Automation India

Enabling Global Competitiveness

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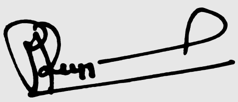
As India integrates with the world, Indian industry is staking its rightful claim in the emerging global economy. The 'complete value proposition' today, encompasses several key parameters including price, quality, productivity, efficiency, aesthetics and delivery systems among others. State-of-the-art automation technologies have a vital role to play in enabling all of these.

Metals & Minerals is among the fastest growing sectors in India today. In keeping with its primary mission of increasing knowledge and awareness levels and helping Indian industry leverage cutting-edge automation technologies, AIA is organising 'Metal Tech 2005'. Metal Tech 2005 is an important part of AIA's initiative of organising 'industry-specific' seminars.

Metals form the backbone for many industries. India has vast untapped resources of coal, iron-ore and bauxite which will hold the country in good stead. But without doubt we still have a long way to go. For instance, India's per capita consumption of steel is currently about 30 Kgs as opposed to China's 180 Kgs.

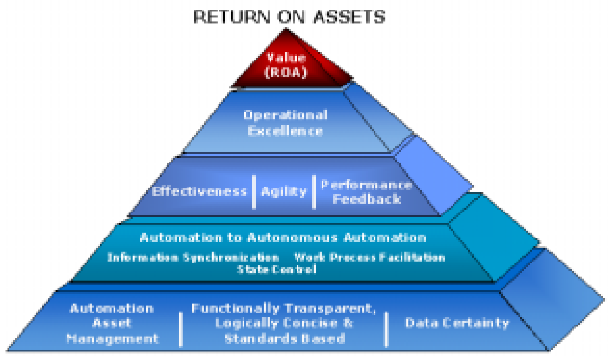
More than 100 million tonnes of additional capacity (over and above the 38 mpta of existing capacity) has been announced by Indian and foreign steel companies for the country. This addition could catapult India from the world's 8th largest steel maker to 3rd largest, behind China and the US.

In addition to new capacities and expansions, there is an increasing need to focus on productivity and efficiency as the Indian metal industry increases its international reach and strives for competitive advantage. The automation industry is ready, willing and fully capable of partnering the Indian metals sector in this journey.



Ravi Uppal
President, AIA

Collaborative process automation systems in the steel industry

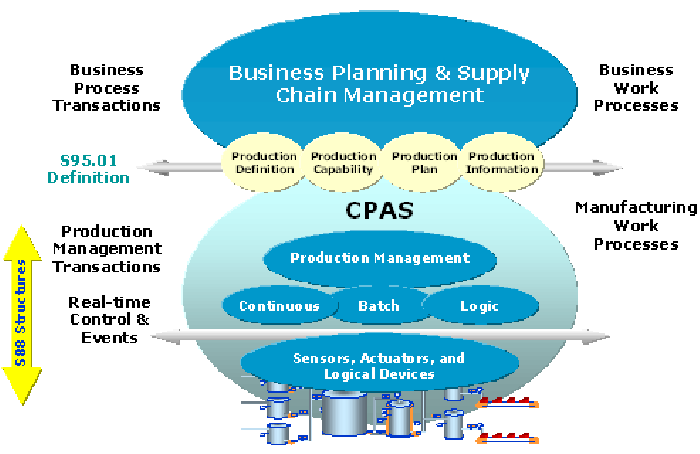


Collaborative Process Automation System (CPAS) Guiding Principles

Steel consumption in the world, around 1000 MT in 2004, is expected to grow at a steady rate. The global steel market is presently highly influenced by the demand from the emerging economies of the world significantly from China both in terms of production and consumption. China produced a record 270 MT of Steel in 2004. Back home in India, the production was of the order of 38 MT and is expected to reach around 120 MT in the next decade. With exports growing and many large global manufacturers besides domestic players setting shop in India, the steel horizon is encouraging.

Process manufacturing is headed into a new era that will require a level of coordination and functional autonomy that current systems are not designed for and cannot effectively support. This situation is aggravated by the fact that approximately $65 billion worth of legacy process control systems worldwide are in use that are rapidly approaching the end of their traditional life-cycle of fifteen to twenty five years. This is also applicable to the Indian steel industry to an extent.

The need for process automation is acute. The process industry on an average is faced with manufacturing assets that make up 75 percent of their total capital assets, while raw material and conversion costs account for 65 percent of their total operating costs. Process automation systems are controlling these assets and if they are not performing effectively as an overall part of a



CPAS Architecture

company's business strategy then profits and competitiveness suffer. Process automation can deliver an extraordinary competitive advantage. This is precisely what the Indian manufacturers should plan for, given the extreme competitiveness that has been brought about by the Chinese influence in the world steel market. In the words of Lakshmi Mittal, the business model of the world steel industry; "firstly, global demand has entered a new growth era, largely driven by China's industrialization, and secondly, significant consolidation has occurred, leading to a stronger industry." Consolidation phase includes competitiveness not only in terms of cost, quality, and product mix but also in terms of global benchmarks of efficiency and productivity and it is pertinent that the Indian Steel Industry adopts such an approach.

Steven Wheelright states that the effectiveness of a manufacturing company operating at the highest level is directly correlated to it being "internally synchronized and supportive". This should also be the measure for process automation performance. The highest level is only achievable by information empowerment. The Information Revolution has delivered the highest level at the business level but unfortunately has by-passed process manufacturing.

Collaborative manufacturing era

The collaborative manufacturing era will increase attention on the need for process automation performance. As manufacturing objectives have grown progressively more dynamic and complex, process automation as a major contributing factor to the success of the enterprise has lost its performance focus. A fundamental change is required to align the functions of process automation systems with higher-level business objectives in order to achieve enterprise performance in a dynamic business environment.

The Collaborative Process Automation System (CPAS) provides a strategy on how to address the demands of Collaborative Process Manufacturing and insight into what users should expect from their Process Automation assets. CPAS is a platform for applications. It is grounded in the principle that, beyond considerations for health and safety, the primary function of manufacturing is to deliver maximum Return on Assets (ROA). As a platform for applications CPAS delivers mission critical robustness, has no barriers to functionality, imparts the benefits of structure by embracing internationally ratified standards, and utilizes internet-core technology to provide common data and infrastructure. CPAS also provides a foundation for the next generation of automation which we refer to as "Autonomous Automation". It is based on flawless operation and aligning manufacturing work processes based on best practices and a culture of continuous improvement.

Challenges that are well understood by process manufacturers include the familiar requirements for increased quality and throughput, faster turnaround, and reduced variability. These pressures are increasing. The second set of challenges, the ones that are not well understood, have to do with the realities of Supply Chain Management in context of collaborative manufacturing.

Manufacturing meets Information Revolution

In the late '80's and early '90's, many companies identified a disconnect between their company, their customers and their suppliers. This disconnect had become a barrier to commerce and was compromising performance and competitiveness. Ultimately, enormous amounts of capital were spent on re-engineering business processes and adding new technology. The information age was born.

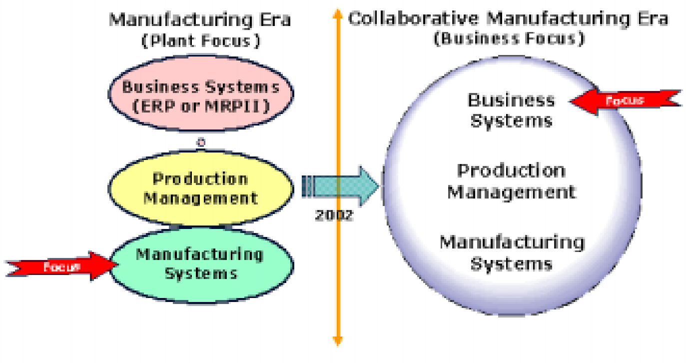
The results have been impressive. Productivity has increased dramatically, barriers to information have been eliminated, best practices and continuous improvement have been instituted and commerce can be conducted at internet speed.

The changes made at the business level were made to improve business by eliminating barriers to information and responsiveness. This was to be true within manufacturing systems and between manufacturing and business systems.

Collaborative manufacturing realities

In the manufacturing era, the focus was on the plant and it operated relatively independently based on high level targets such as maximum tons per day. Process control was loosely connected to Production Management through proprietary bridges that provided point access at best. Business systems were seldom electronically tied to manufacturing. Collaboration was done on need basis, typically with person-to-person communication.

In the fast-evolving collaborative manufacturing era, things are considerably different. Collaborative Manufacturing Management (CMM) provides the overall structure. Process control is no longer independent or the focal point of manufacturing. The focus is on enterprise performance and as such, business systems are the focal point and responsible for optimizing planning and scheduling while the manufacturing systems are responsible for responding optimally.



Transition to Collaborative Manufacturing

We are all familiar with the gap that has traditionally existed between businesses and manufacturing. The biggest difference has been that business was transaction based, primarily because MRP/ERP was transactional, while manufacturing has operated in real-time because the process runs in real-time. As a result, the boundary point at which people needed to react in real-time was much closer to manufacturing than business. In the collaborative manufacturing era, business systems are no longer schedule driven. Instead, they are real-time systems focused on the real business issues of capacity and product mix. They are driven by market opportunities and empowered with a view from suppliers to customers.

In this picture, something has also changed in manufacturing. The luxury of shift-to-shift planning is gone, the real-time boundary has moved to the business systems and plants are asked to make capable-to-promise and profitable-to-promise commitments in real-time to capture market opportunities for capacity and product mix.

In this scenario, Collaborative Process Automation Systems (CPAS) assumes a critical, supportive function that encompasses process control, field measurement, and actuation and production management functions. This level of collaboration places new emphasis on data and information access. Data needs to be accessible globally; information synchronization is required and revealed within the context of work processes both in manufacturing and business systems. Clearly fundamental changes are imminent and the barriers to performance need to be eliminated.

Legacy process automation systems are in place that have reached the logical end of their life cycle and were not designed to work in this type of collaborative environment. The biggest shortcoming in these systems is the ability to present a common view, common data and offer a common infrastructure for third party applications. Elimination of these barriers will force the replacement of these systems; however users need to make acquisition decisions based on a clear understanding of the need.

Operational excellence dictates CPAS requirements

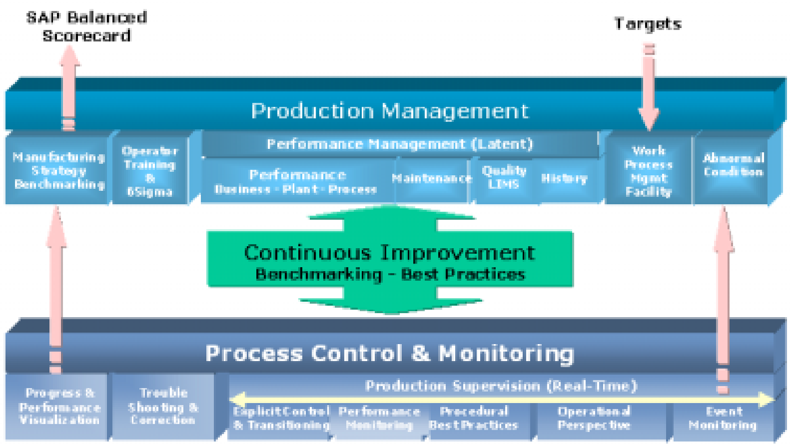
Under the CPAS Guiding Principles, Operational Excellence is the first supporting layer to asset utilization and ROA. Operational excellence delivers measurable performance improvements with support from synchronization. Effectiveness, agility, and performance visualization are keys to operational excellence. Effectiveness and agility support the principle of flawless operation. Effectiveness is the result of combining the right decisions with the ability to profitably perform the revenue producing activity and relates to highly efficient execution during steady states of operation. Agility relates to periods where the plant or process needs to transition between states or make adjustments as opportunities present themselves. The objective of agility is to sustain as close to the same efficiency as steady state in these transitions.

Autonomous automation is what makes operational excellence work. The concept of autonomous automation offers a coordinated basis for using process automation to address the performance issues in process manufacturing. Best Practices are central to successful autonomous automation. Technology is becoming available in emerging CPAS systems that instantiates Best Practices in an environment of real-time contextual data.

From	To
Unstructured work processes	Work Process Management
Too much information not in context	Information Synchronization
Implicit State Transitioning	Autonomous State Control
Passive Operator Involvement	Proactive Operator Engagement

From Automation to Autonomous Automation

You need to be able to measure performance before you have any hope of improving it. The reality is that most plants have no performance feedback. Most plant managers don't know their profitability until it is too late to take action, condition and capacity of manufacturing assets is vague, and actual vs. optimal chemistry is a



Operational Excellence Strategy

mystery. The resolution to these issues is clear: plant managers need activity based costing mechanisms for real-time feedback in time to take corrective action. The health and availability of manufacturing assets should be visible to operations in order to make "Capable to Promise" commitments, and reconciled process performance must be visible to make "Profitable to Promise" commitments.

Technology limitations are no longer an issue, the issue is how to revitalize lazy manufacturing assets to capture dormant productivity. CPAS is first and foremost platform for applications. It should use technology to eliminate any artificial barriers to business performance, at the same time support manufacturing and business work processes that optimize business performance.

CPAS delivers business performance

In order to deliver a true value proposition to process manufacturers, the next generation of process automation systems must clearly understand the requirements for operational excellence and translate them into an effective execution solution. Process manufacturing is under-performing and in many cases not returning its cost of capital, largely as a result of disconnected manufacturing and enterprise entities and the information depravation that creates. A collaborative environment of information empowerment built on proven technology can eliminate this disconnect and deliver a mutually supportive environment of synchronized, profitable operations. This is the vision of the Collaborative Process Automation System (CPAS).

CPAS is a scalable, high availability platform that facilitates a robust, data rich, and unbounded environment for control of the process. It is work process-centric where the work process is the manifestation of a commitment to achieving best practices. In process control terminology, CPAS provides the means to close the loop on business, plant, and process performance.

The scope of tomorrow's CPAS embraces production management (PM) applications as a core component as well as its traditional role of process control. This architecture reflects ARC's belief that process control and PM should be tightly bound into the same system. CPAS also facilitates the introduction of third party products from suppliers who possess a deep understanding of the process, plant, and operations. Likewise, continuous process improvement is also bound into the basic system to help improve integration of separate packages.

A unified communications structure lies at the heart of CPAS. This framework consists of two parts: a unified field framework (UFF) and a unified application framework (UAF). The UFF hosts sensors, actuators and logical devices in their primary functions and provides a standards-based distributed computing environment for field control. The UAF portion of the functional infrastructure provides synchronization.

Structure and purpose are very important to CPAS's performance orientation, and are embodied in the concept of autonomous automation and associated standards. Consistency fosters clarity and standardization, therefore creation and use of formal standards will provide the required structure.

State logic control finds it's time

At its essence, process automation is state-based. As it is implemented today, the operator usually has the implicit responsibility to transition the plant between states. In the past, this has worked reasonably well where transitions to new states of operation were infrequent and within the operator's ability and time constraints to make the transition.

ARC believes the operator has a more important role to play in the future. To achieve the goals of collaborative manufacturing, the operator must have the responsibility to supervise plant performance, intercede when alternative action is required, and participate in work processes defined by best practices. This is what the operator does best. The automation system is best at performing repetitive processes and it should be empowered to do so. Thinking of the operator as a knowledge worker is a step in the right direction and towards autonomous automation.

In the new collaborative manufacturing era, these state transitions will occur more frequently. The answer lies in the ability of the process automation system to be able to handle the majority of the transitions autonomously, with the knowledge worker (operator) having the time and information required to make more strategic decisions.

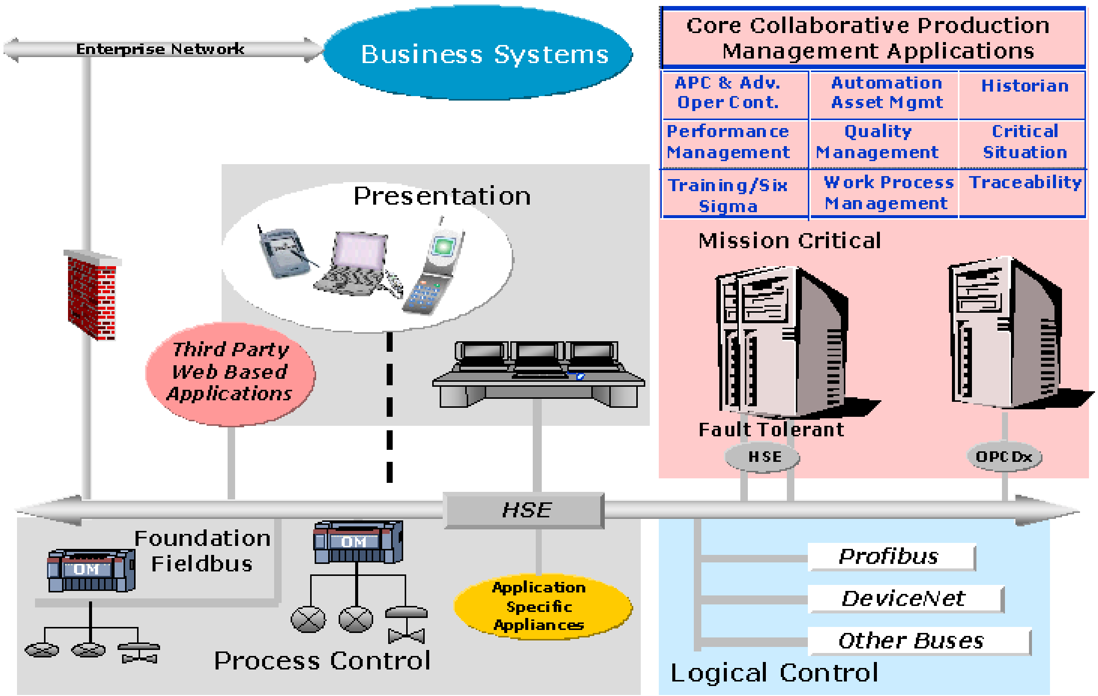
CPAS is a platform for applications

The value of CPAS comes from the applications it supports. In the context of operational excellence, we have developed an industry generic application strategy that embodies the approaches to process automation that have been discussed up to this point. This strategy discusses those applications that are generic across industries, it does not discuss applications such as material management that exist in all industries but tend to be unique in each industry. The strategy is split into process management & control and production management.

Process Management and Control

This is the domain of the operator recast as the Performance Supervisor. As we mentioned earlier, the operator has quite a different role to play with respect to collaborative manufacturing. The operator is no longer implicitly the center of control execution, the CPAS has explicitly assumed the responsibility for control of each state and transitioning the process between states all within the context of "best practices". CPAS also performs performance monitoring and provides a visual "Operational Perspective" (OP) of unit or plant operations.

OP is a good example of how things will change. Based on a finite number of plant parameters, most of which are dictated by production assets, it is possible to determine where the plant is operating in relation to its present capacity. This is possible in a real-time context



CPAS Takes Full Advantage of Today's Technologies

including all health, environmental and maintenance considerations. When this perspective is reduced to a single display, the operator has a very powerful tool in the new role of Process Supervisor. This tool would provide critical insight to plant management.

Event monitoring and logging is also performed at this level. In the new role, the operator has the responsibility for troubleshooting and correction assisted by new CPAS facilities. Finally, progress and performance data are collected, presented to the operator in relation to his KPIs, and then passed up to Production Management.

Production Management

The second part of the strategy is the Production Management level. The level is not real-time but has a near real-time focus on five primary functions. The first function is Performance Management and it is centered on the view of performance: business, plant asset and process performance. It also utilizes input from maintenance, quality and history. The Work Process Management Facility accepts targets from the business systems and is responsible for aligning automation and in turn manufacturing assets to execute to targets.

Critical Situation Management provides surveillance of manufacturing assets to determine abnormal situations and in that event provides guidance on how to maintain manufacturing assets in a safe state. 'Manufacturing Strategy Benchmarking' relates performance trending to targets, then typically delivers that perspective to Balanced Scorecard programs residing in the business systems. Operator training and Six-Sigma tools are off-line quality facilities.

CPAS logical view

CPAS focuses on Process Control and Logical Control separately to leverage the richest functionality of each. Process control utilizes the functionality of Foundation Fieldbus to provide process control anywhere. It takes full advantage of the common function block structure and Foundation Fieldbus services which are optimized around process control. It also uses the publish/subscribe facility of FF to support peer to peer and peer to host communications.

CPAS Platform Requirements

Another principle of CPAS is "the best automation system is one that is invisible". Automation should be a performance enabler, not something that exists for itself. The value of technology lies in its ability to eliminate barriers.

The functional architecture should not be encumbered in any way by the physical architecture. Current Process Automation System (PAS) architectures continue to have an element of restriction in the way functions can be deployed. For example, typically anything more advanced than regulatory control strategies needs to be deployed in computer hardware added to the PAS. Current physical architectures require resulting applications to pass through at least two layers of technology to reach the intended target-the plant floor.

From a functional view, there should be no barriers to data or information. ARC uses the term synchronization, and defines it as having the information when you need it to perform your function and satisfy your customer. We feel this is the essence of information empowerment and key to Collaborative Manufacturing. From a logical view, the system should not require bridges, gateways, and proprietary interfaces. It should be built on standards and benefit from the clarity and efficiencies inherent in being concise.

The physical architecture should result from the requirements of the functional architecture. Decisions as to where to place a functional component will be the result of answering the question, "where is the most effective location for this function," rather than "what component in the system has sufficient computing power and communication bandwidth to adequately execute this function." In this sense, the physical architecture will become amorphous.

Recommendations

The Collaborative Manufacturing era will offer many opportunities to those that get there fast and get it right. To be able to seize the opportunities, manufacturers must have a vision where they want to be and how to get there. Beginning with this vision, they must put in place supportive strategies to take them in the right direction. Just as manufacturers now have process automation systems that are at the end of their life, the next system purchase will some day become a legacy. Whether that legacy will become a dead end in 15 years or more, as many of these systems have, is dependent on how well they have developed their current vision and strategies.

We believe, manufacturing will have a collaborative future. The challenges will not be technical; the technology is available and proven. The challenges will be how to use technology to enhance business performance by implementing unified business and manufacturing Best Practices flawlessly. This will require common information, common business objectives, a common view of business performance and individual KPIs and flawless execution. Above all, assets must be aligned toward maximizing enterprise ROA.

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– ARC Advisory Group

Technological control for cold rolling processes

Key components for high-end thickness and flatness performance

Roll gap control

Two basic modes, either gap position or total roll force can be applied. Selection of mode depends on the type of superimposed Automatic Gauge Control (AGC) and the threading strategy. To ensure a constant response time over the whole working range, various process related adaptations and supervisions are included.

AGC for break down mills

Depending on the sensor concept based on customer needs, different thickness control strategies are possible:

- Thickness feedback control
- Thickness feed-forward control
- Mass flow control
- Speed feed-forward control
- Roll eccentricity control
- Tension feed-forward control

Thickness feedback control

The basic control strategy is thickness feedback (monitor control) based on the measured thickness deviation at the exit side of the mill.

The delay time, transport of the strip from the roll gap to the thickness gauge, essentially determines the control system's dynamic response, particular at a low rolling speed. The software package provides with a predictive model-based option to improve the dynamic behaviour of the thickness feedback controller significantly.

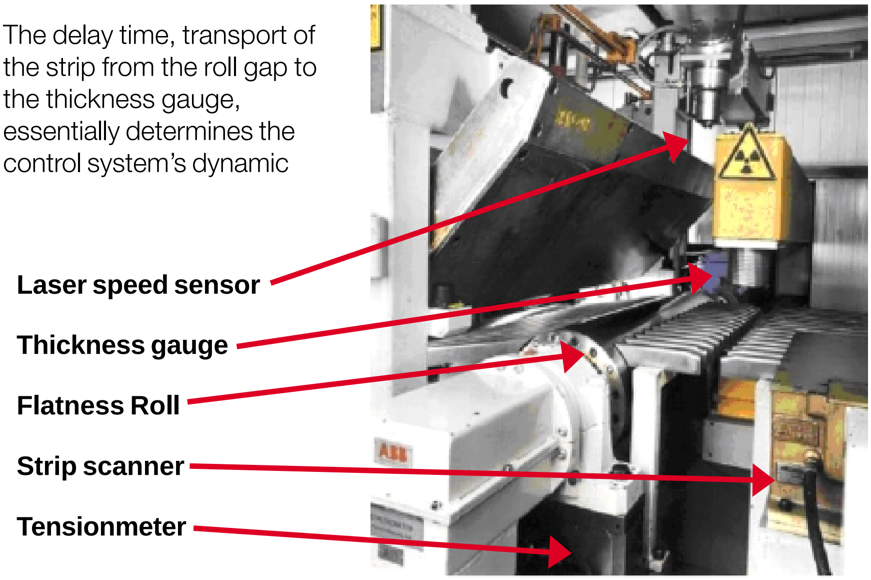
Thickness feed-forward control

If a thickness gauge at the entry side of the roll gap is available, the thickness feed-forward control can be applied. It is able to compensate any thickness deviation caused by changing entry thickness.

A correction value is calculated according to a stored entry thickness deviation and forwarded to the roll gap control for interaction when the strip section reaches the roll gap.

Mass flow control

Using the mass flow principle, the outgoing strip thickness at the instant of rolling can be computed from the incoming strip thickness and the in-and-out coming strip speeds. By means of this mass flow control concept, high control accuracy can be achieved. Therefore it enhances clearly the concepts of thickness feedback



Important sensors in a cold rolling mill and thickness feed forward concerning product quality.

Speed feed-forward control

With the speed feed-forward control solution, velocity dependent process variations are compensated.

Roll eccentricity control

Irregularities in roll geometry cause periodic variations in the roll gap, which can lead to variations in thickness of the rolled product. The predominant sources of these variations are the backup rolls of the stand.

The function compensates for periodic disturbances from geometric asymmetries on the backup rolls. An automatic adaptation to compensate changes during rolling (e.g. due to thermal effects, wear, loading, etc.) is implemented.

Tension feed-forward control

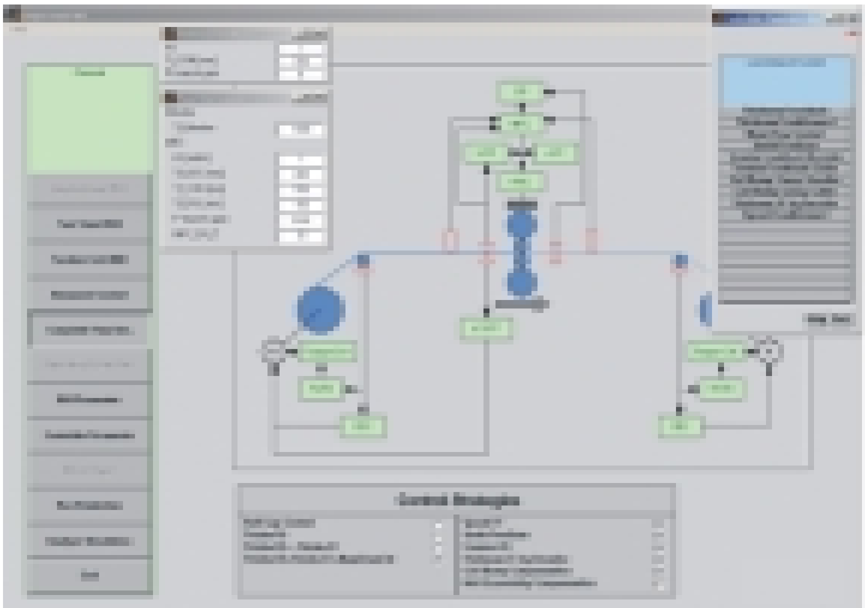
The tension feed-forward control responds to entry thickness deviations and applies a suitable adjustment to the coiler torque in order to consider the interactions between roll gap and tension.

AGC for foil mills

Speed-tension optimization is used in foil mill applications, since the strip thickness depends very closely on tension and rolling speed. In order to achieve maximum material throughput, the speed of the stand is increased until the strip tension has reached its control limit or the speed has reached a pre-selected technological limit value.

AGC for temper mills

Based on the measured elongation and the actual strip dimensions, fed into an algorithm, the elongation control module calculates a correction for the reference value of total roll force and /or tensions.



Example of a control concept for a single stand mill

Coil eccentricity control

The coil eccentricity compensation minimizes periodic tension oscillations generated by changes in the circularity of the coil. A major reason for it, is the strip head pressed in the slot of the mandrel or wrapped on a sleeve or mandrel. Tension torque corrections are applied at each rotation when the diameter change passes the contact zone of the strip on the coil.

Adaptive control concepts

The phenomena in the roll gap during rolling process are largely non-linear and time-variant.

Adaptive controller is used to detect changes in the system and its disturbances to modify the parameters accordingly. This adaptation is achieved under consideration of quality and stability criteria for the entire control loop.

Flatness control

Correct strip flatness is essential to ensure an overall product quality, productivity and successful subsequent processing.

Homogeneity of stress distribution and material shape is controlled by modular flatness software. Example of a control concept for a single stand mill. The flatness error, given as difference between the measured strip flatness and the target curve, can be minimized by modifying the roll gap with various control functions, such as roll-bending and skewing, shifting of rolls, cooling patterns and eccentric positioning control for multi-roll stands. The influence of each separate type of control action is defined by evaluated action curves. A least square fit of these action curves to the flatness error results in the most efficient combination of control actions needed to reduce the flatness deviation.

Coordinated control

Given the complexity involved in interaction of the final control elements and the demanded dynamics, the desired results can be assured only by automated coordination of all screw-down reference values and control commands for strip thickness, tension and shape.

At any time manual operations such as set-point changes or selection and de-selection of control loops can be performed with bump less transitions.

To ensure best possible performance for a mill, latest generation Automation Systems are able to simulate the rolling process based on a non-linear simulation model. Comparison of different control strategies based on various sensor and actuator concepts allows the selection of the best technological solution.

Andreas Vollmer

The capture and analysis of stress waves provides significant improvement in condition monitoring of critical rotating machinery

Stress waves accompany metal-to-metal impacting, fatigue cracking, scuffing, abrasive wear and other defects commonly encountered with rotating machinery faults. These stress waves are short-term (fractional to a few milliseconds) transient events which introduce ripples on the surface of the machinery as they propagate away from the initiating event. The important features to capture for fault diagnostics is the magnitude of the events and rate (periodic or random) of occurrence. In this study, the stress waves are captured by (a) separating them from the normal vibrations through the use of high pass filters, (b) capturing the magnitude through recording the peak values (identified as Peak Value measuring methodology) over repeated continuous small time increments consistent with the analysis bandwidth and (c) identifying periodicity through spectral analysis. The analysis methodology has been implemented into a standard data collector/analyzer employed in routine condition monitoring of rotating machinery based on vibration analysis.

This methodology has proven to be a very valuable tool to add to the analyst tool box. Representative results showing bearing faults and cracked gear teeth are presented. The faults demonstrated are:

- Outer race bearing defect in a critical pinion stand gear box on a tandem mill
- Cracked gear teeth on output shaft of a double speed reduction precision tension bridle gear box
- Outer race bearing defect on a mandrel drive motor
- Outer race bearing defect on a centrifugal water pump
- Inner race bearing defect on a Basic Oxygen Furnace (BOF) vessel

The conclusion from this study is that this methodology significantly improves the analyst capability to detect and classify severity of bearing and gearing defects commonly experienced in the steel industry.

1.0 Introduction

Representative results from vibration analysis employing standard vibration and stress wave analysis for two gear boxes, a motor, a pump and a basic oxygen furnace (BOF) vessel are presented. The faults detected and presented are from defective bearings and cracked teeth in a gear box. The standard vibration analysis employs the velocity spectral data methodology. The stress wave analysis employs the peak value measuring methodology implemented on a standard portable data collector/analyzer.

For very slow speed machinery such as the BOF vessel and gear boxes, the stress wave analysis employing the peak value measuring methodology is demonstrated to be a valuable tool for the purposes of (a) detecting faults, otherwise missed with standard velocity spectral analysis and (b) assist in establishing the severity level.

In the next section, a brief discussion of stress waves and reasons for the appearance in rotating equipment are presented. This will be followed by a brief discussion of the analysis methodology employed. Representative case studies from two gear boxes, a motor, a pump, and a BOF vessel are presented in Section 3. The conclusions drawn from this study are presented in the final section.

2.0 Stress wave activity and analysis methodology

2.1 Stress Wave Activity in Metallic Systems

Stress waves are set up in a metallic system when events such as impacting, fatigue cracking, scuffing, abrasive wear, etc., occur. Stress waves in metal appear as both longitudinal and bending waves. Bending waves introduce ripples on the surface (hence excites an accelerometer attached to the surface) as they propagate away from the initiating site at the speed of sound. The stress waves are of short duration (fractional to a few milliseconds) and hence appear in the output of an accelerometer as short-term transient events.

2.2 Analysis Methodology

The velocity spectral analysis was carried out using standard guidelines for selecting analysis bandwidth, resolution, etc. Stress waves, which are short-term transient events, are characterized by broad frequency content. This makes possible the separation of the stress waves from the normal vibration through the use of high pass filters. For gearing systems, the general rule for selecting the high pass filter is greater than three times gear mesh since excessive wear on teeth will often manifest itself at three times gear mesh. For other systems, the high pass filter is typically selected at 30 to 50 times shaft speed (greater than 3 to 5 harmonics of inner race bearing defect).

The spectral analysis bandwidth for peak value measuring is selected following the same general rules as used in normal spectral analysis. The selection of the spectral analysis bandwidth, Fmax, defines the sampling rate to be employed (the sampling rate typically is set at 2.56 times Fmax).

In normal spectral analysis, the signal is routed through a high order, low pass (anti-aliasing) filter to remove maximum energy associated with frequencies greater than one half the sampling rate (avoids aliasing). The analog signal which emerges from the anti-aliasing filter is converted to a digital representation by sampling the analog signal at the discrete time intervals established by the analysis bandwidth. Each digital representation is the amplitude of the signal emerging from the anti-aliasing filter at the instant in time the analog signal was digitized. The anti-aliasing filter removed any significant variation of signal (possibly short-term transient event) which could have occurred between sample times. Hence normal spectral analysis generally are not responsive to stress wave activity.

Stress waves accompany many mechanical faults found in rotating machinery. The specific frequencies found within stress waves generally are not of interest. What is most useful is the detection and quantification of the events relative to (a) rate of occurrence and (b) magnitude of individual events. In this methodology, the detection and specification of magnitude of individual events and identification of rate of occurrence are accomplished by:

- Separate stress waves from normal vibration with high pass filter
- Find absolute peak value of signal over each time increment specified by analysis bandwidth. The block of data acquired for further processing, e.g., FFT, consists of peak values for each increment of time in lieu of instantaneous values used for normal analysis
- Perform spectral analysis, FFT, for the block of peak values which will identify any periodic event rate. Random event rates will increase the spectral noise floor. The time waveform consists of the peak value block of data used for FFT analysis

3.0 CASE STUDY

3.1 Introduction

A typical case is selected for presentation and illustration of the importance of peak value stress wave analysis and normal spectral vibration analysis for the detection and specification of severity level of faults found in machinery in the steel-making industry. The case consists of a BOF vessel with defective bearing.

3.2 Basic Oxygen Furnace (BOF) Vessel

The basic oxygen furnace vessel, see ‘Figure14’, is one of several very slow speed machines in the steel industry which are critical to operations. These generally are very large machines with bearings that are large, expensive, long lead times, etc. Advanced warning of impending failure of specific components becomes very useful information relative to scheduling repairs, etc.

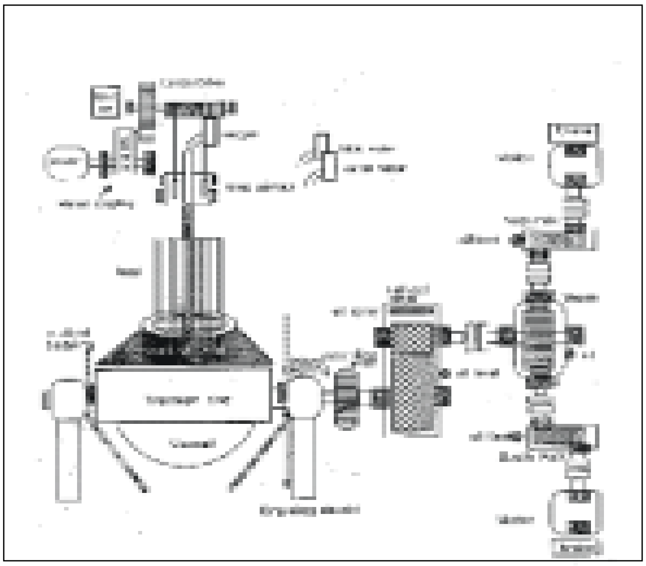


Figure 14. Basic Oxygen Furnace (BOF) Vessel and Associated Drive.

In machinery rotating at speeds in excess of 300 RPM, normal velocity spectral analysis has proven to be an effective tool for early detection of commonly occurring faults such as bearing defects. Additionally, the incorporation of stress wave analysis has also proven to be helpful for these class of machines and are capable of detecting other faults such as cracked teeth in gear boxes, etc. For very slow machinery (less than 10 RPM), normal velocity spectral analysis provides little or no reliable detection capability. On the slow speed machinery, stress wave analysis provides the only reliable detection methodology.

Stress waves are transient events characterized by reasonably high frequency (1 to 10 kHz). To reliably capture these events in a digital manner, the time domain data must be sampled at a high rate (order of 50,000 samples per second). For a vessel like the BOF vessel which is turning at 0.5 RPM, very large data blocks would be required to store data (one complete revolution would require 12 megabytes). The BOF only turns about 160, hence only 3 megabytes are required for data storage for one swing.

Once the data is captured, the analyst has the task of “analysis”. The use of spectral analysis is not an option here. What has been done is to capture the data (usually at a less than desirable sampling rate such as 12K samples per second) and store in a spectrum or transient capture instrument. Then the data can be displayed as a “compressed time trace” where the entire block of data is displayed on a single screen where only max. and min. values within the horizontal resolution are displayed. The number of points over which the max/min values are selected is simply determined by dividing the total number of data points by the horizontal pixel resolution, e.g., if we have 106 data points and 103 pixels, the max/min values are selected from 103 data points for each pixel.

An example of capturing a large block of data and displaying a compressed time waveform from a sensor on the bearing housing of a BOF vessel is presented in Figure 15. This data was acquired at a sampling rate of 2.56 time 5KHz or 12.8 K samples/sec (which is about 1/4th the generally accepted required sampling rate). In this data, it is clear that there are impacting events occurring at some reasonably repetitive rate. The task for the analyst then is to determine the most probable source for these events and then estimate severity. For this task, it would be helpful to have historical data to compare with, trend, etc. The large blocks of data from which this compressed time waveform was extracted makes trending difficult due to large storage requirements, etc.

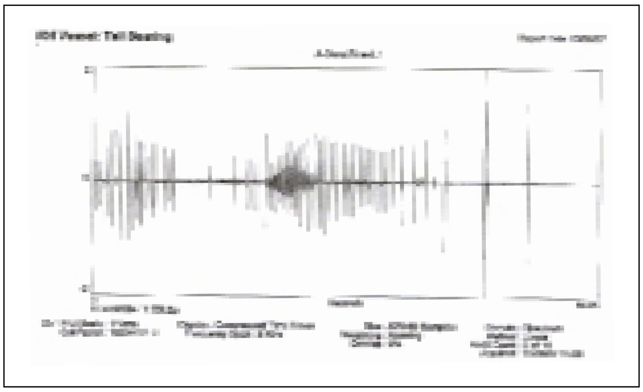


Figure 15. Compressed time trace 5 KHz bandwidth block for 45 second block of data from accelerometer located on BOF bearing.

At a certain facility where two BOF vessels are present, the vessels were turned through two complete turns (at nominal rate of 0.5 RPM) and the peak value measuring time waveform captured. One of the two vessels showed an indication of a defective inner race. The time waveform covering the two revolutions are presented in 'Figure 16(a)'. The portion of the peak value measuring time waveform through the defective regions are expanded and presented in 'Figure 16(b)'. Here the time between impacts which would indicate inner race are highlighted. The conclusion is that there is an inner race defect which has initiated (a) trending and (b) scheduling replacement.

In Peak value measuring methodology, currently implemented, a sampling rate of 100,000 samples per second is used to find the peak values. For a specified analysis bandwidth of 20Hz and 1600 lines, the time waveform is 4096 data points for 1600/20 or 80 seconds of elapsed time. This clearly encompasses one work swing of the BOF vessel. Since we are dealing with only 4x103 data points versus 4x106 data points required for the raw data, trending, order tracking, etc., becomes a very practical capability.

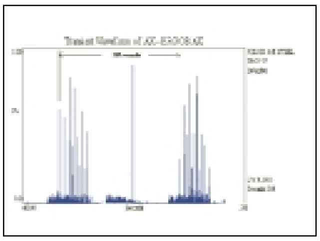


Figure 16(a). PeakValue measuring methodology time waveform from accelerometer mounted on BOF vessel bearing.

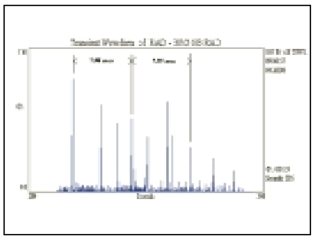


Figure 16(b). Expanded PeakValue measuring methodology time waveform through active region.

4.0 SUMMARY AND CONCLUSIONS

Emphasis has been placed in this paper on the analysis of stress waves employing the peak value analysis methodology for detecting and classifying severity level of faults typically experienced in machinery commonly encountered in the steel industry. The speed range for the machinery monitored for this study ranged from 0.5 to 900 RPM. Both stress wave and normal vibration analysis were employed for machinery greater than 100 RPM. Only stress wave analysis was considered for machinery less than 10 PRM.

The implementation of the peak value stress wave analysis was accomplished using the same instrumentation as was employed for the normal vibration analysis and required minimal effort (no additional hardware or software) from the operator. The primary source of information from normal velocity spectral analysis is the velocity spectral data. In the peak value data analysis, both the spectral and peak value time waveform data are important for fault identification and severity evaluation.

For the faults such as cracked teeth in gear boxes and bearing faults on the BOF vessel (0.5 RPM), the analysis was the only methodology which permitted detection and severity evaluation. For other faults, both Peak Value measuring methodology and normal velocity spectral analysis contributed to detection and severity evaluation. In some cases, it was Peak Value measuring methodology which was paramount in initiating corrective action while in others it was normal velocity spectral analysis which initiated the corrective action.

The main conclusions are:

- The condition monitoring program should continue with the normal velocity spectral data collection, trending, alarming, etc.,
- The inclusion of stress wave analysis employing a methodology which provides both spectral data and equally important, maintain the true peak values in the time domain should be a part of the standard condition monitoring program

David M. Stobbe
Marc Phillips
James Robinson

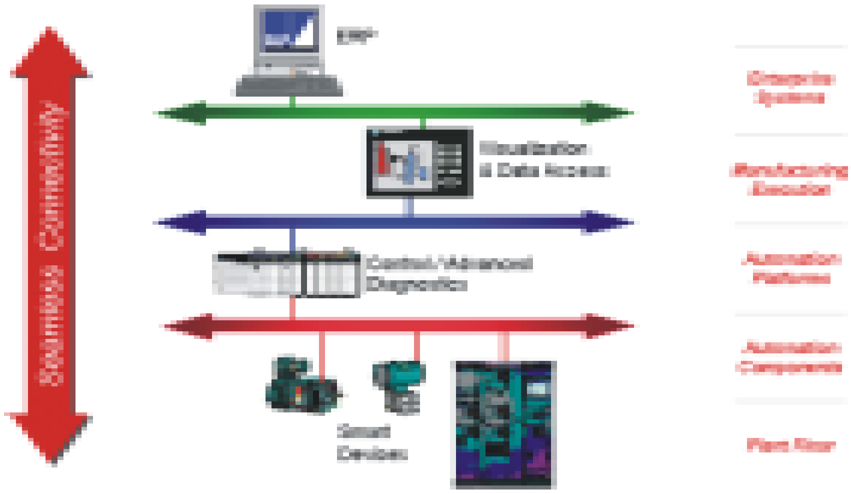
A seamless blend of process control and automation in steel

State-of-the-art multi-disciplinary controllers can now handle all steel plant controls together, in a single integrated architecture.

Historically, process control and discrete automation lived together peacefully in many steel plants, but no one ever thought to forge that relationship into a real union. The closest most distributed control systems (DCSs) came, was to assign sequential logic to traditional programmable logic controllers (PLCs) for tasks such as material handling or strip propulsion in direct reduction or other steel making and processing facilities.

This is because personal computers (PCs), RISC workstations and (in the old days) minicomputers' mathematical process capabilities could handle such continuous-control functions as PID loops, data acquisition, and supervisory control with ease. However, these systems did not have the hardware capabilities, response speeds, operating systems, and software reliability for handling digital I/O. Hence, many distributed or supervisory process control systems used gateways to delegate their digital I/O tasks to reliable and fast PLCs.

Today, architectures that use gateways are no longer adequate for data transfer, since production data now has to seamlessly move from devices to enterprise management systems. Also due to increased market competition, steel producers and processors are facing increased pressure to cut costs, increase productivity, eliminate downtime, and reduce product changeover times. These tasks require multiple engineering and maintenance teams—each with its own I/O network, human-machine interfaces (HMIs), parts suppliers, and skill sets—addressing a different area of control and service. In addition to the cost of running these teams, communication and coordination



barriers between process engineers, control engineers, maintenance personnel, and information technology (IT) departments are often subconsciously erected.

It is important for companies to use ERP (Enterprise Resource Planning), supply-chain management and asset management to integrate all aspects of a control system and unify its disparate parts. In spite of advances in networking, gateways and hardware interfaces, there is often no communication between ERP systems and the plant floor. Many legacy control systems use proprietary technology, making it virtually impossible for resource planning employees to obtain data for ERP purposes.

Most steel plant management teams do not have the internal knowledge and expertise to deal with multiple control systems and ERP connections. Therefore, steel plants need an open-control system that combines all aspects of process control and discrete automation. This way, end users can forget about interface problems, multiple teams, walls between disciplines, and the cost burdens of carrying two or more systems.

Steel plants continue to require the traditional functions of DCSs and PLCs, but their control functionalities need to work together. To address these integrated control issues open-architecture and single multi-disciplinary controller platforms have evolved. It defines a single integrated architecture to handle all logic-control requirements, including high-speed discrete, drives coordination, high-speed motion control and process control, supervising processes and controlling complex analog and batch applications.

With the multi-disciplinary platform, users have a common backplane, I/O, and network, which support DCS-type functionality associated with controllers and PLC-type control. In this hybrid control system, process control and discrete control sit side-by-side in the same rack. And because this multi-disciplinary Control System share the same architecture, users achieve genuine short and long-term cost reductions because of reduced spare parts and fewer control, batch, network, I/O and HMI training needs.

Another advantage of this multi-disciplinary controller is their built-in flexibility. They are used for running process and batch control, and for executing discrete control functions. They are built to handle any combination of sequential, drive or motion control and can handle analog process functions to cover plant-wide automation with seamless connectivity.

Debi Prasad Sen

Level measurement for metallurgic applications

Level Measurement in the Metal industry is very challenging. This is because conventionally the process implies a dirty, dusty surface with slag and very high temperature range applications. Radar Level Technology has been proven over time to be an excellent level technology delivering high reliability and improved process availability.

Challenges

- Very high temperature, range 200 to 1600^{0}C
- Turbulent surface
- Dusty & dirty
- Long ranges , 60m.

Solution & Benefits

To use Radar Level Gauges designed for Metal industry which offers the following benefits

- No moving parts and no contact with product , ensures no regular maintenance and highest reliability
- Special Radar antenna for high temperature with purging and cooling device
- Insensitive to heat, dust and change in pressure, temperature and density
- No recalibration
- Digital signal processing software module

Applications

- Blast furnaces
- Torpedo cars
- Open ladles
- Converters
- Rotary coolers
- Oil fuel tanks
- Smelteries
- Any kind of liquid metal vessels

Application examples

Blast furnaces - Stockline detectors

The use of non-contact and maintenance-free level measuring equipment in the blast furnace is essential to ensure the correct level for loading material at all times.

The furnaces can be equipped with either one or several transmitters. Application specific sensors are suitable for both "Bell-Top" and "Rotating Chute" blast furnaces and are not affected by the chute.

Torpedo cars - Automation of filling

The installation of Saab Pro Steel or Pro Hot, for the measurement of the iron level in torpedo cars during filling optimizes the use of the torpedo car fleet. It reduces the number of over-filled or under filled transports to a minimum. If the level values are sent for example to a DCS system, the filling of the cars can be controlled and optimized. The data can also be displayed on an optional display mounted on the gauge or separately.

BOF or LD converters - improved lance positioning

Saab Pro Steel installed for bath level measuring in a Basic Oxygen Furnace or LD converter results in improved process control. The exact level is determined by sending the microwaves down to the surface, where they are reflected back to the transmitter. The transmitter can be mounted as fixed or mechanically movable to a measuring position. It takes less than 10 seconds to set an accurate reading even if mounted movable. Data about level position ensures optimal positioning of the oxygen lance and gives more information about estimated blowing time. High temperature, smoke and dust do not affect the function.

K. Nagraj

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