

The real-time diagnostic COMPACS System™

An analysis of reliability of refineries and petrochemical plants shows that more than three quarters of malfunctions are due to failures of rotating equipment. High density of machines at the facility too often is a reason of accidents and breakdowns, downtimes, reducing of technical readiness of refinery and petrochemical units. Even if just 100 machines are operated at a facility, and the probability of fail for each one equals not more than 1%, there is one machine to fail for sure (**100 machines x 1% = 1 machine**).

To increase safety, reliability and availability of the facility, first of all, it is necessary to provide a visibility of machinery health during its life-circle (Fig.1). Most important is to provide early detection of machinery defects in operation, because almost 80% of malfunctions happen due to machine's operation mode changes and operation related issues including "human factor". So, if we can eliminate operation issues we can increase both safety and reliability and cut the gap in five times.

Nowadays we have made visible the machinery health in operation (Fig.2). We do offer tailor-made Real-time Diagnostic COMPACS System for refining and petrochemical units as wholes. The system transforms sudden defects into gradual ones

DEPENDENCY OF COSTS AND LOSSES FROM THE MOMENT OF A DEFECT DETECTION

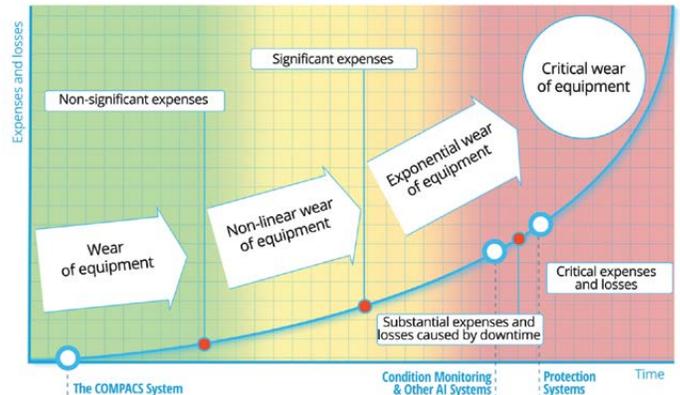


Figure 1. Expenses and losses within different defect development time points

through early detection and timely warning of the personnel about defects development. Since the system is installed, you forget about accidents and fires, breakdowns and downtimes. The COMPACS System warns personnel at early stage of machinery's degradation and pushes them to fulfill nearest urgent actions to eliminate destructive forces and to stop defect's development. The proper monitoring system educates operators to increase safety and reliability of operation therefore to achieve the best possible availability and operational costs of an equipped unit.



Figure 2. The COMPACS System monitors any machines of refinery Units



Becoming a customer of the COMPACS System, you obtain all advantages of the world class process plants at the same instance. At first, you totally eliminate accidents, fires and breakdowns in case of machinery fail. Next, you eliminate unplanned downtimes and make its duration as short as possible. Then, you significantly decrease the turnaround time because you exactly know what kind of machine has what kind of problem which should be solved. And of course, you dramatically drop both repair quantity and complexity and other maintenance actions. Finally, after overall vibration level will be decreased, you save an energy consumption of the unit up to 7% as well. All advantages mentioned above provide a payback period of the COMPACS System less than 6 month after it was commissioned at the Unit.

The COMPACS System monitors all machines which can influence on safety or on operational efficiency of the Unit (Fig.3). The system detects almost all possible defects of rotating equipment (Table 1) using vibration analysis and other non-destructive testing methods. The system executes totally automatic diagnostics and predicts defects with highest probability 97-98%. The system warns personnel at early stage of degradation of machines, therefore a staff has enough time to resolve most of issues. The system assesses the maintenance effectiveness in real time, provides the actual machinery health information to the management and other involved personnel, and helps to identify properly those responsible for what happened.

The COMPACS System provides an objective real-time monitoring of both machinery health and personnel's involvement. It gives a possibility to create honest and strong cooperation between management, and reliability, operation and maintenance teams of refinery or petrochemical plant. If do so, you achieve the longest possible equipment's life-time. Also, an equipment's maintainability is being saved. Timely and cause-oriented maintenance actions including operation mode's changing are being executed by all of teams together. Everybody is involved to extend operation time as long as possible and to cut downtimes as much as they can.

Once you have a common plan of cause-oriented maintenance provided by the COMPACS System



Figure 3. The Monitor mode of the COMPACS System – all machinery at a glance

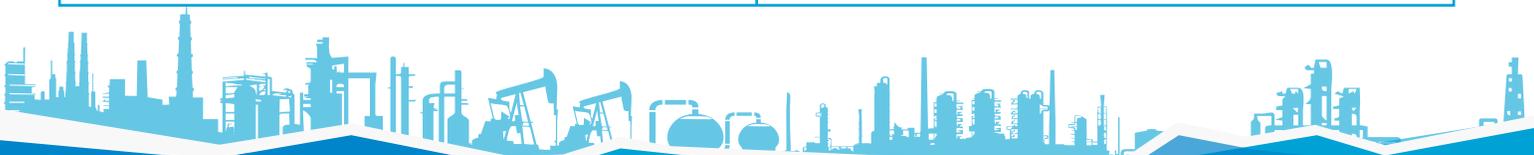
according to the actual machinery health, you can delegate responsibility for reliability decision making to operators. Nobody can be uninformed, nobody can do wrong or additional maintenance more than actually needed, nobody can stop funding under the budget – all these activities are monitored by the COMPACS System. Everyone at the refinery exactly knows what and when must be done, who and how must do it. Are you ready to be absolutely visible? Saying “Yes” you only can achieve the world class level in safety and operation efficiency.

Since 1972 Vladimir Kostyukov, his colleagues, pupils and followers have been researching vibration and acoustic signals of various machines and the associated defects. Whether you know, that Industrial Internet of Things (IIoT) was born more than 25 years ago, while the first generation of the COMPACS System was being developed at Omsk Refinery. The system is developed based on the unique patented algorithms of diagnostics of all possible machinery malfunctions which can be detected using vibration analysis by measuring of periodic and noise components of most informed bands of signals. The COMPACS System is the only monitoring system in the world which utilizes a wide range of nondestructive testing methods and has own thresholds for each of measuring signs to provide the real-time diagnostics of rotating equipment.



Table 1. List of machinery malfunctions automatically detected by the COMPACS System

Centrifugal machines	Piston machines
<p>Bearing:</p> <ul style="list-style-type: none"> • Lack of lubrication • Looseness • Outer ring faults • Outer ring deformation (out-of-roundness, pitting, spalling) • Inner ring faults • Inner ring deformation (out-of-roundness, pitting, spalling) • Rolling element faults • Cage faults • Journal bearing oil-film failure • Intolerable journal bearing clearance <p>Machine:</p> <ul style="list-style-type: none"> • Fastening problems • Rotor unbalance • Impeller faults • Intolerable rotor runout • Intolerable axial thrust • Coupling faults • Face seal faults <p>Package unit:</p> <ul style="list-style-type: none"> • Shaft misalignment • Rotating mass imbalance • Lubrication problems • Loose fastening to the base and attached structures • Gear faults • Belt drive faults <p>Electrics:</p> <ul style="list-style-type: none"> • Current overload • Phase mismatch • Stator faults • Rotor faults • Rotor/stator misalignment • Electric discharge activity in insulation • Internal insulation faults, voids • Contact sparking • Corona discharge • Partial discharge in cables <p>Temperature:</p> <ul style="list-style-type: none"> • Overheating • Uneven heating • Intolerable gradients <p>Hydro-Gas-Dynamics:</p> <ul style="list-style-type: none"> • Cavitation • Hydraulic impact 	<p>Valve:</p> <ul style="list-style-type: none"> • Broken springs, plates • Leakage • Hydraulic impact • Disturbance of process conditions <p>Main bearing:</p> <ul style="list-style-type: none"> • Wear of layer • Looseness • Lack of lubrication <p>Slider-crank mechanism:</p> <ul style="list-style-type: none"> • Wear of layer • Loose components • Lack of lubrication • Increased rod-slider joint clearance <p>Cylinder-piston group:</p> <ul style="list-style-type: none"> • Ring wear • Liner wear • Loose components • Lack of lubrication • Hydraulic impact • Disturbance of process conditions <p>Package unit:</p> <ul style="list-style-type: none"> • Loose housing parts • Rotating mass unbalance <p>Piston rod:</p> <ul style="list-style-type: none"> • Wear of rod glands • Bent rod • Broken rod



The COMPACS System has a distributed fieldbus. The sensors are installed on machines without damaging their bodies. Small pumps and motors less than 50kW power capacity are being equipped with just one vibration sensor. The particular quantity of sensors is being considered within project development study of system implementation, but usually we put just one accelerometer on the bearing's shaft, which is completely enough for diagnostics. Up to eight sensors measuring different parameters are connected to peripheral interface module placed close to machines (Fig.4). Modules are connected to each other and send analog signals to a diagnostic station. The diagnostic station is placed in the control room of the unit where operators serve as always 24/7. The diagnostic station analyses the signals, displays the current information about all machinery of the unit on the monitor, warns the personnel by color and text on the screen and by the computer voice of nearest urgent action to be done to increase the life-time of a particular machine.

Current machinery health information from all systems of the refinery is integrated into the COMPACS-Net plant diagnostic network (Fig.5). This source presents objective information to all involved staff of refinery – operators, maintenance, reliability teams, management about machinery's health and effectiveness of personnel's actions. The plant's network saves all measured parameters into the own databases and provides the users with signal trends, logs and issued diagnostic prescriptions within 9 years since the system was implemented. The COMPACS-Net makes networking process between involved staff more visible, reliable and sustainable.

Nowadays the 7th generation of the COMPACS System provides real-time monitoring and diagnostics of more than 25,000 machines of 2430 types (with different kinematical diagrams) at hundreds of units of dozens of enterprises in 12 process industries and railway. We provide the system implementation on a turn-key basis. It means that we develop the project including all installation drawings, we manufacture the system according to the devel-

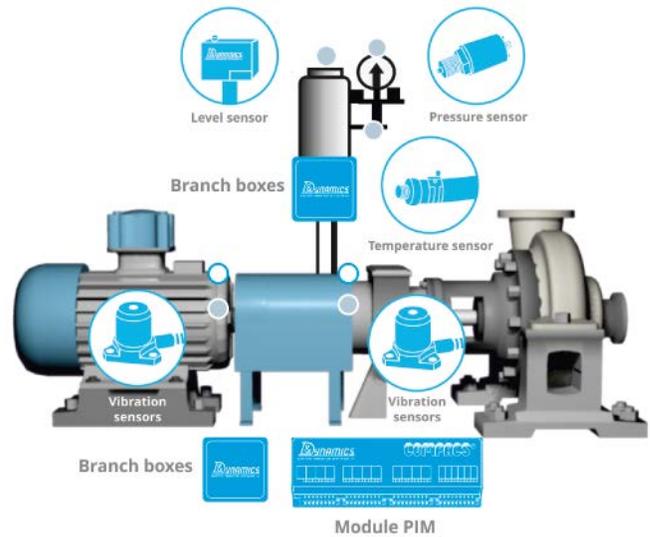


Figure 4. The COMPACS System fieldbus

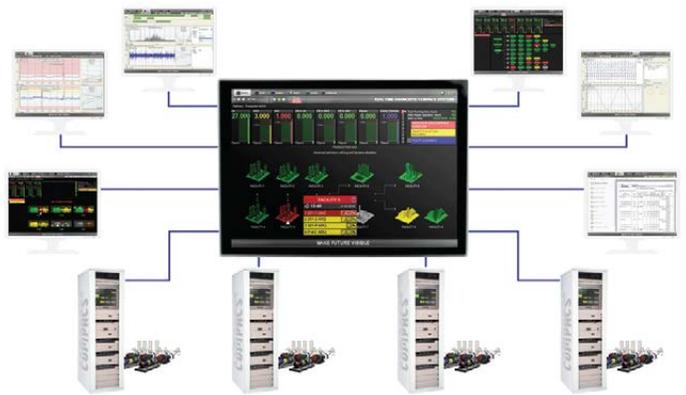


Figure 5. The COMPACS-Net plant diagnostic network

oped project, we deliver the system to the customer's site, install and commission it. Finally, we provide pre- and post-installation services including system's maintenance and other. Depending on customer's requirements the COMPACS System can be sold by both possible ways – the system as is or the system as a service (SAAS). **Would you like to achieve the world class safety and reliability? Let's install the COMPACS System and your dreams become a reality!**

