Risks and Faults *We Can Detect* Using Machine Learning and Physics

Condition monitoring has grown up.

In its earliest form, technicians manually took condition status readings from individual pieces of equipment and used them to shape maintenance conclusions.

Today, critical machine and system data can be streamed continuously, automatically, from industrial internet of things (IIoT) sensors for real-time analytics, diagnostics, and suggested actions.

The advantages of getting it right are substantial. Armed with awareness of emerging risks and faults, maintenance and reliability professionals can preemptively adjust, repair, or replace affected equipment before costly and potentially devastating consequences occur. However, not all the enabling solutions are alike. What varies is the application of advanced technologies; the caliber of the data analytics; the scope of adverse conditions detected; and the time and skills required to implement the solution.

Key Findings

- Distinctive condition monitoring and analytics capabilities for connected industrial systems set the Tignis solution apart.

- Multiple mechanisms for automating detection of risks and faults provide time to correct course before threats lead to crises.

- The ability to detect diverse types of hazards optimizes preventive and predictive maintenance effectiveness.

Tignis couples IIoT sensor data with a unique physics-driven approach to analytics, driving insights into connected mechanical systems that were inconceivable not long ago. The company provides software-as-a-service (SaaS), accelerating implementation and time to value. Because it applies multiple automated threat detection mechanisms, the software can identify at least eight different categories of detrimental conditions, providing a complete reliability and optimization solution.

Differentiated by Design

The Tignis condition monitoring and analytics solution automatically generates intelligence that complements human learning, ensuring ongoing improvements in predictive and preventive maintenance.
Machine learning (ML), digital twins, adaptive modeling, and simulation bring hidden threats to light in time for skilled users to proactively apply corrective actions.

It is a novel approach that employs the physics of flow— whether fluid, electricity, mechanical energy, or heat—to produce high-speed analytics, refined diagnostics, and root cause evidence of degrading conditions or performance. Cloud-based ML algorithms continually monitor and learn from the asset or system's physical properties to detect risks to reliability and predict operational impacts. Because the algorithms adjust easily with changing conditions, false positives are avoided.

Another distinction is its delivery: ML-as-a-service (MLaaS). No new roles need to be staffed internally because the necessary IT, data science, and domain expertise are provided along with the software. The customer needs only its existing piping and instrumentation diagrams (P&IDs) and historical sensor data for the learning process to begin, even for the most complex systems.

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Intuitive Detection Strategies

The Tignis solution contains four automated mechanisms for detecting risks and faults, each of which requires a different set of available information:

Anomaly Detection

When monitoring a system, the observed value of a given physical property is constantly compared to the predicted value, and if there is significant or sustained variation, it is marked as anomalous. This may include flow, load, force, pressure, temperature, vibration, or other performance variables.

Powered by ML, anomaly detection involves taking historical sensor data, picking a measurable outcome that matters (usually one sensor that measures a particularly important physical property), and then training an ML model to predict that property based on the measurements of other correlated properties across the system.

Anomaly detection can be applied to any digital twin with sensor data, even when Tignis data scientists personally have no idea how the system or machine works before seeing it. This minimizes barriers to value.

Engineering Principles and Statistics

Issues can be detected based on known engineering/physics principles and statistics using Tignis' proprietary analytics query language. The digital-twin-aware query language sits somewhere conceptually between SQL and Excel, and it is designed to enable non-technical subject matter experts such as mechanical engineers to easily and quickly build rules about how a system with a given digital twin should perform. Compared to anomaly detection, this mechanism can be more prescriptive about detected problems and possible solutions.

Engineering principles require encoded engineering/physics rules for at least one of the components in the system being modeled. Fortunately, many basic components are common everywhere, including pumps, fans, tanks, compressors, and more.

Tignis works with each new customer to add new rules for the processes and assets they really care about, whether they are common or not. The efforts are facilitated by the increasingly large library of encoded engineering knowledge we are amassing.

Supervised Machine Learning

The most effective ML develops when training examples are available; specifically, records of past occurrences of events that should be preemptively predicted and prevented in the future. Supervised ML enables early detection of previously experienced issues. Think of this as training a machine to recognize the signature of an undesirable condition.

Supervised ML requires well-documented and annotated digital records of past failures along with associated sensor data. That data often does not exist but is incredibly effective when it does.

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Simulation

Never-before-experienced issues can be detected early by combining supervised ML with simulation. If a high-fidelity simulator is available for a process, Tignis can use it to simulate any possible state of the system and generate training data, which is then used to train an ML early-detection algorithm. The ML detection algorithms are orders of magnitude faster than the simulation and can be practically applied in real time.

High-fidelity simulators are not widely used in industry at the moment. They are most often reserved for the most risky or complicated plants or processes, such as nuclear plants or some hydrocarbon plants, because they can cost millions to build and will only apply to a single plant. That will change as Tignis has developed techniques and tools that make simulation more accessible. Tignis has world-class experts in chemical engineering, mechanical engineering, and physics who can build simulations for high-value processes. For example, Tignis recently built a simulator for the physics of one process step within semiconductor processing.

Comprehensive Condition Intelligence

While most plants do not have the necessary data to immediately start utilizing supervised ML, many plants have collected at least a few months of historical sensor data. With this data, here are examples of classes of faults that Tignis can detect using anomaly detection and engineering principles:

Mis-sized or out-of-spec equipmemt:

Tignis can detect incorrect or improperly sized equipment. For instance, a pump that had been shipped from the manufacturer with the wrong size impeller inside could have produced devastating outcomes had it not been discovered by the software. Another example is valves not sized for the expected differential pressure, which can make them hard to control.

Sensor Failures:

Stuck sensors, bias sensors, drifting sensors, miscalibrated sensors—Tignis has discovered these and more. Failed or failing sensors can invalidate decisions made based on their readings. In systems with automated control loops, a bad sensor means an incorrect control decision. Depending on how bad the sensor error is, outcomes could be catastrophic.

Out-of-control / unstable controls:

Almost every plant that Tignis monitors has an automated control loop that attempts to maintain certain setpoints. Control loops must be tuned to ensure that they are stable and will always converge. Just as a car constantly overcorrecting will swerve back and forth, posing a dire hazard, issues like this can occur in control systems. They are technically "out of control" not only because they may never reach the setpoint in some cases, but the oscillations can propagate through the system and cause havoc in unpredictable ways. Tignis has detected and resolved issues where systems had multiple control loops that interacted with each other in unpredictable ways.

Mechanical wear and obstruction:

When the right sensors are available, Tignis can pay close attention to the amount of work a system is doing and compare it to the power utilization of the associated assets. When changes or trends in asset or system efficiency are identified, it often can be traced back to problems such as a bearing that is starting to wear, a filter that is becoming clogged, fouling on the inside of pipes, or stuck and leaky valves or dampers. Identifying these issues when they are just emerging provides time to avoid critical conditions and failure.

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Hidden component failures:

Tignis brings hidden conditions to light. For example, large and complex monitored systems often have redundant components. In the case of multiple fans ventilating a cleanroom, when one fan fails, another can provide the full service, but that "backup" fan is now the "critical" system as it does not have its own backup. If Operations is unaware of the primary fan's failure and need for repair or replacement, it puts the cleanroom at risk. Another hazard is intermittent or momentary component failures, which can precede a complete failure. These, too, may be missed by Operations if not automatically detected.

Automation programming errors:

PLCs and similar control hardware must be programmed. The quality of automation programming can be highly variable, particularly with respect to handling exceptional conditions. When a system enters a state that was not predicted by the programmer, unexpected results may occur and lead to unanticipated and potentially catastrophic situations. Tignis' automation can detect some or many of these errors by monitoring the resulting physical properties.

Incorrect schematic data or incorrectly labeled sensors:

P&IDs are not always updated correctly, and sensor tags are frequently wrong or undecipherable. These issues raise the potential for detrimental events, as both humans and computers may be making decisions based on faulty knowledge of how the system is built or currently being operated. Tignis can help to detect such errors so they can be proactively corrected.

Violations of best practices or regulatory compliance:

Most plants have well-documented design standards for equipment, and some plants are subject to governmental regulations. The standards and requirements can be encoded in Tignis' proprietary query language and continuously monitored to prevent violations.

See what Tignis can do for your business.

For more information on applying physics-driven analytics to your systems monitoring data,

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