Need for Vibration Monitoring

Agriculture productivity is dependent upon various factors like soil properties, climate conditions, irrigation facilities, seed quality and variety, cropping pattern, techniques of farming, prevention from pests etc, but more importantly usage of optimum primary, secondary and micro nutrients. Fertilisers play an important role in making the country self reliant in food grain production. The has been consistently pursuing policies conducive to increased availability and consumption of fertilisers at affordable prices. It is for this reason that the annual consumption of fertilisers, in nutrient terms (N, P & K), has increased. Maintenance and instrumentation engineers at fertiliser plants face several challenges to ensure high uptime. Monitoring the running condition of rotating plant machinery is necessary as it gives indication of failures that could develop. The use of condition monitoring allows maintenance to be scheduled, or other actions to be taken to avoid the consequences of failure, even before the failure occurs. Predictive maintenance does not predict failure. Machines with defects are more at risk of failure than defect-free machines. Once a defect has been identified, the failure process has already commenced and Condition Monitoring Systems can only measure the deterioration of the condition. Intervention in the early stages of deterioration is usually more cost effective than allowing the machinery to fail. So there is a need to monitor machines like compressors, pumps, etc for preventing the downtime of machinery.
Causes for Vibrations

Vibrations can be due to several reasons such as:
- Unbalance and misalignment of rotor shaft
- Bearing problems, gear inaccuracy, partial rub
- Fluid coupling problems
- Oil whirl and other dynamic instabilities
- Rotor Crack
- Cavitation
- Surging

These problems can gradually become very severe and result in unplanned shut downs. To avoid these, plants have a Time Based Maintenance (TBM) or preventive maintenance system. One can extend the life of machines by monitoring these online in a cost effective way. Vibration monitoring and analysis is the easiest way to keep machines healthy and efficient in the long run and increase the overall efficiency of the plant. It reduces the overall operating cost as well as down time. Vibration sensors are used to predict faults in a running machine without dismantling it and give a clear indication of the severity by showing the amplitude of vibration.

Key Areas in Fertiliser Industry

<table>
<thead>
<tr>
<th>Urea plant</th>
<th>Ammonia plant</th>
<th>CO₂ plant</th>
<th>Utility and off-site</th>
<th>Power plant</th>
</tr>
</thead>
</table>

Ammonia Production Process

Ammonia is produced by the Haber process, in which nitrogen and hydrogen react in the presence of an iron catalyst to form ammonia. The hydrogen is formed by the reaction of natural gas and steam at high temperatures and the nitrogen is supplied from air. Other gases (such as water and carbon dioxide) are removed from the gas stream and the nitrogen and hydrogen passed over an iron catalyst at high temperature and pressure to form the ammonia.

**Step 1: Hydrogen Production**

Hydrogen is produced by the reaction of methane with water. However, before this can be carried out, all sulfurous compounds must be removed from the natural gas to prevent catalyst poisoning. These are removed by heating the gas to 400°C and reacting it with zinc oxide.

Following this, the gas is sent to the primary reformer for steam reforming, where superheated steam is fed into the reformer with methane. The gas mixture is heated with natural gas and purge gas to 770°C in the presence of a nickel catalyst. At this temperature the following equilibrium reactions are driven to the right, converting the methane to hydrogen, carbon dioxide and small quantities of carbon monoxide. This gaseous mixture is known as synthesis gas.

**Step 2: Nitrogen Addition**

The synthesis gas is cooled slightly to 735°C. It then flows to the secondary reformer where it is mixed with a calculated amount of air. The highly exothermic reaction between oxygen and methane produces more hydrogen.

In addition, the necessary nitrogen is added in the secondary reformer.

As the catalyst that is used to form the ammonia is pure iron, water, carbon dioxide and CO must be removed from the gas stream to prevent oxidation of the iron. This is carried out in the next three steps.
Step 3: Removal of Carbon Monoxide

Here the carbon monoxide is converted to carbon dioxide (which is used later in the synthesis of urea) in a reaction known as the water gas shift reaction. This is achieved in two steps. Firstly, the gas stream is passed over a Cr/Fe$_3$O$_4$ catalyst at 360°C and then over a Cu/ZnO/Cr catalyst at 210°C. The same reaction occurs in both steps, but using the two steps maximises conversion.

Step 4: Water Removal

The gas mixture is further cooled to 40°C, at which temperature the water condenses out and is removed.

Step 5: Removal of Carbon Oxides

The gases are then pumped up through a counter-current of UCARSOL solution. Carbon dioxide is highly soluble in UCARSOL, and more than 99.9% of the CO$_2$ in the mixture dissolves in it. The remaining CO$_2$ (as well as any CO that was not converted to CO$_2$ in Step 3) is converted to methane (methanation) using a Ni/Al$_2$O$_3$ catalyst at 325°C. The water which is produced in these reactions is removed by condensation at 40°C as above. The carbon dioxide is stripped from the UCARSOL and used in urea manufacture. The UCARSOL is cooled and reused for carbon dioxide removal.

Step 6: Synthesis of Ammonia

The gas mixture is now cooled, compressed and fed into the ammonia synthesis loop. A mixture of ammonia and unreacted gases which have already been around the loop are mixed with the incoming gas stream and cooled to 5°C. The ammonia present is removed and the unreacted gases heated to 400°C at a pressure of 330 bar and passed over an iron catalyst. Under these conditions 26% of the hydrogen and nitrogen are converted to ammonia. The outlet gas from the ammonia converter is cooled from 220°C to 30°C. This cooling process condenses more than half the ammonia, which is then separated out. The remaining gas is mixed with more cooled, compressed incoming gas.

The ammonia is rapidly decompressed to 24 bar. At this pressure, impurities such as methane and hydrogen become gases. The gas mixture above the liquid ammonia (which also contains significant levels of ammonia) is removed and sent to the ammonia recovery unit. This is an absorber-stripper system using water as solvent. The remaining gas (purge gas) is used as fuel for the heating of the primary reformer. The pure ammonia remaining is mixed with the pure ammonia from the initial condensation above and is ready for use in urea production, for storage or for direct sale.
The urea manufacturing process is designed to maximise these reactions while inhibiting biuret formation. This reaction is undesirable, not only because it lowers the yield of urea, but because biuret burns the leaves of plants. This means that urea which contains high levels of biuret is unsuitable for use as a fertiliser.

**Step 1 : Synthesis**

A mixture of compressed $\text{CO}_2$ and ammonia at 240 bar is reacted to form ammonium carbamate. This is an exothermic reaction, and heat is recovered by a boiler which produces steam. The first reactor achieves 78% conversion of the carbon dioxide to urea and the liquid is then purified. The second reactor receives the gas from the first reactor and recycle solution from the decomposition and concentration sections. Conversion of carbon dioxide to urea is approximately 60% at a pressure of 50 bar. The solution is then purified in the same process as was used for the liquid from the first reactor.

**Step 2 : Purification**

The major impurities in the mixture at this stage are water from the urea production reaction and unconsumed reactants (ammonia, carbon dioxide and ammonium carbamate). The unconsumed reactants are removed in three stages. Firstly, the pressure is reduced from 240 to 17 bar and the solution is heated, which causes the ammonium carbamate to decompose to ammonia and carbon dioxide. At the same time, some of the ammonia and carbon dioxide flash off. The pressure is then reduced to 2.0 bar and finally to -0.35 bar, with more ammonia and carbon dioxide being lost at each stage. By the time the mixture is at -0.35 bar, a solution of urea dissolved in water and free of other impurities remains. At each stage the unconsumed reactants are absorbed into a water solution which is recycled to the secondary reactor. The excess ammonia is purified and used as feedstock to the primary reactor.

**Step 3 : Concentration**

75% of the urea solution is heated under vacuum, causing some water to evaporate and increasing the urea concentration from 68% w/w to 80% w/w. At this stage some urea crystals also form. The solution is then heated from 80º to 110ºC to re-dissolve these crystals prior to evaporation. In the evaporation stage, molten urea (99% w/w) is produced at 140ºC. The remaining 25% of the 68% w/w urea solution is processed under vacuum at 135ºC in a two series evaporator-separator arrangement.

**Step 4 : Granulation**

Urea is used as fertiliser in 2 - 4 mm diameter granules. These granules are formed by spraying molten urea onto seed granules which are supported on a bed of air. This occurs in a granulator which receives the seed granules at one end and discharges enlarged granules at the other as molten urea is sprayed through nozzles. Dry, cool granules are classified using screens. Oversized granules are crushed and combined with undersized ones for use as seed. All dust and air from the granulator is removed by a fan into a dust scrubber, which removes the urea with a water solution then discharges the air to the atmosphere. The final product is cooled in air, weighed and conveyed to bulk storage ready for sale.

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**Rotating Machinery in the Urea Plant**

![Rotating Machinery](image)
Fertiliser plants are divided according to the criticality into categories as shown in the triangle below. The most critical machines are turbine, compressors and pumps which depend on the secondary critical machines like fans, motors, pumps, cooling towers fans, blowers.

Looking at today’s scenario, monitoring of these machines is imperative for increasing the efficiency and thereby reliability of the plant.

Implementing predictive maintenance leads to a substantial increase in productivity (up to 35%). However, the need can be determined only after understanding the health of the machine without dismantling it. This is possible only by online monitoring.

### Philosophy of Machine Condition Monitoring and Forbes Marshall Shinkawa Solution

#### Pyramid for Machinery in Fertiliser Plants

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Machine</th>
<th>Suitable Product</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1st level critical machines</td>
<td>Compliant to API 670 Std.</td>
<td>EX / ATEX /GEO certified</td>
</tr>
<tr>
<td></td>
<td>Compressors (air and gas type)</td>
<td>Transducer : FK series, CA &amp; CV Series monitor : VM7B</td>
<td>Radial shaft, axial shift, casting vibration, key phasor measurement</td>
</tr>
<tr>
<td></td>
<td>Turbines</td>
<td>Series and Invisys RV200 analysis and diagnostic software</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Boiler feed and Ammonia feed pump</td>
<td>Transducer : FK series, CA and CV Series monitor: VM-5, VM7B or VM-25 monitoring system</td>
<td></td>
</tr>
<tr>
<td></td>
<td>– 1st critical</td>
<td>Non API VMS, Transmitter based system</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>2nd level critical machines</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pump (HP/LP/MP)– 2nd critical</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Turbo blowers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cooling tower fans</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In a fertiliser plant, vibration sensors of the machine monitoring system for ammonia, urea, utilities and off-sites are mounted on the turbine, compressor, pump shafts or bearing. All sensor inputs are connected to the machine monitoring system which is housed in control room or purge panel. All the offered sensors are ATEX certified with tropicalisation (Geothermal) coating suitable for field requirement. Separate LCD display is installed in the control panel to view vibration data in the form of a bar graph and digital display.

All the critical equipment in the plant is equipped with Shinkawa machinery management software and hardware, i.e., proximity probes FK series for radial/axial displacement and keyphasor measurement, CA series accelerometers, VM-7B series machinery protection system as per API670 compliant and Infisys RV200 advanced machine monitoring analysis and diagnostic software which will be installed in a data gathering computer system.

Infisys RV200 software allows plant management to manage their machinery and minimise the possibility of an unplanned shutdown which can result in huge production losses. Planned shutdown also allows plant personnel to plan for manpower and spare parts greatly reducing downtime since the nature of the problem understood in advance.
Transducer System

FK Series Displacement Eddy Current Transducers

The FK-202F transducer is the eddy current type non-contact displacement/vibration transducer, used for measuring shaft vibration, axial position, rotating speed and phase mark (phase reference) from small rotating machinery to large critical machinery such as turbines and compressors in plants. In addition, the FK-202F is designed to meet the API (American Petroleum Institute) standard 670 (5th Edition) requirements, often referred by the machinery protection systems for the petroleum refinery and the petrochemical plant in world wide.

Suitable for various applications: shaft vibration, axial position, rotating speed and phase mark of the critical rotating machinery.

Environmental friendly design: lead-free soldering, RoHS directive compliant and downsized.

Wide variety of driver mounting: DIN-rail adaptor, 4-screw cramp plate adaptor (to replace VK series and others)

API standard 670 (4th Edition) compliant

Intrinsically Safe: TIIS, CSA, ATEX, NEPSI, KTL

CE directive compliant

CA/CV Series Velocity Sensor and Accelerometers

Multi-purpose and intrinsically safe accelerometers. Available in both top and side connectors, or with top and side exit integral cables.

High temperature, low frequency and piezo velocity transducers

Available in both top and side connector versions

Machinery Protection / Monitoring System

VM-7B Series – Simple, highly functioning and consistent performance - four channel API 670 Std. Monitoring System

The VM-7B series monitor is designed according to ISO international standards and the API standards, and has the functions and features of the machine condition monitor, is used for machines in plant, and is used for the machine protection system defined in the API standard 670 in particular.

Features

- Redundant power supplies.
- True redundant communication to DCS / PLC
- Isolated 4-20 mA output
- Single monitor module (VM 701B) for 7 parameters
- Inbuilt analysis function in each module (optional)
- Inbuilt relay in each module
- Fully programmable relay in the rack for any configuration and logic

Raw signal output – front BNC and rear terminals

API 670 compliant

24 Bit microprocessor

Lead free soldering – caring environment

44 Input channel in each rack
# System Configuration VM-7 B

## Monitor Modules and Monitoring Parameters

<table>
<thead>
<tr>
<th>Monitor Module</th>
<th>Monitoring Parameter of Inputs</th>
<th>Number of Outputs</th>
<th>Number</th>
<th>Input Transducer</th>
</tr>
</thead>
<tbody>
<tr>
<td>VM-701 B Vibration / displacement monitor module</td>
<td>Displacement vibration</td>
<td>4</td>
<td>4</td>
<td>FK</td>
</tr>
<tr>
<td></td>
<td>Velocity vibration</td>
<td>4</td>
<td>4</td>
<td>CV</td>
</tr>
<tr>
<td></td>
<td>Acceleration vibration</td>
<td>4</td>
<td>4</td>
<td>CA</td>
</tr>
<tr>
<td></td>
<td>Dual path vibration</td>
<td>2</td>
<td>4</td>
<td>CV or CA</td>
</tr>
<tr>
<td></td>
<td>Thrust position</td>
<td>4</td>
<td>4</td>
<td>FK</td>
</tr>
<tr>
<td></td>
<td>Differential expansion (single input)</td>
<td>4</td>
<td>4</td>
<td>FK</td>
</tr>
<tr>
<td></td>
<td>Ramp differential expansion</td>
<td>4</td>
<td>2</td>
<td>FK</td>
</tr>
<tr>
<td></td>
<td>Complementary input differential expansion</td>
<td>4</td>
<td>2</td>
<td>Fk</td>
</tr>
<tr>
<td></td>
<td>Case expansion complementary expansion</td>
<td>3</td>
<td>3</td>
<td>FK &amp; LS + VM-21</td>
</tr>
<tr>
<td></td>
<td>Case expansion</td>
<td>4</td>
<td>4</td>
<td>LS + VM-21</td>
</tr>
<tr>
<td></td>
<td>Valve position</td>
<td>4</td>
<td>4</td>
<td>LS + VM-21</td>
</tr>
<tr>
<td>VN-702 B Absolute vibration monitor module</td>
<td>Shaft relative vibration and shaft absolute vibration or casting vibration</td>
<td>4</td>
<td>4</td>
<td>FK &amp; CV</td>
</tr>
<tr>
<td>(for 2CH)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VM-703 B Tachometer and eccentricity monitor module</td>
<td>Rotor speed</td>
<td>2</td>
<td>2</td>
<td>FK, RD or MS</td>
</tr>
<tr>
<td>CH1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH2</td>
<td>Rotor acceleration</td>
<td>0</td>
<td>1</td>
<td>Rotor speed of CH1</td>
</tr>
<tr>
<td>CH3</td>
<td>Eccentricity</td>
<td>1</td>
<td>2</td>
<td>FK &amp; Ø</td>
</tr>
<tr>
<td>VM-704 B Temperature monitor module</td>
<td>Temperature</td>
<td>6</td>
<td>6</td>
<td>TC or RTD</td>
</tr>
<tr>
<td>VM-706 B Rod drop monitor module</td>
<td>Rod drop</td>
<td>4</td>
<td>4</td>
<td>FK &amp; RD</td>
</tr>
</tbody>
</table>
VM-25 Digital BOP Monitor

VM-25 monitoring system is designed with IoT in-mind, contains features and functions required for BOP (Balance of plant) monitoring. VM-25 can be customized to suit end user needs, and its compact design means it fits almost anywhere.

**Features**
- Digital communication – Modbus/TCP communication with IoT system via single Ethernet cable
- Right-sized – available in 4, 6 and 8 channel monitoring arrangements along with up to 4 recorder outputs and up to 8 relay outputs, and
- An optimized design – enables installation in small spaces along with multiple mounting arrangements. Dimensions, 120 x 160 x 100mm.

**Functions**
- Standard vibration measurement (velocity, acceleration transducers)
- Modbus / TCP communication
- A 7 digit LED front-facing display
- Recorder output (non-isolated)
- Optional recorder output (isolated)
- Relay output
- Dedicated configuration software enables operators to change monitor settings

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**Example System Configuration**

This is a real time processor for steady state and transient measurements from monitor racks via raw signals for analysis and diagnostics purpose. Output from these units will be ether net and connected to software. Monitoring system (as per API 670 Std) has sensor signal output either on monitor front BNC or rear terminals. This signal will be connected with a multipair cable to the Shinkawa terminal box which will convert this into D connector output. This D Connector output will be then be connected to the Shinkawa analysing processor which will process this signal and give high speed analysis data output in form of ethernet TCP IP. This output will be then connected to a server where RV200 analysis software will be loaded and further processing and GUI plots will be made as an expert analysis and diagnosis system.
The complete vibration analysis and diagnostic system. With the latest analysis technology, online vibration analysis systems are capable of analyzing and managing all sorts of data essential for large rotating machinery, on personal computers. The software based on WindowsNT platform allows easy operation and various analysis functions. InfiSYS RV200 has analysis view software that takes data out from the analysis module VM-742B and displays the same. It displays the set value, measurements, and the status of the analysis module and the analytical data.

**API 670 - 19” Rack Based Monitoring with Analysis and Diagnosis System**

**Analysis Software Features**
- Machine train diagram (24 machine train diagrams or less can be registered)
- Current value summary
- Trend graph: overall, GAP, 0.5X amp. / phase, 1X amp. / phase, 2X amp. / phase, Not 1X amp., and RPM
- Bar graph: overall, 0.5X, 1X, 2X, Not 1X
- Other graphs
- Waveform / spectrum
- Lissajous, lissajous and waveform, vector plot
- Orbit, S-V graph, X-Y graph.
- Transient trend, transient waveform / spectrum.
- Transient lissajous, transient lissajous and waveform
- Transient polar plot, transient (bode diagram), transient orbit
- Trend during alarm, waveform / spectrum during alarm, system history, alarm history

**InfiSYS RV200** has diagnosis software that gives the health of the rotating machinery i.e. displays the reason of the internal faults caused.

**Diagnosis Software Features**
- A malfunction cause is displayed in order from the high thing of the factor as a result of diagnosis.
- Diagnosis possible malfunction causes: unbalance, permanent bow, lost rotor parts, misalignment, critical speed, rotor crack, non symmetrical rotor, gear inaccuracy, seal rub, oil whirl, oil whip, steam whirl / seal whirl, cavitations, wing vibration, draft core, surging.
**Condition Monitoring and Assessment of Rotating Machinery through Remote Vibration Monitoring System (RVMS)**

**Need for 24X7 Vibration Monitoring for Machines**
Currently, in many plants, the technical know-how of vibration monitoring is limited, which calls for specialised support and timely guidance to avoid emergency shutdown.

Forbes Marshall provides the solution for advanced remote vibration monitoring through an analysis software.

All the data related to vibration and process values of the machines are captured 24x7 at intervals as required by the user. So whenever we request for any data of any period, we will be able to get it. This will give the information of when the alarm had occurred and what was the fault i.e. abnormality in the machine.

**Benefits**
Remote monitoring through analysis software is effective for old and new power plants – starting from 1MW to 1000MW.

User can monitor and analyse the vibration of his rotating machinery very well, which will result in better maintenance of the machinery.

Dynamics of machinery like critical speeds, behavior of machinery in transient conditions like startup and shutdown will be better understood to pinpoint any abnormal condition.

Analysis and display functions i.e. machine trains, trend graph, spectrum, shaft center line position, bode/polar plot, orbit display, vector plot, alarm status, etc. The user can prevent any possible failure by taking corrective action.

This will eventually increase equipment availability and reliability and reduce costs.

Internet explorer via web connectivity can be used to see details anywhere globally on any PC or mobile.

It is used on any machine for any vibration analysis function requirement.

It gives advance information to customers on machine issues to avoid shut down. Experts use know how of multiple plants to guide plant O&M teams.

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**Vibration Consultancy Services Agreement (VCSA)**

**Proactive Care for Critical Rotating Machines**
Imagine if you could monitor the health problems of critical rotating machines – even before the symptoms become evident.

A Forbes Marshall specialist will be promptly available at your doorstep to address the problem.

The Consultancy Services Agreement (CSA) is a suite of proactive asset care services tailored to your individual needs and designed to help you harness the full potential of the installed condition monitoring systems.

**Our Expertise**
Survey of rotating machines in your plants.

Possible suggestions for vibration monitoring requirements.

Vibration consultancy support for giving reports monthly / quarterly for critical machines and secondary critical machines.

Right proposal to optimise the on line monitoring cost.

Complete turnkey execution, engineering and documentation.

Vibration analysis and diagnosis reporting for the right time to shut down to save cost. Customised condition monitoring and reporting plan for your plant.
Specialists Available On Call

When there is a problem, we can perform diagnostics and give you advice on the cause and how to fix it. We can provide this service, quarterly, monthly or on-demand.

Personalised Solutions for Individual Needs

With a complete knowhow of on-line vibration monitoring systems and machine details, we have developed the Vibration Consultancy, a unique service for customers in all types of industries. Through this service, we offer our clients remote vibration analysis and give reports for every critical rotating machine in the plant, by either remote monitoring of critical machines 24 X 7 and/or periodic measurements by visits to the plant for other critical machines such as large pumps, ID/FD/PA fans, centrifuges, large blowers, gear boxes, motors, crushers, compressors and other rotating machines.

Implementing predictive maintenance leads to a substantial increase in productivity (upto 35%), on the one hand preventing unpredicted shutdowns, while on the other, anticipating corrective operations so that they can be carried out under the best conditions.

Recommendations

We recommend that critical machines like compressors, pumps and turbines have a vibration monitoring system designed as per API670. It should be globally proven and should have good service network and support.

For turbo blowers, cooling tower fans and small pumps - we recommend accelerometers and standalone vibration monitoring systems.

We recommend that all machine tripping must be taken from a reliable API 670 design machines.

As far as possible there must be sensors upto JB in rotating machine OEMs and monitoring system with complete integration with owner or large EPC

Supplier should have a proven track record in India for more than 2-3 years for service support of fertiliser plants. There should be a wide spread service network.

Conclusion

In the Fertiliser Industry, maintenance costs account for 10-15% of production costs. Maintenance affects the target, quality and profitability of the plant. Implementation of the modern concept of condition based maintenance can reduce maintenance costs appreciably and enhance the reliability of machine performance and quality of the output.