The Real – Time Diagnostic COMPACS System

DYNAMICS Scientific Production Center USA, Inc.
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# The Real-Time Diagnostic COMPACS System

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2. The COMPACS System for real-time diagnostics and monitoring of machinery health
3. Examples of Real-Time Prescriptions and Predictive Analytics by AI of the COMPACS system
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1. **Accidents** due to equipment failures in operation

2. **Downtimes** due to sudden equipment failures

3. **Extended turnaround time** due to the lack of objective equipment state-of-health data or detection of hidden defects during maintenance

4. **High maintenance expenses** due to a significant quantity of both planned and un-planned repairs

5. **Significant spare parts inventory** due to a lot of different equipment types and lengthy delivery times for spare parts
An existing approaches to prevent losses

Three main failure causes:

- **Equipment wear**
- **Wrong personnel action (inaction)**
- **External factors (failure of infrastructure, natural disasters, etc.)**
The COMPACS system monitors all machinery in a facility on single hardware-software platform.

Communication line with the COMPACS diagnostic station

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The COMPACS is the only system in the world which utilizes a wide range of nondestructive testing methods:

- Vibration
- Acoustic
- Thermal
- Electrical
- Vortex-Current
- Acoustic-Emission
- Optical

Real-time automatic diagnostics and comprehensive health monitoring of machinery.

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- Sensors are installed in a non-invasive manner
- Peripheral interface modules PIM are installed close to machinery, each device is connected with 8 different sensors
- Several devices send signals from sensors to control room over one communication line

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Method of sensor installation without demounting of machinery

It provides installation of the sensor in the direction of the most informative vibration vector, thus integrity of a machine design is not disturbed. It does not require specially prepared places for sensor’ installation or drilling in the machine’s body.

95-98 percent of diagnosed faults with confidence probability of 97-99% failure miss risk less than 5%

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Monitor Mode

**Red** Rectangle – machine is in Unacceptable condition

**Yellow** Rectangle – machine is in Actions required condition

**Green** Rectangle – machine is in Acceptable condition

**Grey** Rectangle – machine is out of operation

**Brown** Rectangle – machine is in maintenance

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 Failures and Defects Automatically Detected by Artificial Intelligence of the COMPACS system

### CENTRIFUGAL MACHINES

**BEARING:**
- lack of lubrication;
- misalignment;
- weakening;
- outer ring defect;
- defect of outer ring form (out-of-roundness, facets, roughness);
- inner ring defect;
- defect of inner ring form (out-of-roundness, facets, roughness);
- roller defects;
- cage defect;
- breach of oil wedge in a plain bearing.

**GEAR:**
- coupling defects;
- gears defects.

**MACHINE:**
- fastening problems;
- rotor imbalance;
- wheel rotor defects;
- shaft cut;
- unacceptable beating of a rotor;
- unacceptable axial shift.

**PACKAGE:**
- violation of shaft centering;
- rotating masses imbalance;
- violation of lubrication system operation;
- violation of basing and attached constructions.

**GAS-AND-HYDRODYNAMIC:**
- cavitation;
- hydraulic impact;
- air-lock.

**TEMPERATURE:**
- overheating;
- irregularity of heating;
- prohibitive gradients.

**ELECTRIC:**
- current overload;
- phase mismatch;
- defects of stator;
- distortion of relative position of rotor and stator axes;
- "squirrel cage" defects;
- air clearance eccentricity;
- rotor eccentricity.

### PISTON MACHINES

**VALVE:**
- springs, plates breakdown;
- lack of hermeticity (omission);
- condensate ingress (hydraulic impact);
- processing mode.

**CRANKSHAFT BEARING:**
- wear of a babbit layer;
- weakening of fastening;
- poor lubrication.

**ROD:**
- wear of stuffing boxes;
- rod bend;
- rod breakage.

**SLIDER CRANK MECHANISM:**
- wear of a babbit layer;
- weakening of fastening;
- poor lubrication;
- increase of pin-slider gap.

**CYLINDER-PISTON GROUP:**
- wear of rings;
- wear of a sleeve;
- weakening of details fastening;
- poor lubrication;
- condensate ingress (hydraulic impact);
- technological mode violation.

**PACKAGE UNIT:**
- weakening of casing components fastening;
- rotating masses imbalance.

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Trend Mode

This window displays diagnostic feature’s trends
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Analysis Mode

This mode displays signal waveforms, frequency and phase responses

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**Oscillograph Mode**

This mode allows you to analyze the amplitude and time parameters of signals as they are measured in real time.

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The COMPACS System’s Event Log

is used for equipment health analysis during operation, adequacy and efficiency of personnel actions

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Event Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>09.24.2016 06:16 p.m.</td>
<td>PK-1 RIGHT_CYLINDER_CROSSHEAD CHECK_LUBR,CLEARANCE K521; CHECK_LUBR Zh520.</td>
<td></td>
</tr>
<tr>
<td>09.25.2016 07:48 a.m.</td>
<td>PK-1 RIGHT_CYLINDER_CROSSHEAD CHECK_LUBR,CLEARANCE K521; CHECK_LUBR Zh520.</td>
<td></td>
</tr>
<tr>
<td>09.25.2016 03:09 p.m.</td>
<td>PK-1 LEFT_CYLINDER_PISTON_RADIAL_DIRECT CHECK_TECH_MODE,VALVE! Zh560</td>
<td></td>
</tr>
<tr>
<td>09.25.2016 11:27 p.m.</td>
<td>PK-1 RIGHT_CYLINDER_CROSSHEAD CHECK_LUBR,CLEARANCE K521; CHECK_LUBR Zh520.</td>
<td></td>
</tr>
<tr>
<td>09.26.2016 05:47 p.m.</td>
<td>PK-1 LEFT_CYLINDER_PISTON_RADIAL_DIRECT ES. Message: CHECK_TECH_MODE,VALVE! Zh560</td>
<td></td>
</tr>
<tr>
<td>11.03.2016 06:05 a.m.</td>
<td>PK-1 RIGHT_CYLINDER_CROSSHEAD CHECK_LUBR,CLEARANCE K521; CHECK_LUBR Zh520.</td>
<td></td>
</tr>
<tr>
<td>11.06.2016 02:55 p.m.</td>
<td>PK-1 RIGHT_CYLINDER_PISTON_RADIAL_DIRECT CHECK_ VALVES! K561; CHECK_TECH_MODE,VALVE!</td>
<td></td>
</tr>
</tbody>
</table>
The Report mode allows you to acquire an existing report or create a customized one of automatically generated and archived system’s records.

A Sample of reports provided by Reports Mode:

1. List of Rotating Equipment at the facility...
   - Operating in “Unacceptable” condition
   - Operating in “Action Required” condition

2. List of Rotating Equipment under repair...
   - Due to “Unacceptable” condition
   - Due to “Action Required” condition
   - Due to Planned Maintenance

3. List of all Rotating Equipment monitored by The COMPACS System

4. List of pumps under repair

5. List of compressors under repair

6. List of all other Rotating Equipment under repair

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The Compacs-Net®
is refinery’s diagnostic network which shows an objective information about machinery health, involvement of operators and maintenance team in the reliability process.

Industrial Internet of Things

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Technology of Safe Resource-saving Operation and Maintenance of Machinery

Management Staff
- Real-time monitoring of asset management and risk of operation
- Profit growth because of uptime increasing and operation costs reduction

Maintenance Team
- Repair of machinery
- Turnaround
- Repair quality acceptance test

Operations Team
- Changing of processing mode and focused timely maintenance
- Root cause failure analysis and causes elimination
- Commissioning of machinery with high potential residual life

Real-time Diagnostic Compacs System
- Focused and timely diagnostic prescriptions
- Real-time health monitoring of machinery

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Examples of Predictive Analytics Usage

- a – Focused maintenance – add lubrication
- b – Poor repair
- c – Repeated repair - COMPACS identified the inadequate repair
- d – Reciprocating compressor hydraulic shock
- e – Valve’s destruction
Examples of Predictive Analytics Usage

40-days trend of vibration feature related to the bearing outer ring defect

1 – the vibration jumps when the motor starts, then after few hours the vibration level sharply decreases – the First Stage of Destruction;

2 – the second vibration jump (up to the level ACTION REQUIRED) - the Second Stage of Destruction;

3 – the vibration is now growing exponentially, and it has reached the UNACCEPTABLE threshold - Third Stage of Destruction

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Conclusions and Outcomes

The real-time diagnostic COMPACS system provides automatically:

- Early detection of machinery malfunctions:
  - totally automatic diagnostics and prediction of the main defects (>97-98%)
  - complete usage of equipment's resource
  - keeping equipment's maintainability
- Timely and focused informing the personnel of the nearest urgent actions to be taken for equipment life time saving
- Forming the plans for timely focused maintenance on the basis of the actual health of the equipment
- Awareness at all levels of management about the quality and efficiency of personnel's actions taken due to the AI system's prescriptions

The COMPACS system provides:

- Commissioning of the equipment providing maximum potential life time
- Detection and elimination of fundamental causes of equipment failures (RCFA)
- Eliminating design and assembly errors
- Optimization of the unit’s equipment configuration

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<table>
<thead>
<tr>
<th>№</th>
<th>Indicator</th>
<th>Best World KPI (Source: Reliabilityweb.com)</th>
<th>KPI of Aromatics Unit operating under The COMPACS System</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total Maintenance Cost / Total Manufacturing Cost</td>
<td>&lt; 15 %</td>
<td>14.9 %</td>
</tr>
<tr>
<td>2</td>
<td>Maintenance Cost / Replacement Asset Value of the Plant and Equipment</td>
<td>&lt; 3 %</td>
<td>0.6 %</td>
</tr>
<tr>
<td>3</td>
<td>Planned Maintenance</td>
<td>&gt; 85 %</td>
<td>~100 %</td>
</tr>
<tr>
<td>4</td>
<td>Reactive Maintenance</td>
<td>&lt; 15 %</td>
<td>~0 %</td>
</tr>
<tr>
<td>5</td>
<td><strong>Availability</strong>: Available Time / Maximum Available Time</td>
<td>&gt; 97%</td>
<td><strong>3,5 years of non-stop operation</strong></td>
</tr>
</tbody>
</table>

Conclusions and Outcomes

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