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DANIELI TOTAL ASSET MANAGEMENT SYSTEM*

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Abstract
This article introduces the Danieli Total Asset Management System, which involves 360 degrees service methods and equipment. Danieli Condition Monitoring System and Danieli Torque Monitoring System are fundamental to evaluate the conditions of the working components in heavy duty transmissions. The first one monitors the vibrations and the lubrication fluid conditions with the purpose to identify the presence of malfunctions, by detecting any variation of the signals from the standard values. The second one monitors the transmitted torque for each spindle and gearbox, with the aim of detecting any anomaly in torque distribution and magnitude, and evaluating the residual life of the mechanical parts, on the base of a dedicated fatigue damage algorithm. All these features are useful in avoiding serious damages to machines, facilities and people, but allow also planning the maintenance and overhaul activities with efficiency, in order to achieve the best plant availability and reliability. The data analysis is made by the IntelliCMS software, which interfaces with plant and Danieli operators and includes the possibility to cooperate by remote connections, simplifying service activities and support. All these features allow providing new full service programs, where the client is totally supported in maintenance, overhauls and substitutions. This is the best way to ensure the most efficient, high quality and reliable after sales assistance.
Keywords: Torque monitoring; Condition monitoring; Vibration analysis; Fluid condition; Failure prevention; Maintenance scheduling; Life prediction; Full service.

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1 INTRODUCTION

The need to get the best performance and profitability of a steel plant requires the implementation of the most efficient service methods and equipment. Safety, productivity and maintenance costs depend all on the reliability and the capability of the installed machines and mechanical components, which could be ensured by a continuous and accurate monitoring of their conditions.
The Danieli Total Asset Management System has the purpose to guarantee a full view of the critical parameters, which have a key role on the duration of each machine and component in power transmissions, and to support strategic decisions for the production management. As a matter of fact, collecting and storing parameters data from machines during the operating conditions such as torque, vibrations, temperature and lubricant state, aids in making decisions about their repair needs, in order to organize an efficient maintenance plan and to achieve high plant availability and reliability. The aim of this system is to switch from a breakdown maintenance strategy to a predictive “zero-breakdown” strategy with the purpose to reach the most economically profitable equilibrium point between maintenance costs and plant availability.

2 MATERIAL AND METHODS

2.1 The Condition Monitoring System (CMS)

The Condition Monitoring System is suitable for every rolling mill drivetrain, on which it monitors different parameters under working conditions, such as vibration frequency and amplitude, lubricant cleanliness and temperature. Any significant change of relevant signal values might indicate a defect, so the possibility to monitor these parameters allows prompt actions in case of malfunctions, in order to prevent more serious and dangerous breakdowns.
Condition Monitoring System is a complete package which includes all the hardware and software along with a complete assistance ensured by certified Danieli personnel.
Its hardware architecture is comparable with all the standard systems for signal monitoring. The signals generated by the transducers (i.e. accelerometers, contamination sensors, water sensors), are amplified and converted by a remote unit (IntelliCMS RIO) before being collected and elaborated by the data analysis unit, which interfaces also with the plant automation to collect operating data and to manage the alarms. A central server (IntelliCMS server) receives and processes the data with the software (IntelliCMS software) to analyze the signals’ behavior. It makes decisions on the alarm management, creates different types of reports (on post analysis, alarms and trends), monitors and manages the hardware, warns the operators via e-mail to reach them wherever they are. In addition to the equipment, the system involves new type of service with periodic controls, remote assistance and maintenance support. The periodic analysis performed by skilled and certified specialists, together with the possibility to benefit a prompt remote assistance, considerably enhance the after sales service ensuring higher efficiency and accuracy.
The return of investment of the CMS is related to the predictive maintenance concept that allows organizing the activities during the scheduled period, avoiding all the costs mainly due to unscheduled downtimes.

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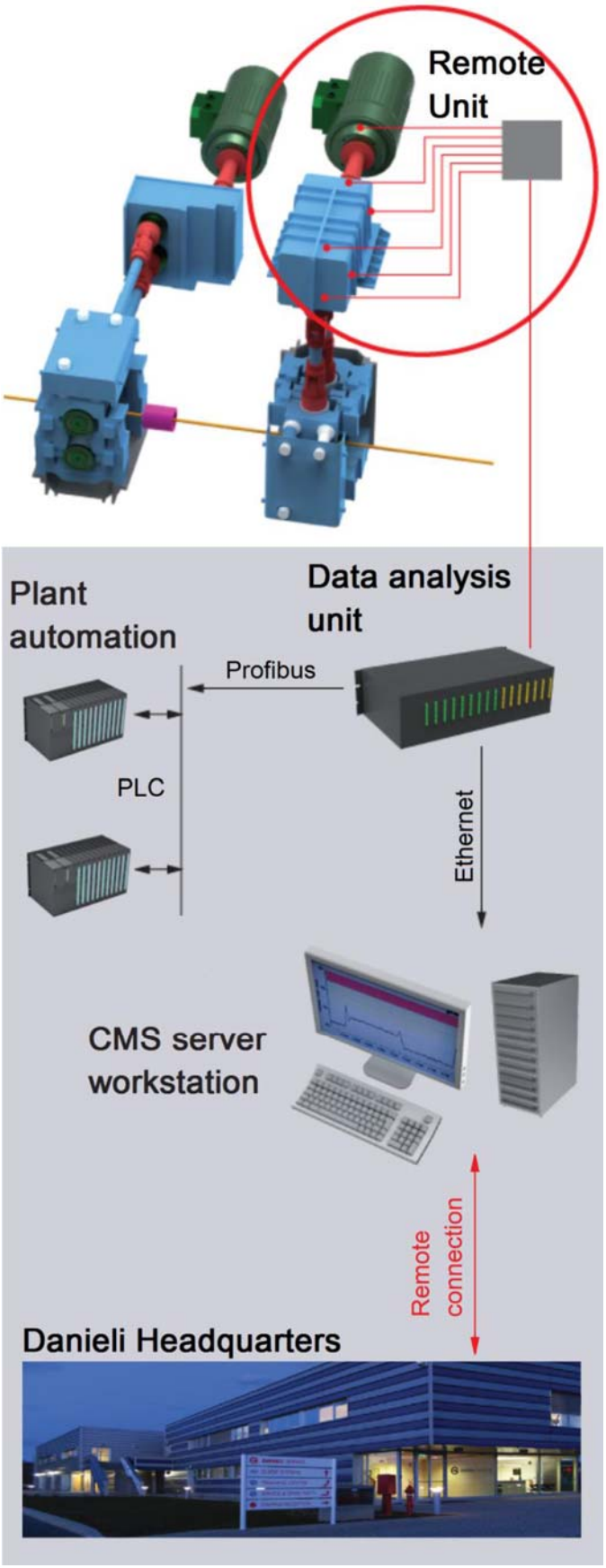

Figure 1 - The Condition Monitoring System hardware architecture allows an easy data processing and a direct collaboration between customers and service provider, characterized by an optimal integration with the plant automation.

2.2 Vibration Monitoring and Analysis

Vibration monitoring can give an immediate feedback on the machine status, because it is the best method to identify unexpected failures, wears and configuration errors. The presence of unbalances and misalignments, as well as mechanical looseness, bearing failures, gear defects and electrical motor problems, has an influence on the system vibrations. Each one of these non desired situations produces different vibratory effects in terms of frequency, peaks amplitude and overall values.
In fact, two main parameters are useful to describe a signal and its time variation due to structural and mechanical problems, that are the signal RMS, which gives a numerical interpretation of the overall signal value, and the FFT, which gives a complete view on the influence of every single frequency present in the signal.

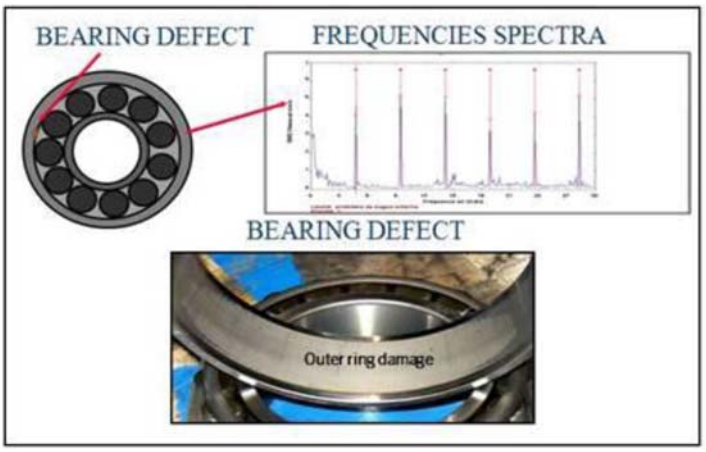

Figure 2 - Each type of failure produces different effects on the vibration signal, depending on its nature and the rotating speed of the component where is located.

All rolling elements turn in accordance with their own speed and generate a specific vibration at a typical frequency which could be calculated according to geometry parameters like gear ratio, number of teeth, dimensions, number of vanes or blades. In presence of defects, the resultant pulsating forces acting on the system are characterized by these frequencies, measured in Hertz, that are called defect or forcing frequencies. The status of the rotating components produces specific conditions in terms of amplitude level of each single forcing frequency. The analysis of these forcing frequencies, with the related amplitude, defines the kind of the defect and its seriousness.
Therefore, the aim of the vibration analysis is to detect the working speed and equipment vibrations in order to identify the conditions of each single component. In doing this, fundamental is the interfacing between CMS and plant automation from which are obtained the operating data to be compared with the frequencies monitored.
The system is very flexible and can be designed for long, flat and tube rolling mills, and for several type of machines like gearboxes for rolling mill stands, cantilever type blocks ESS, BGV blocks, bevel gearboxes, laying heads, gearbox distributors for Kocks blocks, disk saws, motors, pumps and fans.
The alterations of the vibration signal are mainly caused by malfunctions of bearings, gears and shafts. The IntelliCMS software processes all the vibration signals deriving from the piezoelectric transducers, with a real time evaluation of their characteristic parameters to identify non correct behaviors and, in case, start warning procedures.

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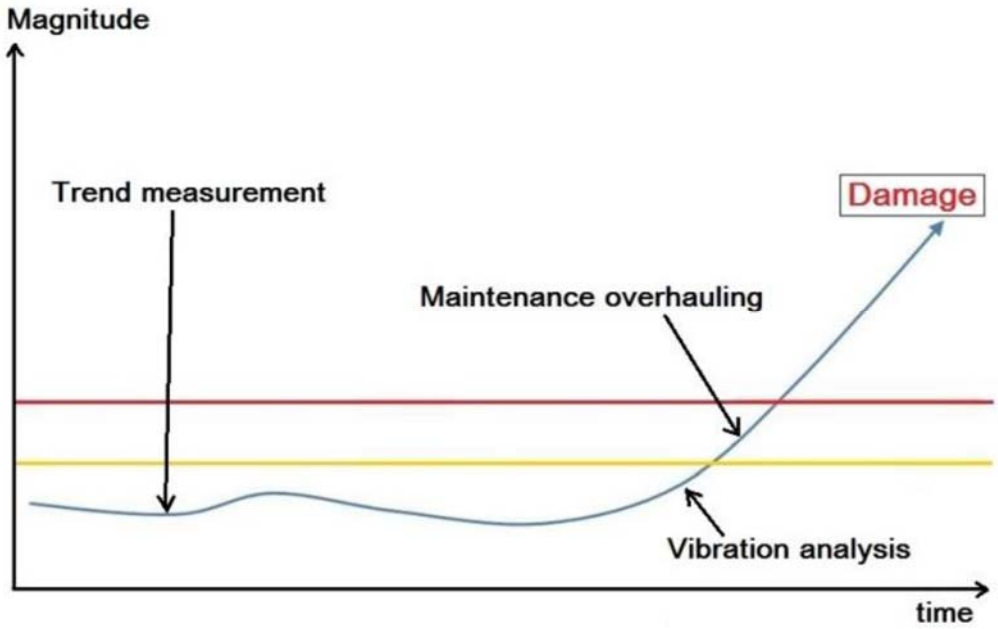

Figure 3 - Software intervention logic. Before the maintenance need, the software detects an increment of the vibration trend and warns about the close necessity of maintenance overhauling, avoiding serious damages to the machines and supporting a smart planning of the activities.

2.3 Fluid Condition Monitoring (FCM)

Another useful control instrument that is used in synergy with the vibration analysis is the Fluid Condition Monitoring.
All the operating fluids, both from hydraulic and lubrication systems, are the primary vectors for debris and polluting elements such as dust particles and water. These undesired elements could worsen the lubrication properties of the lubricant and increase wear between contact parts in relative motion, as well as obstruct the ducts. Their presence could not only be the cause of an excessive wear and a beginning failure, but their consequence.
Debris that are generated by malfunctioning of some operating parts are characterized by a higher hardness as a consequence of the plastic deformation during etching. So, once they are picked up and carried by the fluid in other areas of the machine, they can generate a more aggressive wear in all the relative motion contacts. In any case, whether or not they are produced from the components of the machines, it is fundamental to detect any presence of them in the fluids.

Figure 4 - Examples of metallic debris released from rotating elements as gears or bearings. The 40% of bearing failures are caused by bad lubrication.

In addition to polluting elements, another important parameter to check the working condition of the machines is the fluid temperature. Most of the times the operating fluid have also the function of cooling the mechanical parts, and every increment of its temperature could be a feedback for understanding the presence of malfunctions, such as not well lubricated contacts, failures and wears.
High temperature, debris and polluting elements weaken the lubricant action of the fluid, causing more aggressive wears, choking and breakdowns. So the monitoring of lubricant status is essential to maintain the rolling elements in optimal condition.
The FCM monitors all these parameters, and is a system fully integrated with the CMS hardware and software. In presence of both vibratory anomalies on structures and undesired pollution in lubricant, the nature of these allows to confirm or detect the right defect element and assign the possible cause. Furthermore, this monitoring gives a feedback for change oil service to apply predictive maintenance.
The Contamination Sensor Module includes a contamination sensor, a water saturation and temperature sensor.
As for the vibration analysis, the software evaluates all the parameters in real time, manages the warnings, archives historical trends and identified alarms, generates different types of reports.

2.4 Torque Monitoring System (TMS)

The Torque Monitoring is the most suitable instrument to evaluate the operating conditions for torque transmission parts.
The aim of the system is the real time monitoring of the torque signal detected by means of strain gauges, which are placed on rotating components like spindle shafts and couplings. It could be designed both for spindles and gearboxes, with the purpose to know the workload to which every component is subjected.
If the system is applied on rolling mill spindles related to a single drive unit, which implies the presence of a pinion stand combined or not with the gearbox, it is possible to evaluate the real torque distribution between the upper and lower spindle, and thus between the two pinions.
Measuring the torque on the exit side of the gearbox is also useful to see all the torque fluctuation due to rolling process. These peaks of torque could be very dangerous for the transmission parts closer to the rolling mill.
The system can be fully integrated with the CMS architecture, and interfaces with the operators thanks to the same IntelliCMS software used for vibration and lubricant analysis.
Having a continuous supervision on the behavior of the torque transmission has a great importance both for customers and designers. In fact, knowing the torque signal is useful to find out functioning anomalies, but it supplies also a feedback on real operating conditions in order to design the components and the machines to be suitable for the specific application.

2.5 Life Prediction Module

Life Prediction Module is an integration module for the Torque Monitoring System which aims to control the amount of load that the parts undergo since their installation and to evaluate their remaining operating life. This leads to the possibility to prevent failures and to plan with sufficient advance the maintenance activities and the parts replacements. The system is useful to understand the conditions of the

transmissions' most critical components like bearings, gears, spindles, gear couplings. Monitoring the filtered torque signal allows to recognize, measure and classify the different load cycles acting on the components, on the basis of a "rainflow" method. The stresses produced by the torque on each single component are evaluated thanks to calculation standards, notch factors database and, for complex geometries, Finite Element Analysis. Every torque cycle is related to a component's stress level and endurance detected from the relative fatigue-life curve. So, with all these parameters available, it is possible to evaluate the cumulated fatigue life for each component. The torque value range is split in several classes, each one with its relative stress value deriving from FEM analysis. So, a torque cycle will be approximate with the stress value of the class to which it belongs, and the cumulated fatigue is computable from the number of cycles of each class.

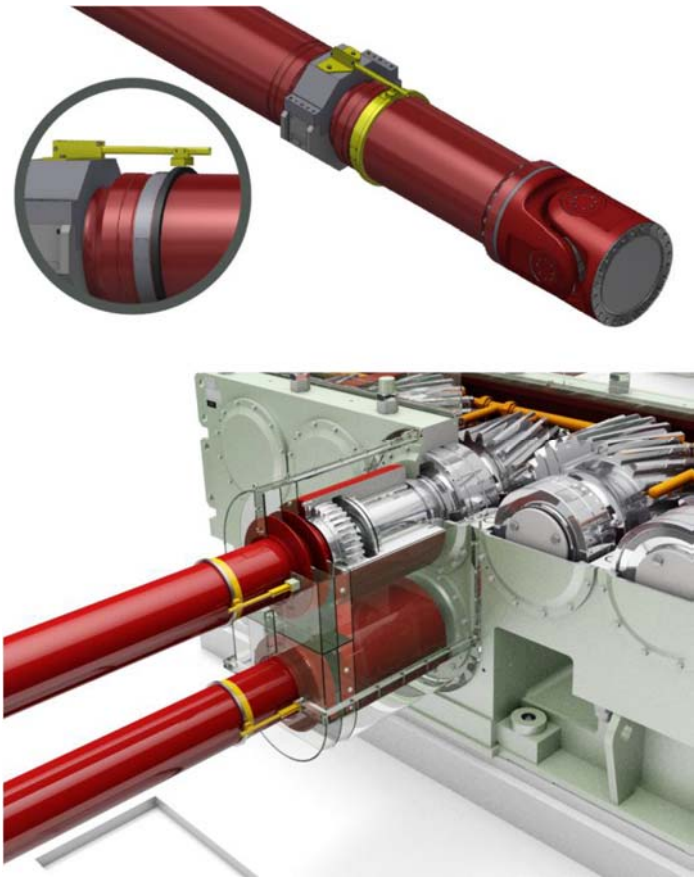

Figure 5 - Torque Monitoring System configurations for a cardan spindle and for a couple of gear spindles mounted on pinion stand combined with gearbox. The signal is collected by strain gauges placed on the shafts and after its amplification is transmitted to a static receiver connected to the same local unit used for CMS.

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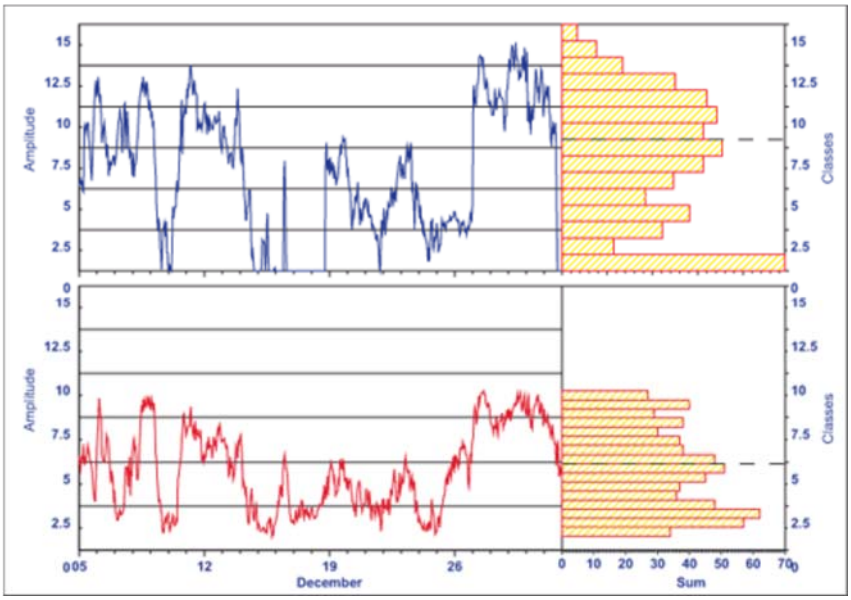

Figure 6 - Continuos integration of the total number of cycles, for every torque class, that the spindles undergo.

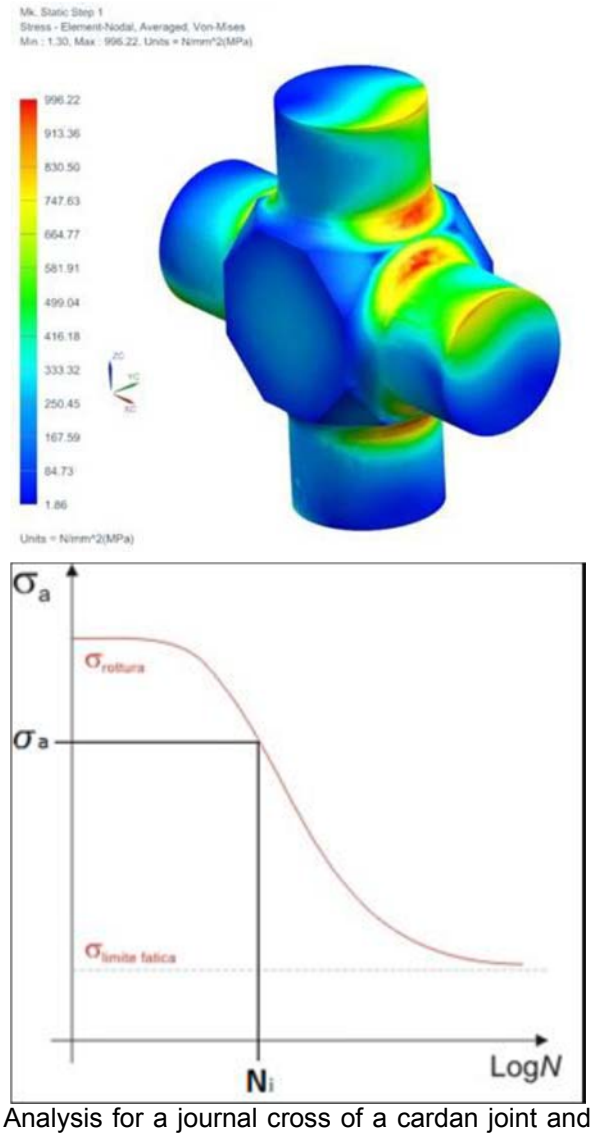

Figure 7 - Finite Element Analysis for a journal cross of a cardan joint and relative fatigue-life curve. The equivalent life consumption is evaluated combining the different cycles.

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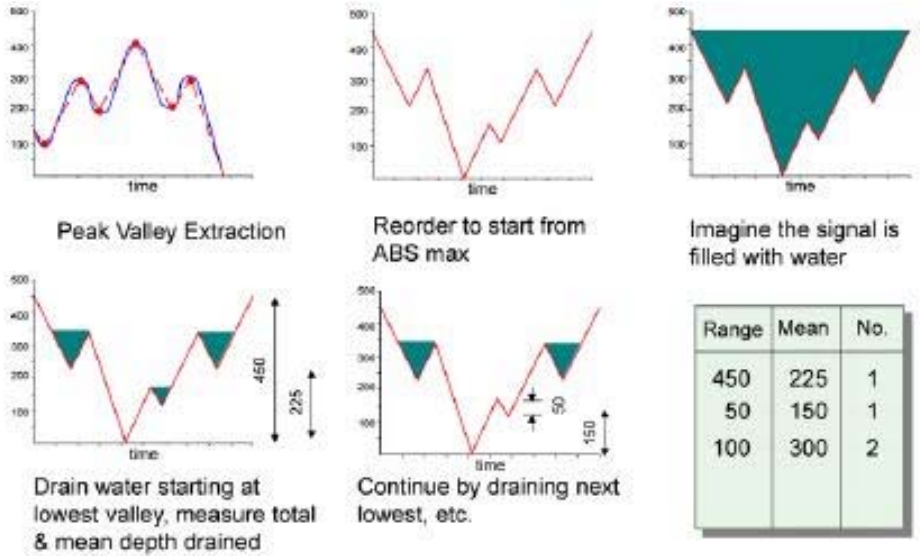

Figure 8 - Typical rainflow method for the identification of the different load cycles.

With respect to the bearings, their life is evaluated with advanced formulation that considers the application times of each force, which is directly related to the torque. In this case the method doesn't count the number of cycles, but only the duration of each applied torque split in classes.
A continuous integration of the parameters ensures a real time consciousness about the components' state.
The most important benefit of TMS is to optimize the maintenance procedures preventing failures before they start. This method allows organizing in the best way and with sufficient advance all the plant downtimes needed to replace the parts.
Therefore, unlike the CMS which acts only when a malfunction already started, the TMS anticipates that moment and gives an earlier estimation on the maintenance need.

2.6 A New Concept of After Sales Assistance

All the features related to CMS and TMS open the possibility to start a new business model.
High precision monitoring methods, together with the experience and skills of the Danieli staff, can ensure a very efficient and reliable service.
Thus, full service or full leasing contracts with the customers are the innovative way to serve them at 360 degrees as a single point of responsibility, thanks to the direct supervision and analysis of the main parameters by the Danieli specialists.
This type of contracts guarantees the customers for a total assistance in maintenance, overhauls and replacement of vital parts, as well as for a professional support in the assessment of the main parameters by certified personnel. Is the best method to prevent downtimes, avoid damaging larger parts of the plant and, last but not least, increase the safety standards for the people who work in proximity to the machines.
On the other side, the supplier has the possibility to directly evaluate the working parameters of the installed machines also from the headquarter, thanks to the availability of remote assistance, and collect useful data to optimize the component design and always offer the best quality solutions.

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3 CONCLUSION

Monitoring the operating conditions of the plant machines is a key point to apply the best maintenance policy and avoid expensive downtimes and damages, which could be dangerous also for the operators. Danieli Total Asset Management System, thanks to its new full service package, will do the difference to obtain the best performance with competitive costs, enhancing the plant availability and reliability.

Abbreviations

CMS	Condition Monitoring System
FCM	Fluid Condition Monitoring
FEM	Finite Element Method
FFT	Fast Fourier Transform
RMS	Root Mean Square
TMS	Torque Monitoring System