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PICKLING OF STAINLESS, SILICON & LOW CARBON STEEL STRIP - LATEST TECHNOLOGIES & TECHNIQUES APPLIED IN TENOVA RECENT PROJECTS[1]

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Abstract

In this paper are described the following Pickling Line projects: Annealing and Pickling Line for Stainless Steel (Hot and Cold band) commissioned in Italy on 2010; Annealing and Pickling Lines for high grades Silicon steel (Oriented and not-oriented) including efficient Si-removal commissioned in China on 2009; Continuous Pickling Lines for low Carbon Steel re-built in Russia on August 2004; Revamping of Continuous Pickling line for low carbon steel in Poland performed on August 2009; Push Pull Pickling Line with Acid Regeneration Plant Zero Effluent Technology for Compact Cold Mill Complex in Romania (under way). The main aspects of the pickling technologies and the techniques are described in the different plants considering also the jobs typologies as new green field plant, overall revamping, transfer and modernization or simply modernization. Annealing technologies of stainless steel and electrical steels upstream of the pickling process are described.

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FOREWARD

The pickling process is present in all the steel strips production routes before the Cold Rolling Mills with the main aim to eliminate the superficial oxides generated in the Hot Rolling Mill.
All the pickling processes are based on the use of acids as HCl, H_2SO_4, HF, HNO_3, often, in combination with a mechanical descaling by tension levelling and/or shot blaster.
In the last 30 years alternative processes not using acids have been deeply investigated and tested but none reached a valid industrial application for high productivity plants.
For most of Stainless steel and Silicon steel production route an annealing process in a continuous furnace is foreseen to improve the metallurgical properties; in this paper are presented the hot strip and cold strip capability, concept and implementation especially in respect of the new cooling section for Stainless Steel and the basic requirements for Annealing of GO and NGO electrical steel as hot strip annealing and cooling, atmosphere control in the direct fired section, post-combustion of reducing flue gas, atmosphere separation, strip temperature control, layout of combined sections for heating and cooling.
In the last 10 years Tenova (part of TECHINT group) consolidated the steel pickling technologies integrating the mechanical expertise of Aetna Standard with the experiences of Italimpianti and the Acid Regeneration Technologies of Key Technologies (previous KCS); the main pickling processes applied in the steel strip productions have been optimized, the most modern technologies have been applied with the aim to minimize the environmental impact and to increase the operational safety.
Furthermore thanks to the acquisition of the furnace maker LOI Thermprocess, Tenova is able to supply all the most modern technologies applied in the Annealing & Pickling Lines for Stainless and Silicon steel.

Annealing and Pickling Line for Stainless Steel (Hot and Cold band) commissioned in Italy on 2010

The job included complete equipment upgrading for furnace, electrics and mechanics, a new and innovative ‘multi-media’ cooling section, revamping of the pickling section, new recirculating and acid management equipments, provision for a future environmental friendly electrolytic de-scaling tank, a new pickling tank, new brushing machines, new final brushing & rinsing section, auxiliary systems, new automation system and the dismantling of the original line in Torino and the relocation and erection in Terni Works.

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Project description

Activities	Date
Start of dismantling	September '08
End of dismantling	November, '08
Temporary stop due to 2008 crisis	Six month Project stop
Start of erection	June, '09
End of erection	October, '09
Cold – Hot tests	October-November '09
1st coil	November, '09
Line fine tuning	December '09-January '10

Figure 1 – APL General view

Main line parameters:
H. R. Stainless Steel (AISI 200,300,400), Titanium
C. R. Stainless Steel (AISI 200, 300, 400 series)
Thickness: 2.0 ÷ 7.0 mm H.R.
Thickness: 1.3 ÷ 5.0 mm C.R.
Width: 600÷1550 mm
Productivity (max): 50 t/h (Hot coils)
The project was conceived and developed following these "guide lines":

- To modernize the plant with the execution of various improvements.
- To minimize the modification of the line lay out to avoid significant changing of the operator interface, operation standard practices and receipts.
- to replace obsolete equipment improving strip tracking and quality
- to minimize environmental impact
- to minimize civil works

In such a way the civil works, erection, and re-commissioning time as well as and the final tuning operations were minimized allowing, in the first weeks of commissioning, to reach the same level of productivity and quality of the existing plant and then to improve the product quality during fine tuning also increasing the line productivity.

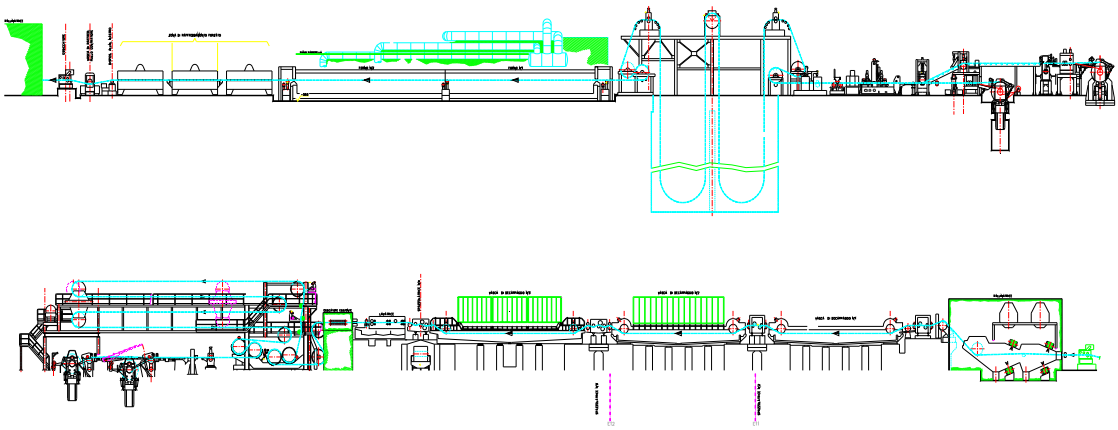

Figure 2 – The APL lay out before revamping

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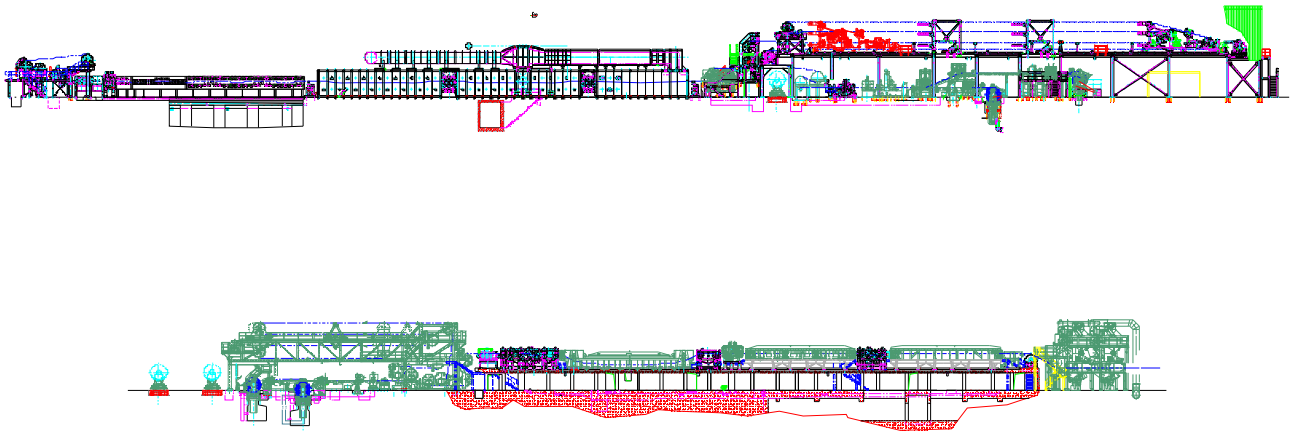

Figure 3 – The APL lay out after revamping

In the Entry section, the existing looping pit had to be replaced with a new 4 strand type horizontal looper provided with two steering roll on board and looping arms actuated by the Tenova "no-scratch design" cam mechanism designed to operate cold rolled strips.
The furnace section was deeply revamped by LOI-Italimpianti

Figure 4. Furnace and cooling section

Figure 5. Steering and tension control section and the shot blasting

Main targets of the revamping actions were :

- increased line speed for 1520 x 4,0 mm hot rolled strip from 15 m/min to 20 m/min
- capability for cold rolled strip treatment 1520 x 1,5 mm at 25 m/min

Before dismantling the furnace was in bad shape. Nevertheless, according to the order as much as possible components had to be reused. As a result of earlier revampings for higher throughput, additional burners have been installed in the recuperative zone. Since this measure resulted in a too high waste gas temperature, these additional burners were not as useful as expected.
The main changes were :

- stretching of the recuperative zone for better flue gas enthalpy use
- new design of the roller stands

In the planning period it has been found that the additional burners were not really required for the increased throughput, as confirmed by the experiences during start-

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up. But they have been re-installed in order to keep an additional margin for later optimisations.
For the new roller stands the up-and-down principle had to be kept. The new design allows to pull out the stand-by roller, for roller changing during production, for longer life time and less heat loss. See Figure 4.
The cooling section could not be re-used and was completely new designed, mainly in respect to the multi purpose operation to treat hot rolled as well as cold rolled strip.

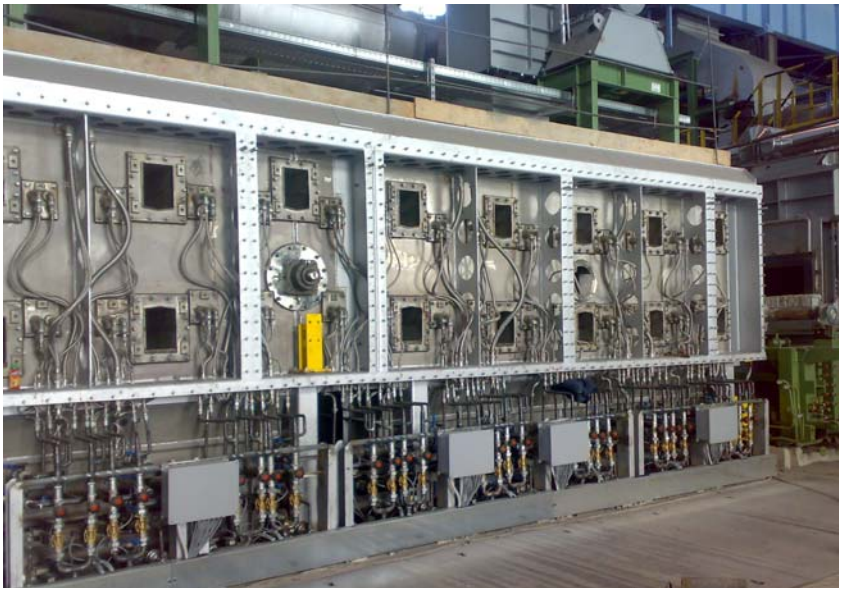

Figure 6. First Cooling Section

The first cooling section allows to be operated as jet air cooling, mainly for cold strip, as well as in the water spray mode for hot rolled strip when higher cooling power must be applied. Figure 6 shows the open air plenum with the jet air headers during erection. Between two jet air headers there are two water spray headers. For best strip shape the intensity of the water spray cooling is adjustable over the strip width. Different cooling powers according to different strip speeds, thicknesses and cooling speeds, are automatically adjusted via line automation.
In order to prevent clogging of the water spray headers when switched off the remaining water is blown out with pressurised air.
An item requiring special attention was the jet air operation, mainly for cold strip. For thinner gages the cooling intensity is low and there is a necessity to cool the inner surface of the cooling section separately with water. This cooling is designed to avoid any water droplets on the strip surface in order to ensure a strip surface without any water stains.
In contradiction to the former status in Torino design the concept of scale removal has been changed completely. Since the exhaust air in the former status was drained with high velocity into an above-the-line arranged scrubber. The first cooling section and the scrubber had to be cleaned manually in the previous case. In the new concept the exhaust air is de-accelerated directly below the strip when passing the cellar. This results in scale deposition in the cellar, which is continuously flushed with water coming from the second and third cooling section. Then the air passes droplet separators. The experience of more then 9 months of operation shows that there is no need for manual work to remove the scale in the cellar and also the droplet separators are not clogged by any remaining scale particles.

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The second cooling section is a two-phase cooling by water and pressurised air. In this case the contribution of the air to the cooling is negligible; the air is mainly used for atomising the spray water in order to achieve a uniform dosage of low amounts of water onto the strip.
The third cooling section is a pure water spray section.
After the cooling section there are new designed squeezing rolls and a dryer.
At the exit of the cooling section were installed a new steering and tension control section composed by a single roll steering device, a tension-meter roll and a new bridle roll unit (to change the strip tension between the furnace and the shot blasting - pickling area).
The single roll proportional-integral steering device with roll crowning and the steering angle has been studied as a function of the cooling section, the furnace geometrical characteristics and thermal cycle in order to improve the strip camber and flatness.
The pickling section is composed of one innovative shallow type Sulphuric de-scaling and two spray pickling tanks one traditional submerging roll tank and are fed with 'reduced pollution acids'; in this way the use of nitric acid is avoided and consequently:
nitrates in waste solutions and NOx (nitrogen oxides) in fumes are eliminated.
In general for stainless steel pickling, when Nitric and Hydrofluoridic acid are used, TENOVA has developed a new technology for mixed acid recovery.

Figure 7. Pickling section overview

All the recirculating tanks, heat exchangers, instrumentation were designed to improve the operation and safety. New storage and buffer tanks were studied and installed to manage and to store the acids.
New brushing unit has been supplied as well the final brushing, rinsing and drying section.
The first tank was modified to install a couple of exit steering-wringer roll improving the strip tracking in the pickling section.

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The tank n. 3, was deeply revamped in order to improve the solution turbulence and heating transfer capacity.
A new double stage type acid fume exhaust system was supplied in order to comply with the severe local environmental regulation.
The electrical and automation system has been completely revamped and new digital drives have been supplied by Tenova automation division.
The complete integration of the mechanical, chemical, thermal and automation activities inside the Tenova teams allowed the execution of this challenging turn-key project in the contractual restricted timing.

Annealing and Pickling Lines for high grades Silicon steel commissioned in China on 2009

Two modern and high productivity Annealing & Pickling Lines were supplied to treat the highest quality Grain Oriented (GO) and Non Grain Oriented (NGO) Silicon Steel grades.
Main lines parameters:
H. R. & C.R. Silicon Steel (GO & NGO) with Si content up to 3,5%
Thickness: 1.3 ÷ 3.0 mm H.R.
Thickness: 1,45 ÷1,55 mm C.R.
Width: 800 ÷ 1300 mm
Productivity (max): 60 t/h (Hot coils)
Process speed 30 – 50 mpm
The line configuration is as follow:

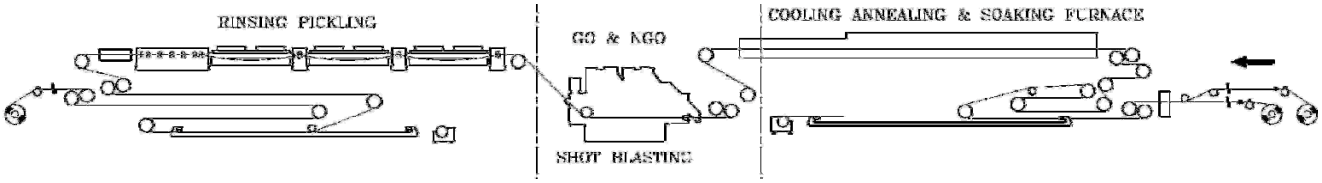

Figure 8 – The APL schematic lay out

Annealing and cooling sections:

Figure 9. Furnace Entry section.

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Figure 10. Radiant cooling & soaking section

Compared with APL's for stainless steel, the Lines for electrical steels are more complex:

- The direct-fired furnace operates under reducing atmosphere with an excess of fuel gas as Non-Oxidising Furnace (NOF). This requires various safety measures and a post-combustion system to ensure that the flue gas does not contain any combustible and toxic components.
- The further sections are for heating, soaking and/or slow cooling under nitrogen atmosphere. This requires a safe and reliable atmosphere separation at the exit of the direct fired furnace.
- The cooling section has to perform a wider range of cooling speeds, mainly dependent on the steel grade (NGO or GO resp. High grade GO).

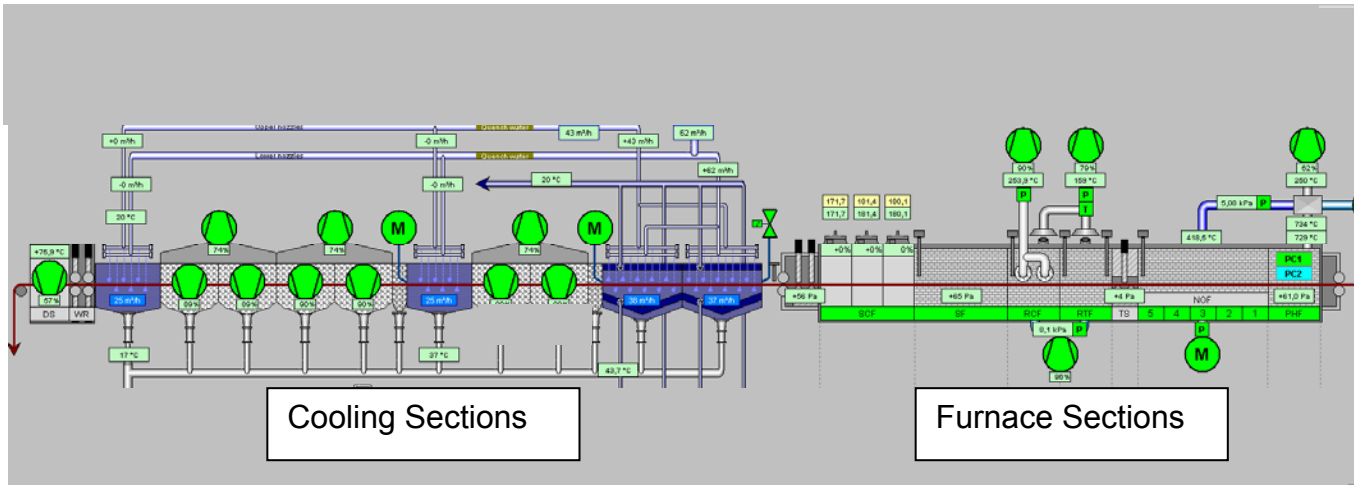

Figure 11. Schematic of an Annealing and Cooling Section for Electrical Steel

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For quality reasons in the automation of this line there is implemented a “strip temperature control mode” instead of the commonly used furnace temperature control. Since the heat transfer in the furnace is mainly determined by radiation, there is an auto-adaptive algorithm, (see Figure 12) to “learn” online the strip emissivity which is used (1) for pyrometric strip temperature measurement and (2) for heat transfer calculation in a thermodynamic model.

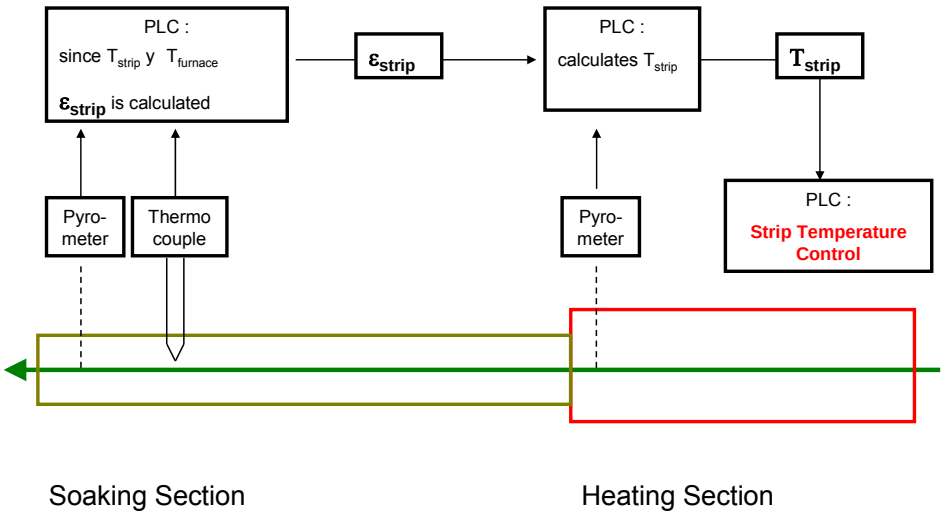

Figure 12. Schematic of the auto-adaptive algorithm to learn the strip emissivity

The pickling section is composed by: One Pre-rinse; Three turbulent pickling tanks ; four stage Rinsing Section and a dryer.

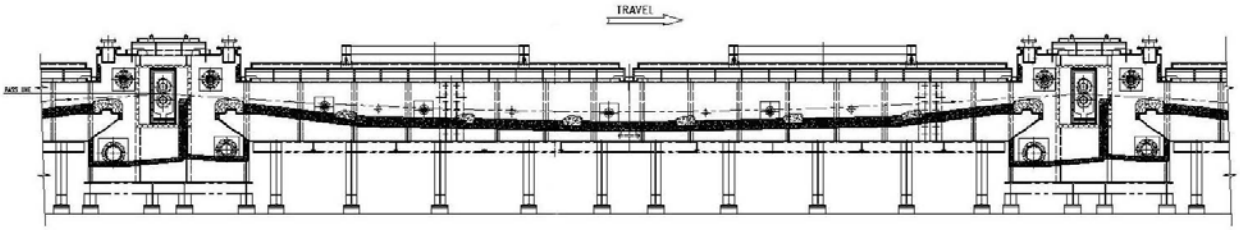

Figure 13. Turbulent type shallow tank using HCl

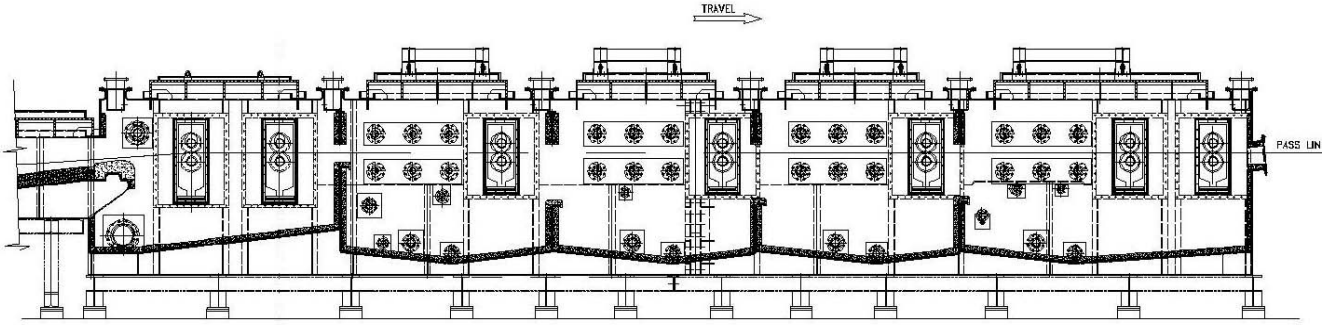

Figure 14. Rinsing section

In these lines the TENOVA MATHEMATICAL MODEL controls the acid concentration of the solution using an algorithm that calculates the amount of iron and controls the make up flow rates with the following input data:

- line automation system (strip width, speed …)
- measurements by the field instrumentation

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Periodical laboratory analysis (of samples) are foreseen to check possible drifts of the calculated values and to reset the zeroes of the mathematical model.
The algorithm accuracy: is 5-10% for set value the acid concentration (g/l) within 24 hours.
The system can manage over-pickling phenomena (i.e. due to slow down) by changing the number of feeding pumps in operation for controlling the pickling solution turbulence.

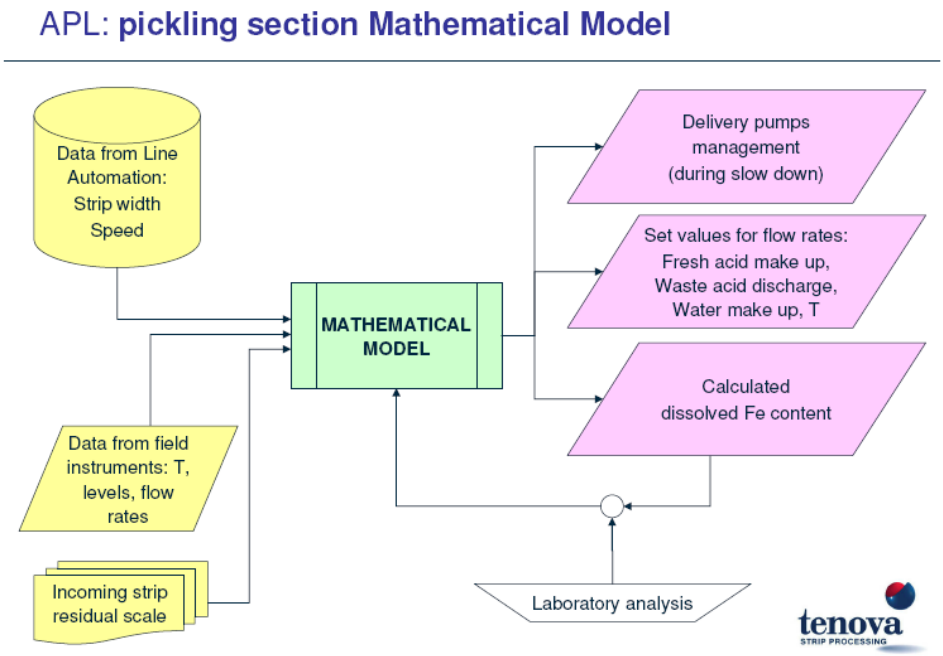

Figura 15. Mathematical model flow chart

Figure 16. Silica Removal Plant

Figure 17. Rinsing Section

The Silica is removed from the Waste Acid by effective state of the art TENOVA silicon removal system.

Reconstruction of High Capacity Continuous Pickling lines for low Carbon Steel in Russia performed on August 2004

The scope of the project was the dismantling of an existing obsolete pickling line and rebuilding in the same place of a modern pickling line with minimum modification to civil works and maximum re-using most of existing heavy steel structures; the

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conversion of a second pickling line from sulphuric to hydrochloric acid; the supply of two new HCl Acid Regeneration Plants.

Pickling Line n.1 Main parameters:

H. R. Low carbon Steel
Thickness: 1.2 ÷ 6.0 mm
Width: 1050÷1850 mm
Productivity (max): 2.200.000 ton/year (405 t/h)
Line speeds 800 m/min entry. 300 m/min process 360 m/min exit.

The Scope of work was design and supply of the entry section, entry looper, tension leveller, process section, exit looper, electrical-automation system and auxiliary plants.

Pickling Line n.2 Main parameters:

H. R. Low carbon Steel
Thickness: 1.2 ÷ 6.0 mm
Width: 1050÷2350 mm
Productivity (max): 1.100.000 ton/year (228 t/h)
Line speed 220 m/min process.

The Scope of work was design and supply of the technological equipment for the process section .

Regeneration Plants:

The Scope of work was to design and to supply 2 new spray roaster Acid Regeneration Plants 11.000 lph and 7.500 lph capacity to regenerate the exhaust acid and the rinsing waste water of both pickling lines.

Mechanical equipment

Terminal equipment

The high capacity coil loading section able to handle up to 20 coils per hour was tailor made designed in order to automatically handle vertical axis coils, without strap, coming from an existing chain conveyor, which are automatically loaded in the Pay-off Reels.

The entry section was provided with double unwinding pass line to reduce the time cycle, allowing high production capacity even processing small size coils.

New entry and exit looper cars have been provided, respectively of the six-strands and four-strands type, with strip smooth cam-lever mechanism separator arms; new steering units were installed between each loop strand, at the exit of the pickling and rinsing sections.

Figure 18. Entry Coil Section

Figure 19. Tension Leveller

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Tension leveller-scale breaker

The tension leveller is designed to break the hot rolling scale on the surface of the strip thus increasing the pickling capacity by more then 12%.This tension leveller unit is also sized to improve the strip shape up to the maximum strip size (6 x1850 mm), thanks to the available maximum strip tension of 650 kN.
To apply this high strip tension the machine is provided with entry and exit roll bridles driven by a main motor through a mechanical differential drive system, with an elongation controlling motor (from 0 to 3 % elongation) and two auxiliaries motors to share the torque between the rolls inside each bridle for compensating the strip elastic elongation.

Process Section

The pickling section is composed by a Pre-rinse section, four 33 meters long turbulent flow shallow tanks, 5 stage cascade spray type Rinse tank with high pressure final spray bars, a strip dryer with edge blowing system, fume treatment system, Acid analyser to control the Fe++ concentration.
The scale layer on the strip is chemically dissolved by the acid by follows main reaction:

$$FeO + 2HCl \longrightarrow FeCl_2 + H_2O$$

In the pickling section the cascade system results in a stepwise concentration of the dissolved scale and free acid among the pickling tanks as shown in the following block diagram.

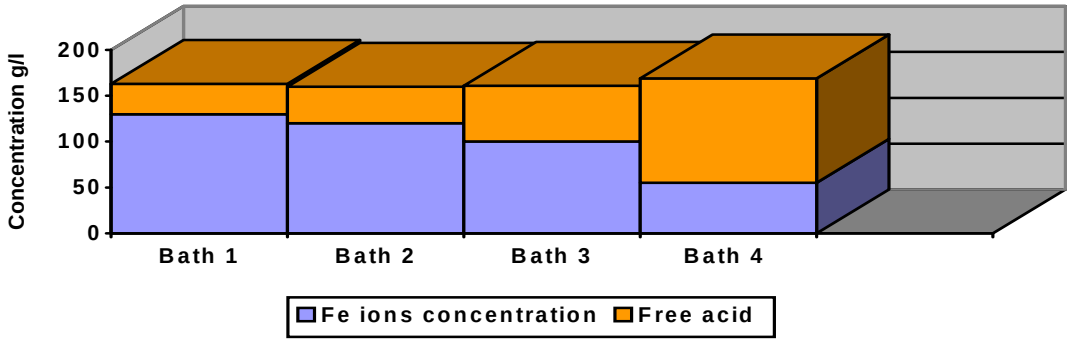

Figure 20. Fe ions and free acid concentration in the pickling tanks

This concentration gradient highly improves the pickling efficiency and permits effective pickling results with up to 130 g/l of metal in the exhausted solution.
To reach this result, between each pickling tanks, overflow chambers with squeegee rolls are located to minimize the acid transport from each tank to next one.
The pickling-requirement-analysis is done automatically by the process PLC taking in consideration coil qualities and size (information coming from the Level 2 system) allowing to operate the pickling line with economical and environmental friendly parameters.
To get high mixing of fresh acid in the pickle bath and to increase the relative speed between strip and pickle agent, the circulating acid is injected into the pickling bath against the strip run-direction. The injection nozzles are distributed both sidewall along all pickling tanks to achieve a homogeneous temperature and concentration distribution. Additional spray bars are located at entry and exit side of all pickling tanks allowing direct chemical interaction of the strip surface with the scale and immediate heat transfer into the strip

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Another advantage of the acid injection from the sidewall is that the main scale layer at the edges of the strip will get in contact with fresh acid at first and the impulse of injected acid is still quite high.
For each pickling tank a separate circulation tank is foreseen; during plant shut down the total acid content from the pickling tank is quickly drained into the circulation tanks in 5 minutes.
The consumption of fresh acid is kept at low level by permanent and reliable iron concentration determination by means of density measurement in the waste acid.
The rinsing of the strip is performed by means of a 5-cascade spray rinse section to minimize the make-up water consumption and most of that is condensated steam.
The job was performed in only 45 days of line shut down in August 2004; the final acceptance certificate (FAC) was obtained in November 2004 after about 80 days of line operation.

Figure 21. Pickling tanks

Figure 22. Exit Loop car

Modernization of Continuous Pickling line for low carbon steel performed in Poland on August 2009

This plant modernization consisted in:

- Replacing the old Tension Leveller/Scale breaker and the Side trimmer and scrap chopper with new more performing machines.
- Replacing two old Acid Regeneration Plants with a new modern one
- Installing a new automation and drive system (By Others)
- Replacing the Flash-Butt welder with a new Laser type one (By Others)

Main parameters :
H. R. Low carbon Steel
Thickness: 1.5 ÷ 4,5 mm
Width: 650÷1600 mm
Line speeds 600 m/min entry. 250 m/min process.350 m/min exit.
ARP capacity 3500 lph
The main target of this investment was to improve the strip quality, to increase the plant productivity, to reduce the environmental impact and to increase the operator safety.
The pickling line revamping on turnkey bases was performed in only 28 days of line shut down in August 2009. The ARP project is still underway.

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Figure 23. Tension leveller with drive system

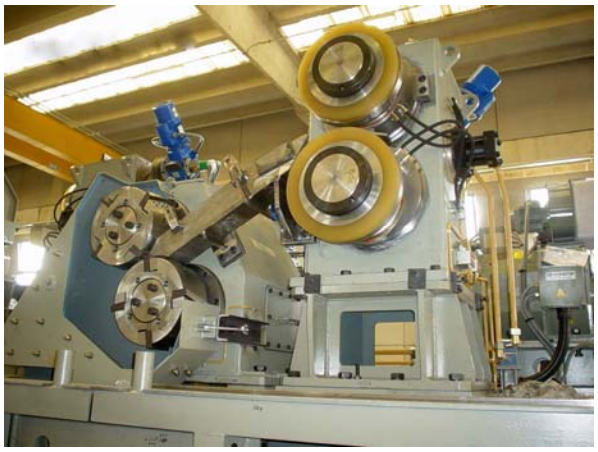

Figure 24. Side trimmer and scrap chopper

Push Pull Pickling Line with Acid Regeneration Plant with Zero Effluent Technology for Compact Cold Mill Complex in Romania.

The increasing market demand for small size & low investment pickling lines, possibly combined with slitting machines require a new approach and a new concept for this kind of application.
As these plants are usually installed in service centers close to the end users, not always in big industrial areas, the cost for consumables and their minimization becomes more and more important. Also restricted availability of canalisation and effluent treatment combined with strict emission values are important design criteria.
TENOVA concept for ZERO effluent is the answer to this new demand with energy saving design and innovative use of recovered waters in the plant, therefore operating without any acidic effluents.
This concept has been applied for a new plant under construction in Romania with the following criteria:

- ***Cost saving Investment***: No Waste Water Treatment for acidic effluents
  Combined scrubber system ARP & Pickling Line
- ***Low Operation costs:*** Efficient use of water, combined Rinse&Offgas scrubber system
  No neutralisation costs chemicals/sludge disposal, etc.
  losses of HCl practically zero
- ***Environmental Friendly:*** Extra-low Emission values as per European Union Standards

This innovative concept consists of an effective 2-tank pickling system (usable for capacities from 100.000 to 300.000 tons/y) and innovative 4 stage rinse system, using part of the rinse water in the tank fumes scrubber. This scrubber has a double function, it is designed to clean a) the off-gas coming from the Acid Regeneration Plant, and
b) the fumes from the Pickling Tanks suction system.
The design is made to reach strict emission values without use of alkaline chemicals, so the acidic water from the scrubber can be fully used in the Acid Regeneration Plant in the Absorption step recovering most of the HCl (see concept below).

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Acid Regeneration Process Cycle

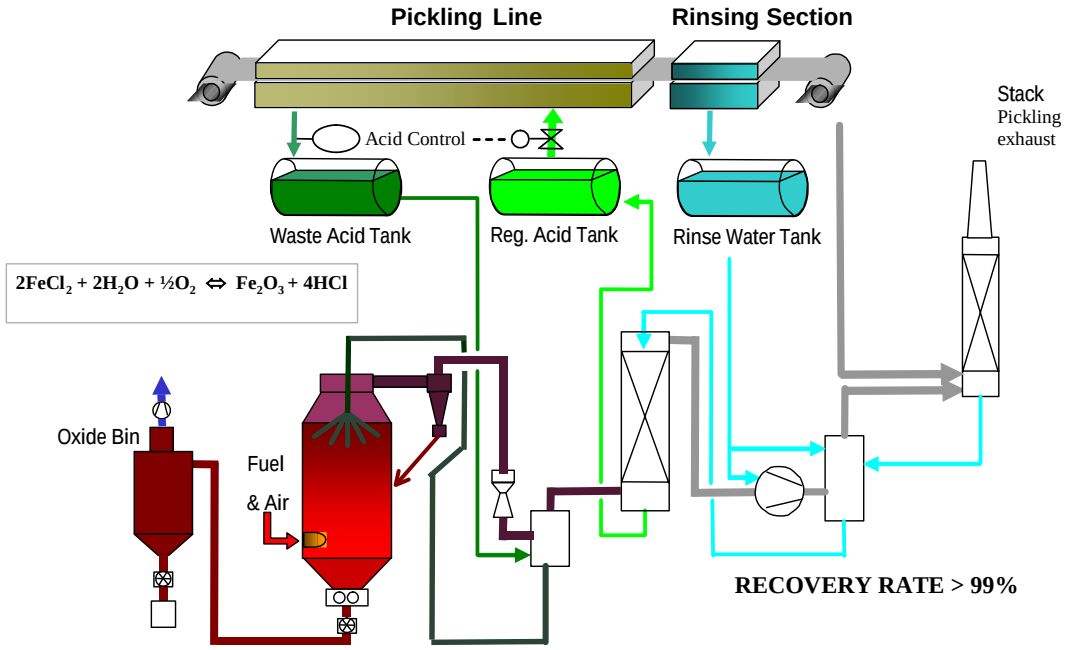

Figure 25. TENOVA Zero Effluent Concept

Conclusions

The designing criteria in the projecting and implementation of the Pickling Lines have been changed in the last Years, the plant maker has to pay particular attention to the new steel producer needs and he has to face with new challenge.
The presented projects are examples of successful solutions to the new steel producer needs.
The capability to manage important and innovative projects including new high productivity and high quality processing line as well as major revamping and modernization activities is the result of a long tradition in building processing lines and the integration of engineering companies having a long history in this field
The very sensitive problem in the steel pickling lines is to minimize the plant environmental impact and the to increase the operator safety due to the use of high polluting and hazardous acids which has to be used in the pickling processes.
The APL for SS, as well as the other mentioned Tenova projects, adopts high reliability and safety-environmental processes widely proven and tested.
In such a way the steel producers minimize the risks can be generated by the use and management of the high polluting chemical agents actually used in most Pickling lines.
The Tenova experience demonstrates that the full integration of all the technologies and techniques applied in the Annealing and Pickling Lines allow the implementation of challenging projects with excellent results.