COMPACT COLD ROLLING COMPLEX FOR HIGH QUALITY STEEL COILS [1]

Pierluigi Curletto[2]
Enrico Lantieri[3]

Abstract
Modern cold rolling and processing lines produce high quality low carbon finished steel coils with capacities from 200 to 650 ktpy. A whole range of end products is produced, but three basic solutions can be provided to produce all the different final cold rolled and processed coils within the same complex, with one push-pull pickling line, one or two cold reversing mills, other process lines and roll grinders.
Key words: Roll grinder; Cold rolling; Pickling line; Mill; Ultrasound

COMPLEXO DE LAMINADORES A FRIO COMPACTOS PARA BOBINAS DE AÇO DE ALTA QUALIDADE

Resumo
Laminadores a frio e linhas de processamentos modernos produzem bobinas acabadas de aço baixo carbono de alta qualidade com capacidades de 200 a 650 ktpa. Toda a gama de produtos finais são produzidos, porém, três soluções básicas podem ser fornecidas para produzir todas as diferentes bobinas laminadas a frio e processadas no mesmo complexo, com uma linha de decapagem "push-pull", um ou dois laminadores a frio reversíveis, outras linhas de processamento e retificadoras de cilindros.
Palavras-chave: Retificadora de cilindros; Laminador a frio; Linha de decapagem; Laminador; Ultrasom.

1 *Contribuição técnica ao 45° Seminário de Laminação – Processos e Produtos Laminados e Revestidos, 21 a 24 de outubro de 2008, Ipojuca - Porto de Gainhas - PE*
2 *Proposal & Sales Manager, Tenova Strip Processing Lines, Genova, Italy.*
3 *Area Sales Manager Roll Grinders, Pomini Tenova, Castellanza, Varese, Italy.*

INTRODUCTION

While the production of hot rolled coils – or sometimes the slab cast to produce them elsewhere – is increasingly concentrated in countries with iron ore mines and low energy costs, their transformation into cold rolled, galvanised or coated coils is more widespread, particularly in newly industrialised countries, close to the final end-users. Modern cold rolling and processing lines produce high quality low carbon finished steel coils in volume. The compact complexes housing them now have capacities from 200 to 650 ktpy. Their output includes annealed & tempered, galvanised, and colour-coated strip, or tinplate. Return on investment for these plants can be very rapid.

Compact cold rolling plants have recently been installed in South Africa, Saudi Arabia, Turkey, Vietnam and Mexico and this trend is continuing with new projects starting in the Middle East, Asia and Eastern Europe.

The success of compact cold rolling complexes rests on four main factors. First, they are easier to operate than full size plants. Second, the hot rolled coils needed to feed them are readily available on the global market, and are easily transported and stocked. Third, compact cold rolling plants have less impact on local communities than full size integrated steelworks, and are designed to be environmentally friendly with technology for waste treatment. Lastly, the widespread use of high-level instrumentation for flatness measurements in the cold mill, or installation of automatic visual inspection systems in the main process lines – plus the application of sensors and automation systems in auxilliary equipment – delivers consistently high quality products.

PRODUCTION ARRANGMENTS

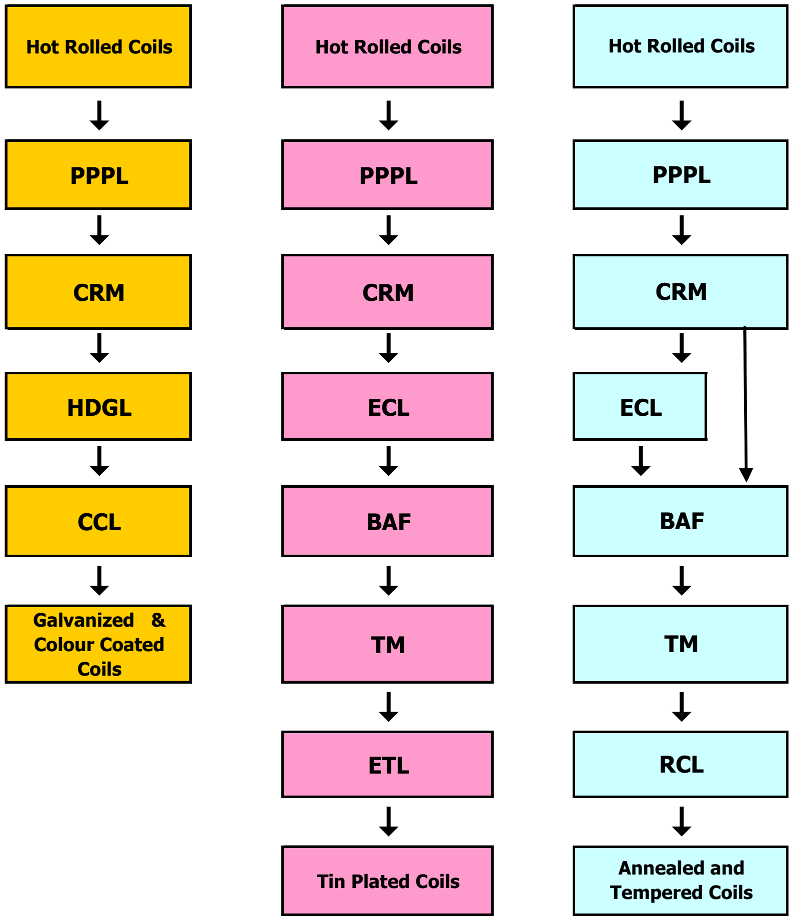

Figure 1: Three basic production arrangements

Key:

PPPL	Push pull pickling line (PPPL) with hydrochloric acid regeneration plant
CRM	Cold reversing mill (CRM)
ECL	Electrolytic cleaning line (ECL)
BAF	Bell annealing furnace (BAF)
TM	Temper mill (TM)
HDGL	Hot dip galvanising line (HDGL)
CCL	Colour coating line (CCL)
ETL	Electrolytic tinning line (ETL)
RCL	Recoiling and corrective lines and coil packaging lines

ELEMENTS OF A COMPACT COLD ROLLING COMPLEX

Three basic solutions can be put together to produce all the different final cold rolled and processed coils within the same complex, with one push pull pickling line, one or two cold reversing mills, and then the other process lines (Figure 1). Plant productivity is strongly influenced by the final production mix and by the size and quality of the incoming hot rolled coils. The auxiliary plants, the coil handling equipment and the storage areas have to be sized carefully to avoid production bottlenecks.

Push pull pickling Push pull pickling lines mainly process heavy gauge strip. They use hydrochloric acid as the pickling medium in a process that allows the line to run at different speeds. One or two pay-off reels and related mechanical equipment form the entry section. The pickling process uses three or more tanks filled with hot acid, where iron oxides on the hot rolled strip surface react with the acid to form iron chlorides and water. A final rinsing tank contains pure water to clean acid off the strip. The exit section has a side trimmer with scrap chopper, a bridle, an oiler, a dividing shear and a tension reel.
Push pull pickling lines process from 200 to 650 ktpy, at speeds ranging from 60 to 150 m/min.
Tenova recently acquired Key Industrial Solution Industriebau, a company based in Vienna, Austria, which specialises in environmentally friendly hydrochloric acid regeneration plants, using both spray roaster and fluidised bed technology. This plant performs the opposite chemical reaction to the pickling line, transforming iron chlorides and water into hydrochloric acid and iron oxides in a thermal reactor, followed by a series of scrubbers and concentrators.

Cold reversing mill Pickled and oiled strip passes through a cold reversing mill to reduce the thickness by 60-90%. Incoming strip with a thickness from 6 to 1.3 mm is reduced to gauges ranging from 2.5 to 0.18 mm.
Cold reversing mills have a pay-off reel, two tension reels, and one or two 4-high rolling stands. Two work rolls, with diameters ranging from 450 mm down to 400 mm, and two back-up rolls, with diameters of 1,150-1,300 mm, are used. A roll cooling system, level 1 and 2 automation with advanced controls and sensors, X-ray-based thickness gauges, and auxiliary mechanical systems such as a quick roll changing car, coil cars and shear, are important elements in a modern cold reversing mill. To ensure the highest level of flatness, a system that includes an automatic flatness control system to measure the flatness of outgoing strip and control rolling in an automatic closed feedback loop, roll bending, zone cooling of work rolls, and skewing of back-up rolls, must be used.
A cold reversing mill with one stand can roll 100-300 ktpy, at speeds varying from 600 to 1,500 m/min, and rolling force values between 1,500 and 2,500 t.

Electrolytic cleaning: Surface quality can be further improved before annealing. This is essential for strip with a thickness less than 0.3 mm to avoid coil wraps sticking and other strip surface defects. The cleaning line has a pay-off reel, shear and strip joiner in the entry section, while the process itself includes a pre-wash tank and a pair of brushes using a hot alkaline solution to start oil dissolution. The strip then passes through anodes dipped in an alkaline solution, where an electrolytic process is applied to deep clean the surface of the strip. Finally, the strip passes through brushes and is rinsed with pure water, dried and recoiled on a tension reel.
Tenova's research and development department is currently developing a new system to increase the efficiency of the process by using special steam injectors. Electrolytic cleaning lines process 100-300 ktpy of coil at speeds of 250-650 m/min.

Bell annealing furnaces: After rolling, strip annealing generates the required elastic-plastic characteristics in the steel. Bell annealing furnaces are traditionally used, each having a base with a fan – above which the coils are piled – burners, and a cooling bell to complete the process. The traditional furnace atmosphere was a mixture of hydrogen and nitrogen, but the development of new sealing devices and advanced controls now allows the use of pure hydrogen. Its use increases heat transfer inside the coils, and makes the process faster and the strip surface cleaner. Compared with the continuous annealing lines used in large cold rolled steel complexes, bell furnaces are simpler and, being modular, can be tailored precisely to the needs of production.

Temper mill: Temper, or skin pass, mills reduce thickness further, after annealing, in order to give the strip exact mechanical characteristics, eliminate the yield point elongation area, improve strip flatness, and achieve the strip roughness desired. The strip is stretched typically by 1-5%. For tinplate, the resulting reduction in thickness can reach 40%, achieving a very thin gauge of 0.14-0.18 mm. Temper mills have a pay-off reel, a tension reel, and one or two 4-high rolling stands. Work rolls have a diameter of 450-550 mm, and two back-up rolls diameters of 900-1,250 mm.
Temper mills can be equipped with an entry/exit bridle system to allow low-tension uncoiling/coiling. The system is equipped to minimise strip threading time. Temper mills also include strip detergent, automation and elongation measurement systems. Mechanical auxiliary systems include a quick roll-changing car, the coil cars, the coil preparation station and a pup-coil discharging device. Temper mills also usually provide strip oiling, and coil head and tail conditioning.
For best flatness, temper mills can be equipped with an automatic flatness control system to measure the flatness of outgoing strip and process control via an automatic closed feedback loop. As in cold reversing mills, roll bending and skewing of back-up rolls further enhances flatness.

Hot-dip galvanising: Hot-dip galvanising lines typically have an entry section with two pay-off reels, two shears, a welder and a strip accumulator. The process section usually includes a cleaning section, an annealing furnace to heat the strip above the recrystallisation temperature, and then a section to cool the strip to a temperature just above the melting point of zinc – approximately 460°C. The heart of the galvanising process is the molten zinc pot and the zinc wiping equipment.
The strip is cooled by means of air jets and water sprays, then to improve drawing behaviour, strip flatness, surface condition and paintability, the strip passes through a skin pass mill, a tension leveller and a chemical coater. The exit section has an accumulator, an oiler, a shear and one or two tension reels. For some applications a side trimmer is added.
Chemical roll coaters with an infrared oven are the latest technology for galvanising lines. They uniformly apply a very thin layer of chrome-free chemical as a final treatment to passivate the zinc with anti-fingerprint and paint adhesion properties. The galvanising line alternative to the electrolytic cleaning, bell annealing and temper mill process route, can be built to produce 70 to 400 ktpy with a process speed varying from 50 to 200 m/min.

Colour coating: Fed with galvanised coils or cold rolled and annealed coils, continuous colour coating lines have three sections. The entry section has two pay-off reels, two shears, a strip joiner and a vertical strip accumulator. The process section includes a cleaning section, a passivation treatment, one primer coater with related curing oven, and two finishing coaters with curing oven. The exit section includes a strip accumulator, a shear, and one or two tension reels. Tenova recently developed a new type of chemical coater and improved the curing oven efficiency, optimising the temperature curve of the strip throughout the heating process. Colour coating lines produce 50-200 ktpy, with a process speed of 50-200 m/min.

Electrolytic tinning: Electrolytic tinning (or chromium) lines receive coils from the temper mill. They have an entry section with two pay-off reels, two shears, a welder, a side trimmer and a strip accumulator. The process section includes an electrolytic cleaning section, a tension leveller, an electrolytic pickling section, a plating section, an induction melting furnace with water cooling tank, the chrome-based passivation section, and an electrostatic oiler. The exit section has an instrumentation stand, a flying shear and two tension reels.

The traditional plating process uses soluble anodes of tin immersed in an acid solution with phenolsulphates or methansulphates. Operators usually manually replace the consumed anodes with new ones on a rigid schedule to maintain coating uniformity. Tenova has developed a plating process with an oxygen-based tin dissolution reactor and insoluble anodes to remove that task. Electrolytic tinning lines produce 80-300 ktpy, with a process speed varying from 180 to 600 m/min.

Recoiling and packaging

Recoiling lines are used for strip inspection, trimming, tension levelling, and oiling strip coming out from the temper mill. Packaging lines have a series of coil cars to move, lift and rotate coils to allow operators to apply protective packaging. High levels of automation are applied where required.

Roll Shop

The Roll Shop is the area dedicated to the maintenance of rolls and chocks. In this area the equipment is designed in order to reduce the total investment and optimize the logistics.

One combination Roll Grinder for back-up rolls and work rolls is used to regrind the rolls coming from the mill within the requested tight tolerances, measuring the roll geometry and scanning its surface with automatic devices.

The objective of roll grinding is to provide a refurbished dimensionally accurate working surface, ensuring a series of parameters lie within tight specification. The conventional 3 step process to prepare a roll for the mill is to:

remove a pre-determined depth of roll surface material,

1. inspect the roll,
2. either return to the mill or initiate a second grinding as in step 1.

This method is simple, but has major deficiencies. It can never be optimal. Either:

- one or more defects will remain after the first grinding program,

and or

- time and roll material are wasted because more than the minimum material is removed.

Due to the potential risk of accidents involving personnel, product or the plant, defective rolls are not an option in today's steel processing environment.

Therefore a method had to be found to provide minimum material removal, prime production and, at the same time, maintain the highest possible confidence that the roll is defect-free.

This could be achieved with the Pomini-patented independently programmable measuring carriage. In this case the measuring calliper is supplemented with an eddy current inspection system. An optimising program was developed which, during the roll roughing stage, determines all the salient features of the roll and generates a map of the roll. This roadmap of information provides input to the grinding logic summarised in the flow chart shown in Figure 2.

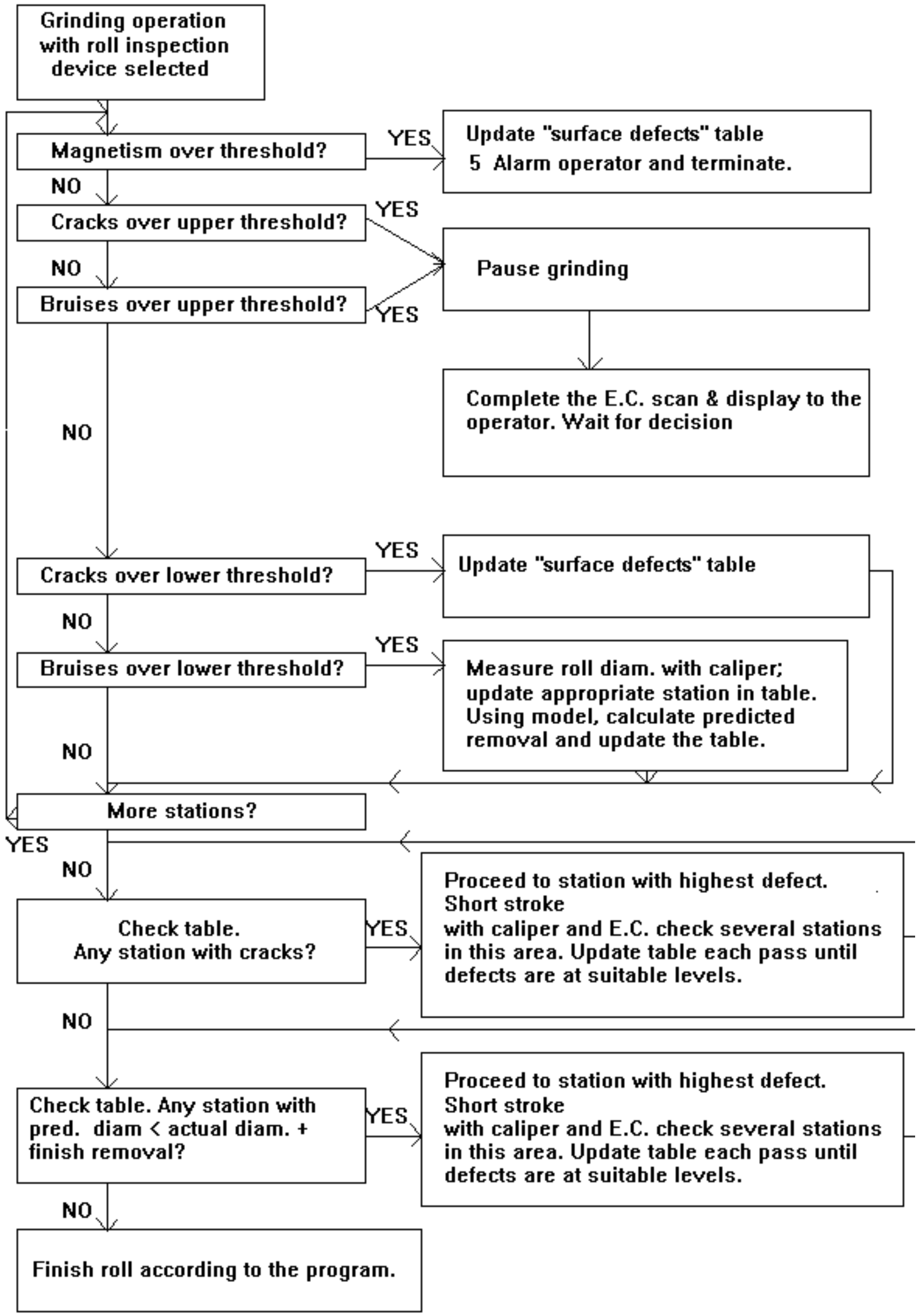

Figure 2: Grinding logic flow chart

In the roll evaluation process three levels of defect classification are used. The first is the upper or 'critical defect threshold'. Defects above this level are critical or very unusual and will require operator intervention. These problems should normally not be corrected in the production machines. So the grinding program is paused and an alarm is set for the operator.
The second classification, 'repairable', indicates that this defect can be repaired using one of the programmed sequences of the machine.
The third threshold is the maximum acceptable defect level. Below this level the roll is released for use in the mill. A similar cycle of checks is done for all defects.
As shown in Figure 2, the system first checks the roll for residual magnetism. If magnetism is detected, the degaussing cycle is initiated with a second check. If significant magnetism is still detected, the process is paused with an alarm messageto the operator. If all the defects are repairable, the diagnostic program locates the most severe defect and the machine starts its repair phase. During this phase, the defects are repaired sequentially, always working on the heaviest remaining defect. The diagnostic program monitors the reduction in defect level, and the machine keeps on grinding until all the defects are below the minimum threshold. Then, the machine completes the normal grinding phases.
Recent developments of the Pomini 'Inspektor' defect measurement system have enabled improved resolution in the defect mapping and classification processes, which are key parts of the roll dressing logic system. At the same time the performance, size and speed of today's digital systems have increased the capability and reliability of the data management systems. One outcome of this is the ability of most recent systems to detect and respond to smaller defects. These defects, which may actually develop during or be uncovered by the grinding process itself, went undetected in the past.

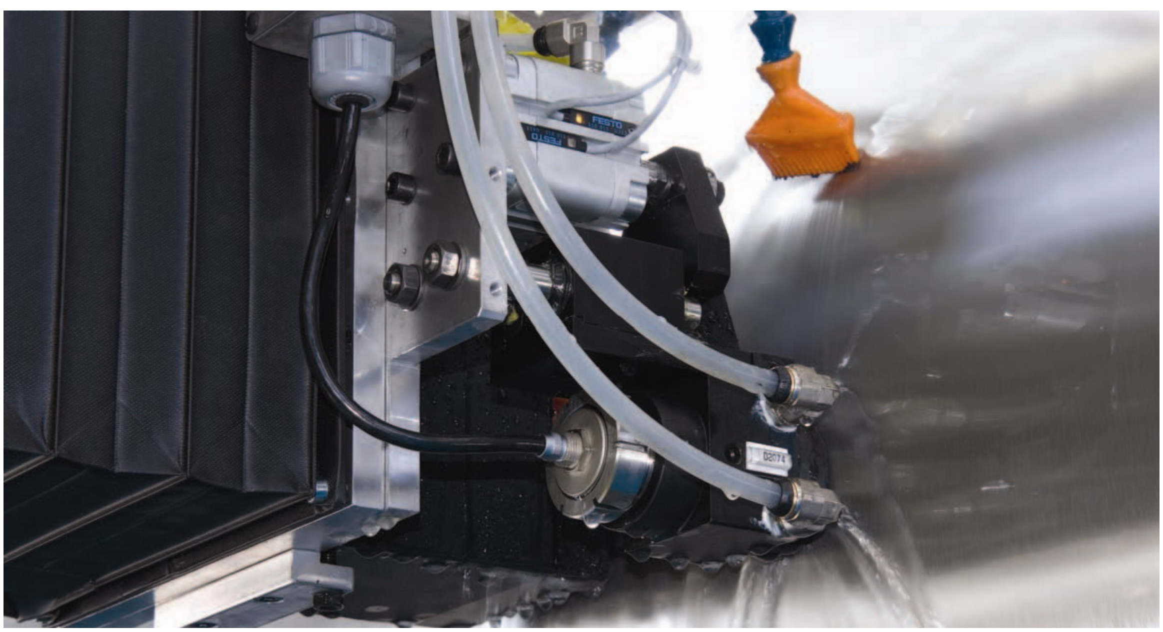

Figure 3. Inspektor device during ultra-sound scanning

The first Inspektor ultrasound inspection system on Pomini roll grinders was installed in 1998 at Dofasco.The new ultrasonic sensor, combined with a new generation of digital numeric controls, was integrated into the existing eddy current based diagnostic system (Figure 3). The Inspektor is controlled directly by a PC, allowing direct automation of data storage and analysis features.

Detection of defects by ultrasound prevents suspect rolls from being placed in the mill, possibly leading to accidents in the rolling mill caused by breaking or exploding rolls.

The main purpose of the ultrasonic analysis is to detect and monitor subsurface defects. Checking the quality of the interface between cores and outer roll shells is only possible with ultrasonic testing. The high hardness of these rolls makes them susceptible to a type of failure where the hard shell breaks away from the core. In these cases ultra sonic scanning is a most effective method to detect and track small defects enabling a safer and more cost effective roll management program.

Many roll defects are quite small, but are still able to initiate a major roll failure. A new detection head with smaller coils (2 mm diameter) has been studied and developed. This head is able to detect 1 mm defects and, at the same time, to create a very detailed map of the defect area. This higher resolution has allowed improved defect classification by comparing the defect with specific patterns.

Newer systems are able to monitor the individual defects every time the roll returns to the grinder after a mill campaign. The ultrasound reading maps are saved in a database and they are easily comparable in order to check if a defect is propagating. They provide better understanding of the

conditions which can influence the defect development. Defect management is not yet an exact quantitative science. However, the tracking of defects provides insight into the processes, allowing the steel plants to develop a better understanding and implement better operating and safety standards.