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Condition Based Maintenance Of Rotating Equipments On OSI PI Platform – Refineries/ Petrochem Plants

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Breakdowns and deteriorated performance of critical rotating equipments can have significant impact on the profitability of a business as the annual capacity utilization of the refineries/petrochemical plants can fall significantly affecting the top line and bottom line of the business. There are various Condition Based Maintenance (CBM) techniques that have been introduced for centrifugal compressors like online vibration monitoring. Also, if you analyze the amount of CBM on a reciprocating compressor, it is comparatively very minimal and cost of maintenance is three times when compared to centrifugal compressor. Centrifugal pump like Sun dyne which is very sensitive to process parameters are not monitored so closely often resulting in major break downs especially in Petrochemical plants like

Purified Terephthalic Acid (PTA). There is huge amount of process and equipment data gathered from field in the Distributed Control System (DCS) or other control system which is not utilized optimally for condition monitoring and in most cases like the black box on an aircraft: data gathered and stored so that they are available when there is an eventuality. Wipro OSI PI practice is trying to leverage OSI PI for making use of plant equipment and process related data for rotating equipment condition monitoring.

Introduction

Breakdowns in Oil & Gas manufacturing systems can have significant impact on the profitability of a business. Expensive production equipment is idled, labor is no longer optimized, and the ratio of fixed costs to product output is negatively affected. Rapid repair of break down equipment is critical to business success; the process of addressing equipment breakdowns after occurrence is known as

Corrective Maintenance exists in some form in all manufacturing companies. However, when equipment breakdowns occur the cost can go well beyond the period of repair. Often process lines require significant run-time after startup to begin producing quality product, and the manufactured goods in process at breakdown as well as the goods manufactured for a period after breakdown may either be unusable or of less value. Because of the impact both during and beyond the immediate downtime, businesses have sought to prevent equipment breakdown by a process known as Preventative Maintenance. With preventative maintenance, equipment is routinely inspected and

serviced in an effort to prevent breakdowns from occurring. Such inspections are based on either

calendar periods or equipment process time.

Corrective Maintenance and Preventative Maintenance approaches have been in use for decades, but each have some important drawbacks. The maintenance efficiency index is one of the key parameters to measure the overall maintenance management system of a process industry. This paper's focus is to enable organization using OSI PI as plant historian for process industries to derive full benefit of improving asset reliability. This is feasible by proactive equipment monitoring for enabling condition based maintenance to get maximum ROI out of OSI PI implementations by leveraging the available data for CBM.

Different Maintenance Methodologies

Need for Maintenance

- To preserve the functional requirements
- To prevent premature failures
- To mitigate the consequences of failure

Also should be technically appropriate, feasible and economically justified.

The current scenario is that a higher percentage of organizations are practicing reactive maintenance than scheduled maintenance. The target for oil companies to improve maintenance efficiency index is to bring down the reactive maintenance scenario to 20%, condition based to 60% and scheduled maintenance to 20% and combined run to failure and reactive to 20% as maintenance options. The objective of maintenance function is to optimize maintenance cost and improve reliability.

A maintenance task is effective when it:

- ... increases the Mean Time Between Failures (MTBF) of the equipment
- ... reduces the consequence of failure
- ... reduces the risk of multiple failures

Maintenance Efficiency Index (MEI) = (BD COST / ETBF1 - BD COST /ETBF2)/ AMP

To approve tasks, MEI > 1

ETBF1 - Estimated Time Between Failure – Zero Maintained Situation

ETBF2 - Estimated Time Between Failure - Maintained situation

BD COST – Break Down Cost

AMP – Annual Preventive Maintenance Cost

- MEI will drop if preventive maintenance is overdone. So instead of time schedule achieve actual operational hours as trigger for preventive maintenance.
- There may be cases where run to failure may be least expensive if there are no Health Safety Security Environment (HSSE) issues.

OSI PI helps in achieving actual running hours based maintenance as it captures actual running hours and the same can be utilized for triggers preventive maintenance work order in SAP preventive maintenance module.

Condition Based Maintenance (CBM)

To maintain the correct equipment at the right time, CBM is introduced. CBM is based on using realtime data to prioritize and optimize maintenance resources. Observing the state of the system is known as condition monitoring. Such a system will determine the equipment's health, and act only when maintenance is actually necessary. Development in recent years have allowed extensive instrumentation of equipment, and together with better tools for analyzing condition data, the maintenance personnel of today are more than ever able to decide what is the right time to perform maintenance on some piece of equipment. Ideally condition-based maintenance will allow the maintenance personnel to do only the right things, minimizing spare parts cost, system downtime and time spent on maintenance.

Challenges with CBM

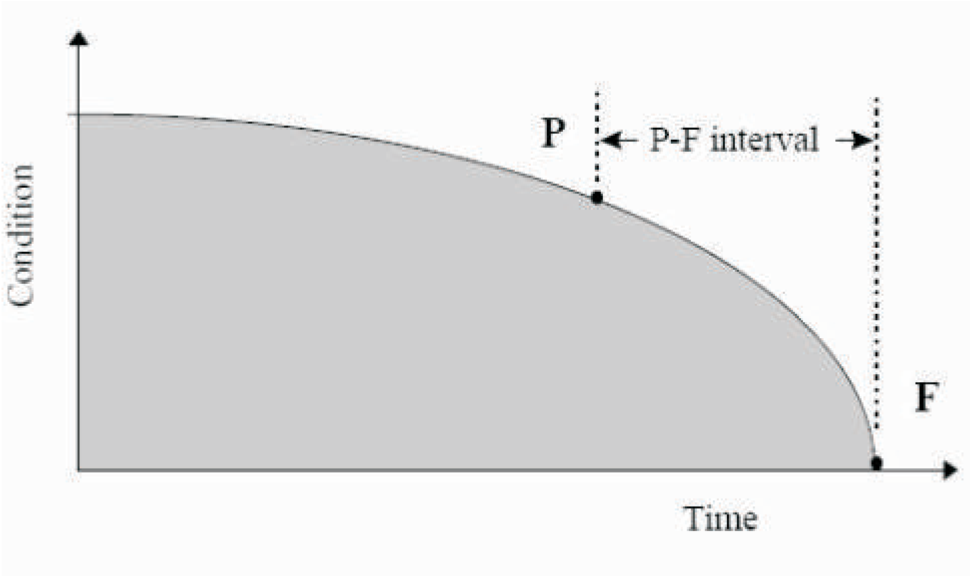
First, starting to use CBM is costly. It will require improved instrumentation of equipments. Often the cost of sufficient instrumentation can be quite large, especially on equipment that is already installed. It is therefore important to decide whether your equipment is sufficiently important to justify the investment. As a result of this, the first generation of CBM in the oil and gas industry has focused on vibration in heavy rotating equipment only.

Next, introducing CBM will invoke a major change in how maintenance is performed, and potentially to the whole maintenance organization in a company. Organizational changes are in general very difficult and need cultural change.

Last, the technical side is also great challenge. Even if some types of equipment can easily be observed by measuring simple values as vibration, temperature or pressure, it is not trivial to turn this measured data into actionable knowledge about health of the equipment.

Although many failure modes are not age-related, most of them give some sort of warning that they are in the process of occurring or are about to occur. If evidence can be found that something is in the final stage of failure, it may be possible to take action to prevent it from failing completely and/or to
avoid the consequences.

Potential Failure-Functional Failure (P-F) curve illustrates what happens in the final stages of failure. It is called the P-F curve, because it shows how a failure starts, deteriorates to the point at which it can be detected (known as potential failure 'P') and then, if it is not detected and corrected, continues to deteriorate until it reaches the point of functional failure ('F'). Condition-based maintenance entails monitoring for potential failures, so that actions can be taken to prevent the functional failure or to avoid the consequences of the functional failure.



The P-F curve

The P-F interval is the interval between occurrence of a potential failure and its decay into a functional failure. It is also known as the warning period, the lead time to failure or the failure development period. If we want to detect the potential failure before it becomes a functional failure, the interval between monitoring checks must be less than the P-F interval. For different failure modes, it varies from fractions of a second to several years.

Condition Monitoring

The specific advantage of condition monitoring is that potential degradation or failure can be detected. This technique enables the user to take maximum advantage of the useful life of a component such as a bearing, because, the equipment can be left in service if it meets the desired performance standards. In general the cost-effectiveness of condition monitoring, either by means of human surveillance or other condition monitoring techniques, should be evaluated against the following criteria:

1. The potential Health Safety and Environment (HSE) consequences if the component/equipment is run-to-failure.
2. The additional repair cost resulting from potential secondary damage if the component/equipment is run-to-failure.
3. The expected longer useful life of the component/equipment relative to scheduled (For Example,time-based) replacement.
4. The efficiency gain in execution of a planned corrective task relative to an unplanned reactive task and the possible additional economic consequences (production loss etc.).

CBM of Reciprocating, Centrifugal Compressors & Pumps

Reciprocating Compressor

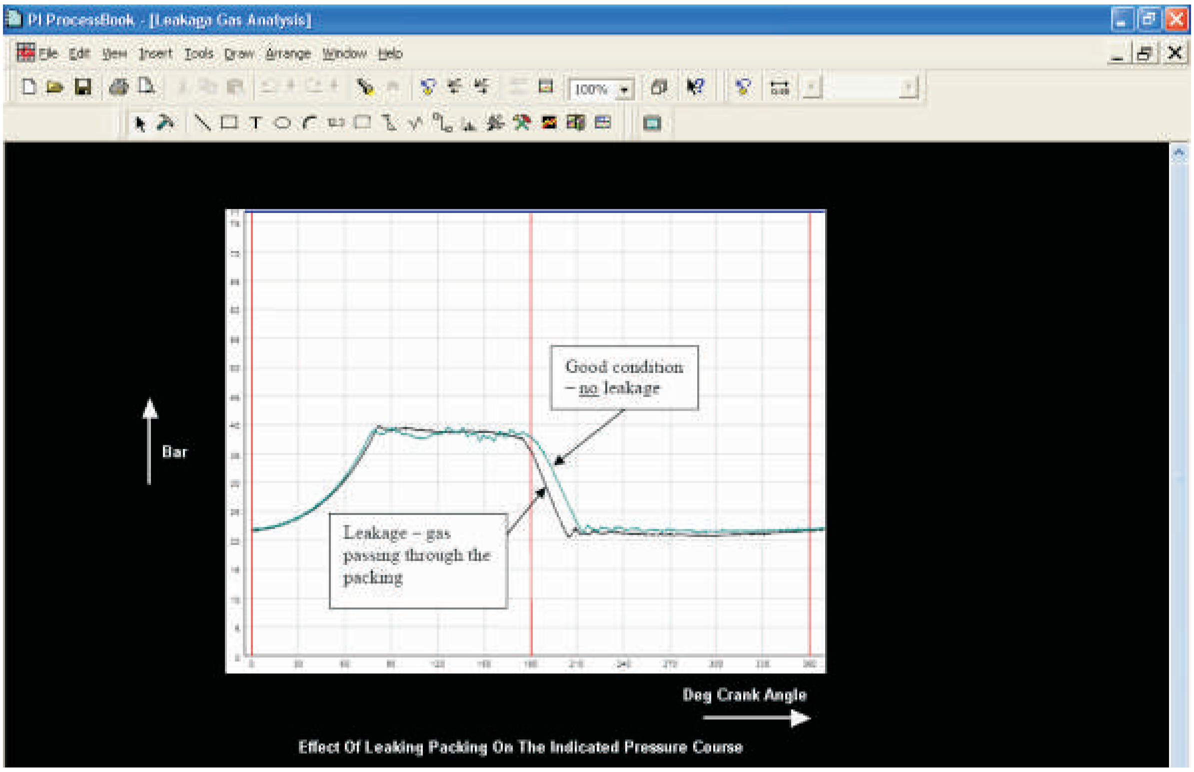
Reciprocating compressor is the workhorse of refineries, petrochemical and oil production units. The general observation is that they are 5 times expensive to maintain per horsepower in comparison to centrifugal compressors.

The condition monitoring of centrifugal compressors is far matured. The vibration monitoring reflects the health much effectively in centrifugal compressors in comparison to reciprocating compressors. When it comes to reciprocating compressors in process plants, there is much less agreement on which monitoring techniques should be standard but at least API 618 contains the basic requirements.

Here are the lists of monitoring parameters going to be used for monitoring using probes, transducers for condition monitoring of Reciprocating compressors through OSI PI plant historian:

Vibration

There are two primary vibration measurements that have been proven effective: measurement on the crack case and measurement on the cross head / distance piece. The best practice is to install traducers at each end of crank case about halfway up from the base plate in line with main bearings. Since the purpose of these transducers is to measure running speed related vibration, a low frequency transducer is required, and velocity is the normal measurement parameter.
The other vibration measurement is acceleration on the cross head /distance piece, this helps in detecting mall functions like liquid carry over, loose piston nuts, loose cross head attachments, valve and clearance problems. The measured values are taken to PI servers and can be trended. Also, alarms and notification can be triggered to respective maintenance engineer's mobile phone and also alert the operation team for a changeover if standby compressor is available.



Temperature

Machine temperature is a valuable indicator of machine condition - lube oil temperature, discharge temperature of various stages, valve temperature, packaging temperature, cross head temperature, big and small end bearing temperatures - are the key measurement points in a reciprocating compressor.

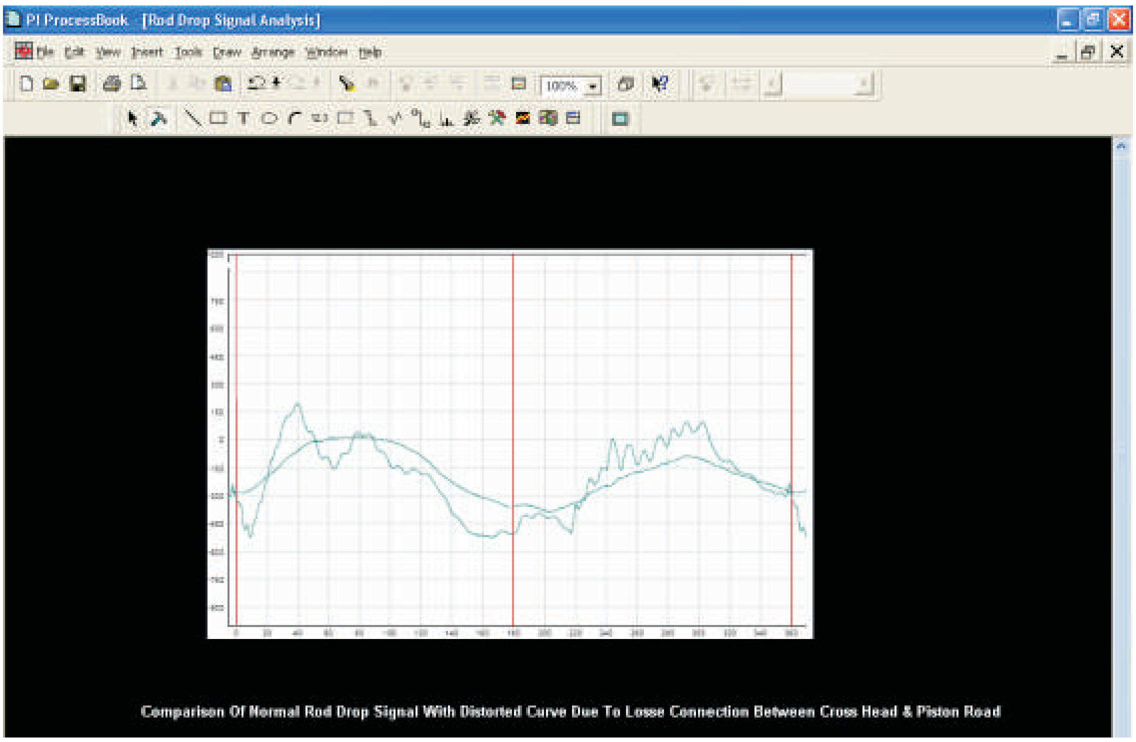
Valve temperatures measured through thermo well indicate the valve failures such as leaky valves. Cylinder discharge temperature is also indication of leaky rings and valves which is also an excellent indicator. Therefore, the measurement of this temperature on continuous basis and comparison with normal operating parameters through OSI PI helps in preventing and alerting valve breakage kind of disasters. A valve breakage can spoil the cylinder liners as well which is very expensive to replace.Through radar wireless gauges big end and small end bearing temperature can be captured and monitored continuously in OSI PI for abnormalities without human intervention.

All temperature readings are acquired and compared with the corresponding design, and normal operating specifications in OSI PI for detecting abnormalities and alerting the concerned engineers in the plant.

Rod Drop and Run Out Monitoring

Piston rod assembly drops during normal operation as the rider band wears, sometimes due to liquid carry over or foreign particles, compressor running on unloaded condition for long. It can wear fast damaging the piston head and cylinder liner resulting in expensive repair. Any excessive maintenance, like time based, may not help in improving maintenance index.

A non contact proximity probe has its electrical output signal proportional to the probe – rod distance can therefore be measured with great accuracy. Rod run out is a measurement of the rod's actual dynamic motion when it moves back and forth on its stroke. Eddy probes can be installed at both vertical and horizontal direction to monitor effectively for any misalignment between cylinder head and cross head.



Readings acquired at manufacturer location, during initial commissioning can be taken as a bench mark for monitoring in OSI PI as a permissible before an alert is generated in the system. This helps in diagnosis of piston ring wear, rider wear, cross wear, misalignment etc by monitoring rod drop and rod run out respectively.

Pressure Volume (PV) Analysis

The PV diagram is the excellent way to represent energy cycle in a reciprocating compressor. By capturing pressure & temperature of all stages and mapping with ideal cycle gives a better understanding of valve leakages and volumetric efficiencies of compressor. The ideal flow balance is 1 and anything between .95 and 1.10 is acceptable. The important consideration for implementation is the number of pressure & volume correlated point's needs to be collected and plotted in process book of OSI PI.

Few Trouble Shooting Guidelines

Flow deviation

- Common cause is failed valve or unloader on one or more cylinders

Discharge temperature deviation

- Common cause is valve failure

Volumetric efficiency deviation

- Common cause is pocket open too far or excessive pressure ratio

Power Deviation

- Common cause is failed bearing, or failed compressor valve or unloader

Centrifugal Compressors

Apart from online vibration monitoring if other process parameters are also monitored and trendedusing OSI PI, this can help in planning the critical single line compressors like FCC recycle gascompressors, Ethylene and propylene compressors in Naphtha cracker plants.

Various pressures, temperature, and gas properties from analyzers can be used for calculating,monitoring and trending of the following compressors: process parameters for the health check of centrifugal

1. Head and polytrophic efficiency vs. flow at operating speed for various stages:

$$H_p = \frac{Z_{avg} . R . T_s}{MW . \frac{n-1}{n}} \left[\left(\frac{P_2}{P_1} \right)^{\frac{n-1}{n}} - 1 \right]$$

- Hp – polytrophic head (also called polytrophic work), kJ/kg
- Z avg – average compressibility factor dimensionless
- R – universal gas constant, 8.314 kJ/kmol·K
- Ts – suction temperature, K
- MW – molecular weight, kg/kmol
- n – polytrophic exponent, dimensionless
- P1 – suction pressure, kPa (abs) or bara
- P2 – discharge pressure, kPa (abs) or bara

Polytrophic Efficiency

$$\eta_P = \frac{H_P}{\Delta H}$$

Gas analysis needs to be done based on analyzer input for various stages.

The operating points and reference curves are both plotted so that the actual compressor performance may be quickly compared to the manufacturer performance specification by means of visual inference. The surge line is also displayed so that it can be easily determined if the compressor is close to surging.

Compressor Operating Parameters		
	ACTUAL	DESIGN
Suction Pressure		
Discharge Pressure		
Suction Pressure		
DischargeTemperature		
Standard Flow		
Speed		
Power (VI COSPI)		
Inlet Flow M3/Hr		
Polytrophic Head		
Lube Oil Pressure		
Lube Oil Temperature		
Filter DP		

A variation of more than 10% sounds alarm for investigation

Few Trouble Shooting Guidelines

Polytrophic efficiency deviation

- Common cause is worn labyrinth seals

Polytrophic head deviation

- Common causes are MW changes, fouled compressor rotor

Power deviation

- Common causes are worn labyrinth seals, balance piston, Molecular weight changes

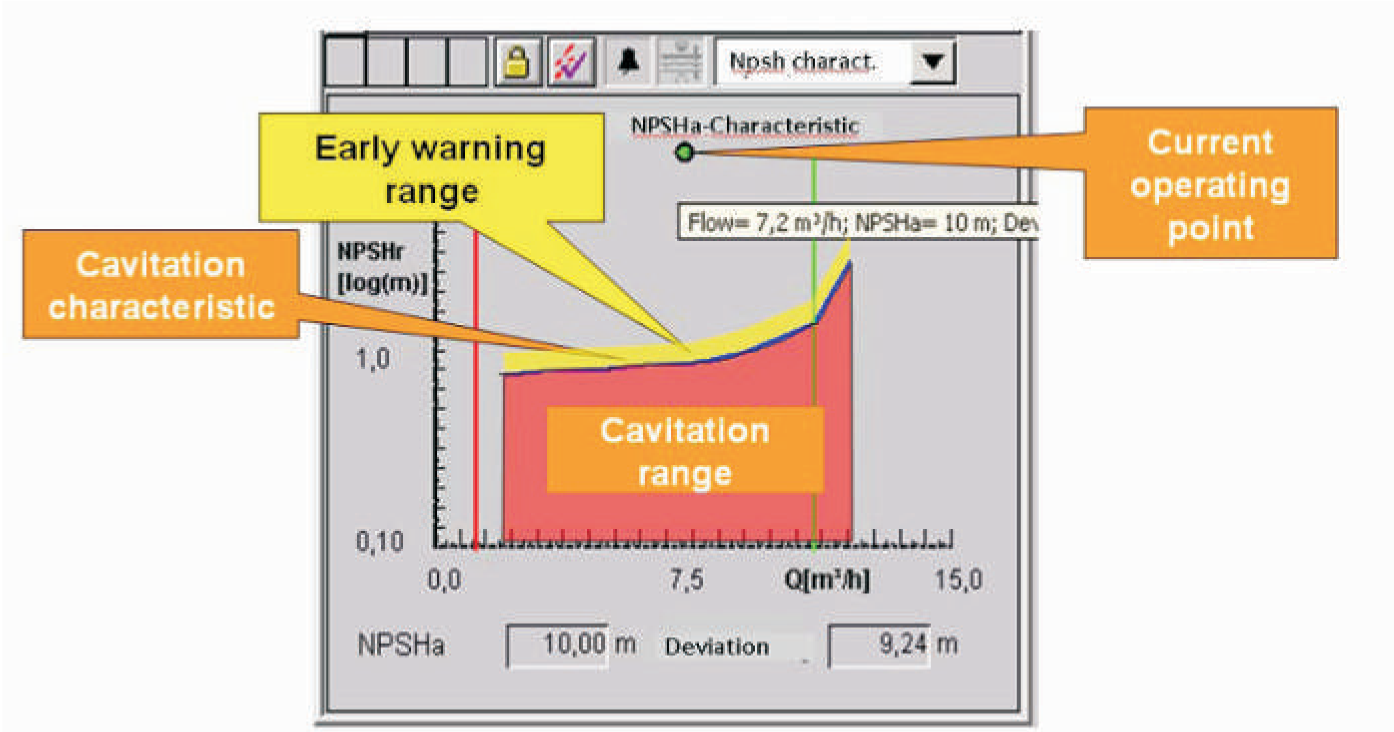
Discharge temperature deviation

- Common causes are worn labyrinth seals, worn balance piston

Centrifugal Pumps

Critical centrifugal process pumps and Sun dyne pumps can be monitored using process variables to track degradation to enable proactive maintenance. Also, by monitoring actual running hours, preventive maintenance notifications can be triggered in SAP preventive maintenance module.

In the case of high speed, Sun dyne pumps, condition monitoring is actually done periodically and many times it results in catastrophic failures. Here vibration monitors can be fixed and tracked through OSI PI with high vibration alarms and alerts.



Since these are very high speed pumps, the Net Positive Suction Head (NPSH) required is very close by. Any changes in operating parameters can result in cavitations which would not get noticed, resulting in costly breakdowns. So, performance monitoring using available process parameters from DCS can be used effectively for better pump reliability.

1. Monitor NPSH available vs. required, delta parameter to be set for high Rotation Per Minute (RPM) pumps
2. Performance curve comparison to manufactures specification
3. Power – VI COS Pi
4. Efficiency of the Pump

Few Trouble Shooting Guidelines

Efficiency Deviation

- Common cause is worn wear rings

NPSH Deviation

- Common cause low suction vessel level
- High product temperature

Power Deviation

- Common cause is failed bearings or worn internals or fouled rotor

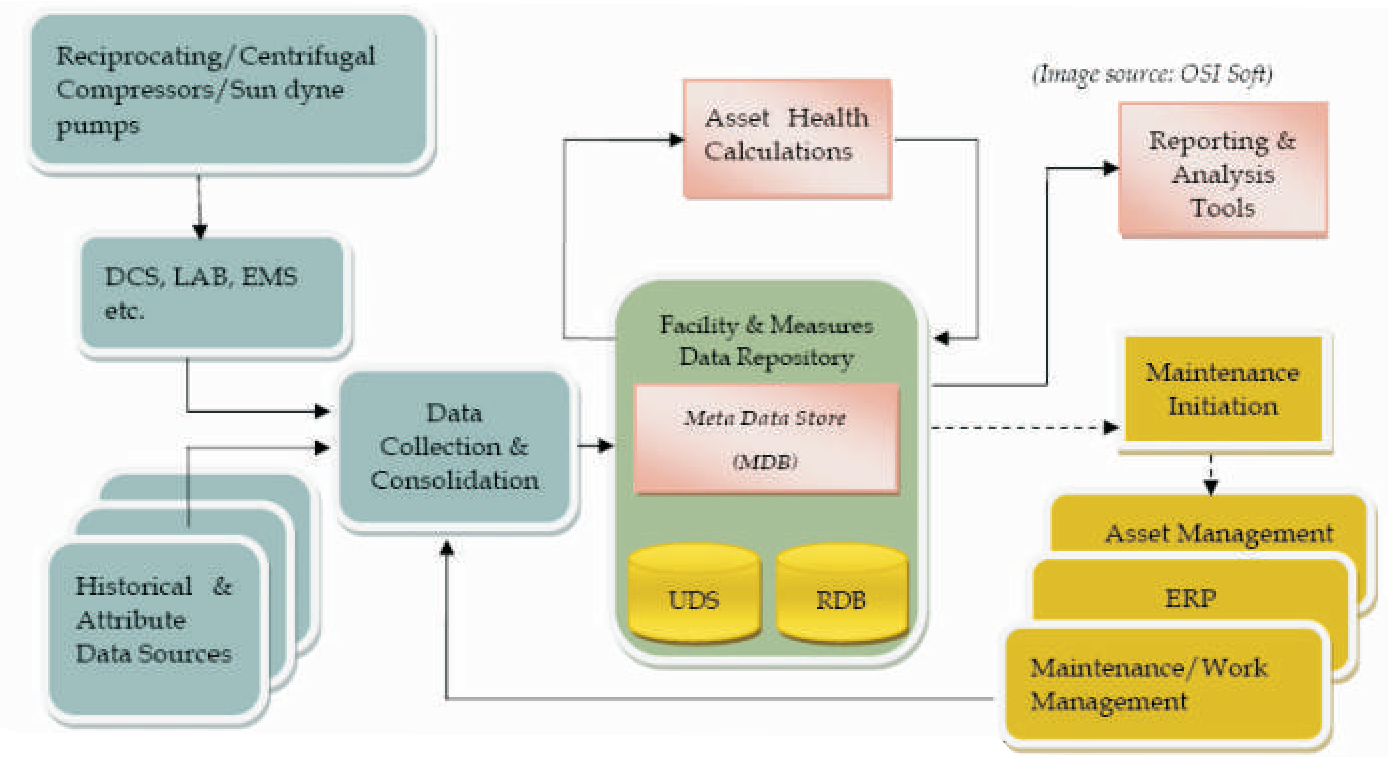
Head Deviation

- Common cause is worn internals or fouled rotor

In most of the refineries, equipment operating parameters are gathered and displayed in DCS and sometimes stored in the OSI PI or any other plant historian. But, this data is not processed, analyzed and trended for condition monitoring of rotating equipments. This data in only used for postmortem if any catastrophic failure happens to any critical equipment.

Keeping this in mind, Wipro Technologies have come up with a solution using OSI PI process book and ACE modules for the benefit of oil industry for maximizing the ROI of PI system.

CBM Conceptual Model – OSI PI Platform



Appendix

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