diagnosis

The expert diagnostic programme Advisor simplifies the monitoring job by allowing one to focus on specific problems. Although for the time being, Advisor is only using vibration data in its diagnoses at Alcoa, it has proven itself in the detection of many machine faults that include rotor instability, rolling element bearing damage, lubrication faults, rotor unbalance and coupling misalignment. Advisor has also proven to be a useful training aid (see Figure 4 for an example).

Conclusions, and plans for the future

All of the powerhouse rotating and reciprocating equipment is now 100% condition monitored, i.e. maintenance is planned according to monitoring results.

Some of the increased time intervals between major overhauls are listed below:

- Steam turbines – was 7 years, now 8 years.
- Compressors – was 6 months for minor overhauls, now 5 years for a single major overall.
- Forced draft fans – was annually; now 4 years

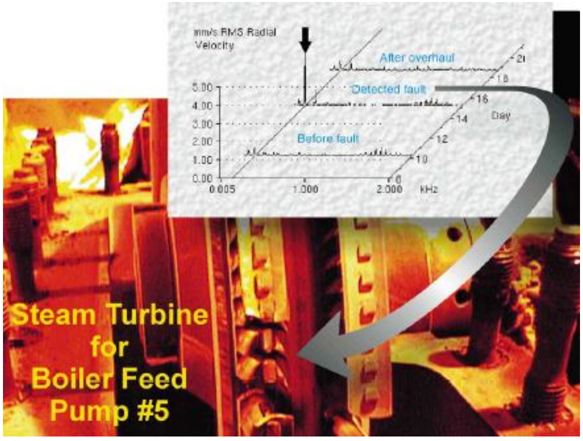
- Induced draft fans – was annual; now 4 years
- Cooling tower fans – was 2 years, now 100% CM based
- Boiler feed pumps – was annually; now 100% CM based

After one year of operation, numerous faults have been detected and maintenance action taken to avoid catastrophic failures. A list of some of the more specific faults (not including lubrication faults) is given in Table 3.

Machine	Fault	Est. maintenance saving
Boiler-feed pump #5	Damaged turbine rotor	$ 450,000 (cost for rotor replacement)
Turbine #2	Excessive radial clearance of bearing #5 (exciter bearing)	
Forced-draft fan #4	Excessive radial clearance between bearing outer race and bearing cap	$ 5,000 (due to planning change out)
Air compressor #4	Damaged 1st stage impeller rotor	$ 40,000 (cost for replacement rotor – and avoiding casing damage)
Cooling-water pump #2	Damaged bearing outer race	$ 5,000 (due to planning change out)

Table 3: Partial list of faults detected and savings made.

Figures 3 and 4 show graphically the fault which occurred in the boiler feed pump train No. 5.



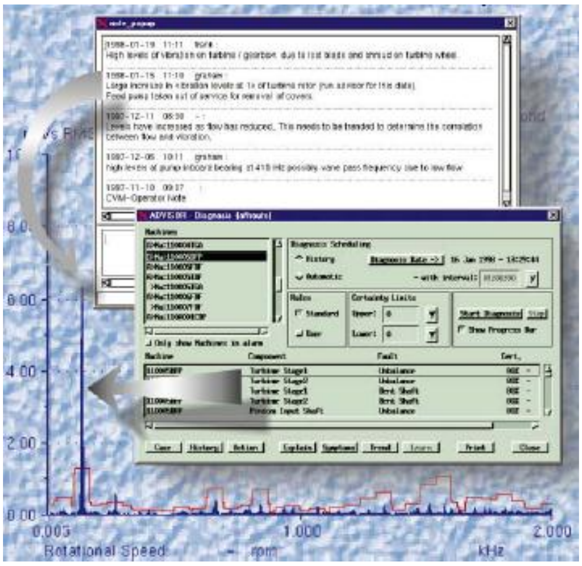


Fig. 3: 1st stage steam-turbine rotor fault at boiler-feed pump #5

Plans were made to expand the on-line system to include all turbines and boiler feed pumps. Since then experience has been gained with the performance monitoring capability and oil analysis results which were implemented, and the concept of the integrated monitoring solution promises further success in the future.

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