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NEW STATE-OF-THE-ART GALVANIZING LINES IN EUROPE[1]

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Abstract
As a global full-liner, Siemens VAI is one of the leading suppliers of galvanizing line plant technology and all related automation solutions covering the full range of applications. In late 2006, Siemens VAI was awarded two contracts for major European steelmakers for the supply of two galvanizing lines. The first new facility with a capacity of 350,000 tpy dedicated to appliance, non-exposed automotive and building applications is part of an investment to increase the original plant capacity to 1,500,000 tpy. The second facility, for which Siemens VAI had the full process turnkey responsibility, is a high capacity wide coated strip production line of 550,000 tpy devoted to high demanding automotive market including AHSS. This article presents the two state-of-the-art types of galvanizing lines which are now established as top quality production facilities in Europe and argues about their respective designs.
Key words: Galvanizing lines; Siroll; DAK®; Dynamic air knives.

NOVAS LINHAS DE GALVANIZAÇÃO ESTADO DA ARTE NA EUROPA

Resumo
Como fornecedora global de toda a cadeia siderúrgica, a Siemens VAI é uma das líderes em fornecimento de tecnologia para plantas de galvanização e todas as soluções de automação que englobam estas aplicações. No fim de 2006, a Siemens VAI recebeu dois contratos para fornecimento de linhas de galvanização nas maiores siderúrgicas da Europa. A primeira delas tem capacidade de 350.000 ton/a, aumentando a capacidade da planta para 1.500.000 ton/a. A segunda linha é de alta capacidade de produção de tiras largas revestidas, de 550.000 ton/a, voltada para o mercado automobilístico, incluindo AHSS. Este trabalho visa expor estas duas linhas em detalhes.

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1 INTRODUCTION

As a global full-liner in strip processing lines, Siemens VAI supplies galvanizing line plant technology and all related electrical and automation solutions covering the full range of applications. Well-known worldwide on account of its standardized products that form the cornerstone of a cost-effective plant solution, Siemens VAI goes deeper and beyond merely listening to customer requirements. Based on the extensive know-how we gained throughout the execution of numerous projects during the past decades, and which goes into the design of our equipment, we provide our customers a significant database of field experience. Our concern is to keep strategic equipment within Siemens VAI portfolio to deliver state-of-the-art technology to our clients. For this reason, Siemens VAI has to invest in huge development of so-called mechatronic packages, but also to be able to select adapted technology in regard to the process, mainly the thermal process as it seems difficult to have an in-house full range of technologies covering all kinds of heating, cooling or ageing concepts. Acting not only as a supplier but also as a consultant for the benefit of our customers, we will offer you a tailored solution from standardized and well-proven products matching not only your needs but also those of your own customers. Depending on the targeted market and the corresponding desired end material, a large spectrum of strip processing line designs is available. The brainwave is to choose the optimum one!

The following part of this article presents two typical cases of custom-tailored galvanizing line solutions:

- the first line concept is dedicated to appliance, non-exposed automotive and building applications requiring a conventional coating quality and served with common steel grades. Let's call it B (like Building application);
- the second one is mostly dedicated to the high demanding automotive market with main focus on the required best coating quality as well as the capability to produce various steel grades from conventional Drawing to AHSS grades. Let's call it A (like Automotive application).

In late 2006, Siemens VAI was awarded two contracts for majors European steelmakers for the supply of two galvanizing lines. On stream since 2009, the first facility, for which Siemens VAI had the full process turnkey responsibility, is a vVv[1] high capacity wide coated strip production line devoted to high demanding automotive market. Featuring an annual capacity of 550,000 t, it processes a wide product mix of cold-rolled strips of low carbon soft steels, HSS[2], DP[3] steels and TRIP[4] steels in strip thicknesses of 0.6 mm to 2.5 mm and strip widths up to 2050 mm. Let it be our A-line.

The second new facility with a capacity of 350,000 tpy dedicated to appliance, non-exposed automotive and building applications is part of an investment to increase the original plant capacity to 1,500,000 tpy. The hHh[5] line is designed to handle cold rolled carbon steels (CQ[6], DQ[7], DDQ[8] grades), having thicknesses

[1] *vVv: Vertical entry accumulator, vertical furnace, vertical exit accumulator.*
[2] *HSS: High Strength Steel.*
[3] *DP: Dual Phase.*
[4] *TRIP: TRansformation Induced Plasticity.*
[5] *hHh: Horizontal entry accumulator, horizontal furnace, horizontal exit accumulator.*
[6] *CQ: Commercial Quality.*
[7] *DQ: Drawing Quality.*
[8] *DDQ: Deep Drawing Quality.*

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between 0.25 mm and 2.0 mm and widths between 750 mm and 1,530 mm. This will be our B-line.

2 LINE DESCRIPTION

Driving force of line concept is, of course, in consistency with the final end user market to be served by the line production with regard to the targeted product quality but it must also consider the best achievable performance at the lowest production cost. Designing a full line keeping in mind the needs of the end customers requires a deep and detailed knowledge of the whole spectrum of available line components to build-up functional process section and ultimately get in-line design as per customer expectations. The custom-tailoring process starts in the early steps of the production route.

2.1 Coil Charging

Because of the large strip width required by an A-application, the entry coils have a greater weight than the traditional ones. As a consequence, the coil cars must be designed to be able to handle coils of about 45 tons (30 tons otherwise). As a result, and also to trim down expensive civil work, Siemens VAI recommends the use of floor-mounted heavy duty scissor type coil cars instead of pit coil cars.

Figure 1. Entry coil storage area, pay-off reel and laser welder.

2.2 Entry and Welding Section[2]

The entry section of the line includes a dual pay-off reel layout to provide sufficient coil loading and joining time necessary to reduce the impact of any unscheduled delay on the front end due to the coil loading sequence. The double pay-off reel arrangement enables new coils to be brought into the line and prepared while the previous coil is being processed through the line.
The welder joins the tail of the previous coil to the head of the new one at the entry of the line so as to create an endless strip for the continuous galvanizing process. One of the main differences between A-line and B-line concept often lies in the sourcing of incoming coils delivered at the line entry. It is commonly recognized that automotive products are coming from an upstream tandem cold mill while building and construction products could also be served through a reversing cold mill. In terms of entry line production, it is mandatory to handle the head and tail ends overthickness by scrapping the affected strip length for the head ends and making a pup coil to be removed at the entry lane for the tail ends.

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Strip joining could be managed using two technologies available in Siemens welder equipment. The old generation, still well appreciated and efficient in performing the weld joint, is defined with a Mash Lap Welder (technology available from ML21L, ML21M and ML21H) while the laser welder is foreseen as the next new generation of welding machines.
For the B-line, it has been decided to install a conventional mashed lap welder. This welder, not only attractive by its rapid return on investment but also by its well-proven technology, fulfilled one hundred percent of the requirements. On the other hand, for the A-line, Siemens VAI decided to go with laser technology. One of the main advantages of a laser welder is that the laser weld joint does not have any over thickness. This feature of the laser welding process not only makes it possible to realize coil build up operation but also produces the highest quality resistance seam welded joint which is suitable for passage through the skin pass mill and tension levelling section of the line without the need to open the work rolls. This ensures maximum yield of prime quality product by minimizing the unprocessed material at the weld joint. In addition, laser system also makes it possible to cut the strips with the laser beam (Siemens VAI laser welder concept) with different advantages such as no wear of cutting tools, perfect cutting quality, no limitation in terms of mechanical properties of the steel grade to be cut. Automatic weld joint quality control could be managed by the Siemens VAI weld control system which is available for both welding technologies.
Until now investment level for a laser welder still remains higher than for a mashed lap welder but the difference is decreasing.

2.3 Strip Accumulators

Continuous process obviously requires a strip buffer at line entry as well as line exit to keep the line running at process speed in the process section to maintain constant parameters in the annealing furnace but also in the zinc coating and mechanical process of roughness transfer and strip elongation.
Dealing with the accumulator design, our spectrum of solutions offers two choices: a vertical design and a horizontal one. First of all, the strip storage capacity is defined to keep up with the transient period of entry and exit coil change, then one of the two different designs can be selected in accordance to the product quality and the targeted market. Several considerations have to be taken into account. First of all, independently from an A or B-application, we must consider all the constraints related to the space available to build the plant. Do we have any restrictions in the civil work? Will the building height be sufficient for a vertical accumulator? Is the length of the building sufficient for a horizontal accumulator? Is the ground appropriate enough to create pits? Then, we have to think about the desired end material. Although horizontal accumulators have the benefit to be on average twice as light as the vertical ones – which is an economical advantage for a B-line, their technical design involving dolly cars or separator arms might cause some marks on the surface of the strip if precautions are not taken.

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Figure 2. Vertical accumulator, horizontal accumulator, cleaning section.

For this reason, A-line design is almost always equipped with entry and exit vertical accumulators for which the design is recognized as the best solution to prevent any possible strip surface marks and not to hamper the building definition, as the maximum accumulator height is defined and limited by the top of the vertical furnace. B-line design is built up in regard to the horizontal furnace. To minimize the building height, a horizontal entry accumulator located underneath the furnace section is conventionally adopted and a compromise solution could be managed for a vertical or horizontal accumulator at the exit depending on the actual targeted throughput quality.

2.4 Cleaning Section

A strip cleaning section is provided to clean the strip surface by removal of rolling oils and iron fines upstream of annealing furnace. It generally comprises a hot alkali spray tank, followed by a brush scrubber, rinse tank/wringer rolls, dryer, fluids circulating system and fume exhaust system. Optional for a B-line, Siemens VAI highly recommends its use for an A-line as it provides an enhanced strip surface condition for the zinc coating process. To put it in a nutshell, a cleaning section ensures good zinc adherence on the product and minimizes production of zinc dross formed in the zinc pot by iron fines which may otherwise have been carried into the pot on the strip surface.
One alternate solution is to have a Direct Fired section at the furnace entry in order to crack the residual rolling oil at high temperature and to partially eliminate the iron fines. Such a technology is more dedicated to a B-line and less demanding products.

2.5 Furnace

This is one of the key process sections that need to be tailor-made according to the incoming material and, of course, to the targeted final throughput. Furnace definition is commonly done in accordance with the product mix and product quality. For an A-line design the furnace section is more sophisticated and in case of high level of production for automotive products the radiant tube technology installed in a vertical furnace is probably the most suitable definition. For comparison, an economic line design could be obtained by installing a horizontal furnace arrangement in a B-Line layout.

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2.6 Zinc Coating Pot

The heart of the process is dedicated to ensure the strip coating according to defined coating type. The most common coating is made of GI[9] whatever the market is, and in some cases for automotive applications GA[10] coating could be applied. In case of GA products, the after-cooling tower is, of course, fitted with an induction heating furnace associated with a soaking zone located after the wiping area and before the strip enters the cooling path.
Key component of a galvanizing line, the coating pot uses electric induction technology to heat the molten charge. This ensures the most efficient and clean heating environment minimizing zinc contamination. Reliable temperature control of the molten zinc bath is ensured by the use of thermocouples installed in the pot. Bath composition is monitored by regular bath analysis in laboratory. To ensure perfect cleanliness of the zinc bath, Siemens VAI recommends for A-application the use of an automatic dross removal system located in front of the snout instead of a manual dross removal by the operators pushing dross towards a dross basket immersed in the bath.

2.7 Wiping System(3)

In manufacturing continuous galvanized steel sheets, wiping techniques are of highest importance for deciding about coating qualities, and wiping nozzles of high quality are essential for ensuring uniform coating weight and excellent surface smoothness of the product. As a consequence, whatever the type of A or B-line is considered, Siemens VAI recommends that a Siroll DAK®[11] wiping system be implemented. In the past 10 years more than 20 world wide customers chose it as the best solution to produce galvanized steel sheets.
Siroll DAK® is unique in that it enables to alter the nozzle lip gap and shape to be altered across the strip width. This ability enables the operator to adjust the system in order to closely match the required zinc coating thickness across the width as well as along the strip length. In constant evolution to integrate the state-of-the-art in terms of technology, this component now includes a transverse coating control, a non-contact baffle system for thin strip products and a heavy duty automatic lip cleaning device to remove zinc particles on the lips. All these improvements are now embedded in the new generation of wiping systems, the so-called Siroll DAK®-E. Its utilization leads to a reduction in zinc consumption and the corresponding cost savings allow a return on investment of less than one year.

Figure 3. Zinc pot, wiping system and temper mill.

[9] *GI: Galvanized steel.*
[10] *GA: Galvannealed steel.*
[11] *DAK®: Dynamic Air Knife.*

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2.8 Skin Pass Mill and Tension Leveler[4]

Once coated with the requested zinc layer, and after been cooled, the strip passes through the skin pass mill and tension leveler.
The aim of the skin pass mill is to modify the mechanical characteristics of the strip, by elimination of the so-called yield point elongation (the area in the elongation curve where the material is both plastic and elastic, which makes defects named “wrinkles” when the strip is stamped). The action of the skin pass mill is done by elongation/roll force. The skin pass mill is also used to print the requested roughness on the strip, by transfer of the work roll roughness to the strip surface.
The tension leveler is used to correct the flatness defects by elongation/flexion. The elongation is controlled with a high accuracy, in order to not affect the roughness given by the skin pass mill.
For B-application, the skin pass mill has typically a roll force between 500 tons and 800 tons (Siroll SPM21L or SPM21M). The pass line adjustment is done by means of a driven wedge system, or shims. The automatic roll change device is a “side shifter type” on operator’s side. The roll cleaning is done by a wet rolling system spraying water and detergent in the stand.
For an A-line, when a high level of constancy in roughness is needed, the skin pass mill may be equipped with small diameter work rolls, for hard product, or big diameter work roll for soft product. The advantage of bigger work roll is a better roughness transfer on soft products (like IF[12] steel used in exposed car body parts) without the heavy pressure on the strip surface, which induces a strip hardening. In order to be used on hard product (like HSS used in structural car body parts), the skin pass mill has a roll force between 1,000 tons and 1,200 tons (Siroll SPM21M or SPM21H). To compensate the difference between the small and the big work rolls, the pass line adjustment is done by means of a driven long stroke screw and nut system.
To permit the quick roll change, necessary to guarantee the requested roughness despite the roll wear, the roll change device is a “through stand type”: the new rolls are waiting on motor side and are introduced in the stand by means of a pushing device, which pushes the new rolls in the stand and, in the same time, pushes the worn rolls on the operator’s side car. An additional high pressure cleaning device ensures the rolls cleaning, and avoids defects like “pick up” on the strip. A fume exhaust system ensures the environment cleanliness.
The tension leveler is equipped with a wet system, which sprays water in the leveling stand for roll cleaning purpose.

2.9 Post-Treatment[5]

In the post treatment section, Cr-Free passivation surface treatment is generally provided to protect and prevent discoloration and oxidation of the galvanized strip surface during coil storage and transport. Spray/dip tanks combined with squeegee rolls is the conventional solution used for B-application. Unfortunately, this solution offers such a level of control that uneven coating, over-coating or even leakages may occur.
This puts in plain words why, to ensure a uniform and controllable chemical coating for an A-line, Siemens VAI recommends the use of a roller coater. Based on its high

[12] *IF steel: Interstitial free steel.*

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knowledge of hydraulic process control in the cold rolling mill activity, Siemens VAI developed the Siroll DynaCoater that eliminates all the drawbacks of the conventional coaters. While its frame stiffness and guiding precision prevents extraneous vibrations likely to cause surface defects on the strip, its fast hydraulic system and automation control allow compensating eccentricity of the applicator and pick-up rolls. In one combined, all these systems guarantee a perfect coating quality, an homogeneous thickness and a controlled paint consumption.

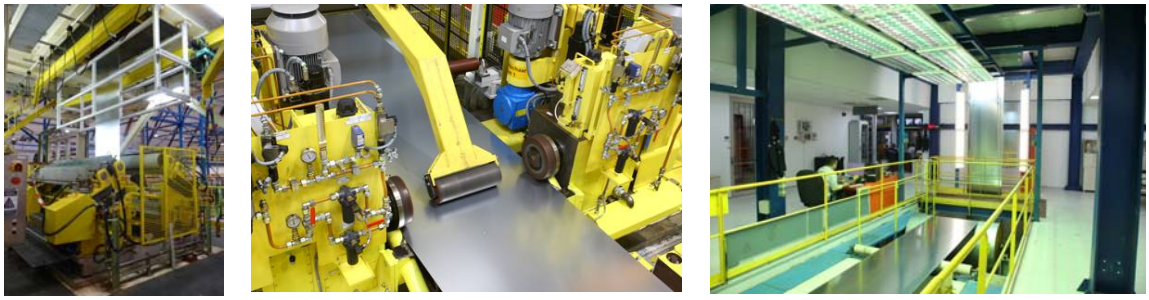

Figure 4. Roll coater, side-trimmer and inspection station.

2.10 Side Trimmer[6]

In order to eliminate the rolling or process defects of the strip edges and to calibrate its width, the strip then goes through the so-called side trimmer which aims to cut the lateral edges of the strip by means of two pairs of rotary knives.
Once again, depending on the kind of end material and application, the design of the solution will be different. First of all, it is worth considering whether a side trimmer is really needed. Only end materials intended for stamping require tight geometrical tolerances.
For B-application, side trimmer is useless, however it is possible to leave a space provision in the design of the line in order to anticipate a future extension of the product mix. When nevertheless requested for low side trimmed production range, then a solution including a single head type side trimmer and a scrap baller is choosen for economic purposes.
For an A-line, when tight geometrical tolerances are needed, a solution offering high cutting quality, fast and easy maintenance must be chosen. Patented Siemens VAI ST21M medium side trimmer is designed and manufactured to meet customers' demand for strong availability and high quality cutting thanks to its precise spindle unit. The turret type side trimmer assembly with double head allows cutting the strip edge with the active running head knife and changing the worn knife with the non active offline head. The machine has been designed for a fast knife change with the bayonet system. This system offers short cycle time to change the head and continuous processing of the strip. Concerning the gap and lap, their adjustments are operated by means of servo-motors engaged with micrometer screw ensuring high accuracy of the cutting operations. A gauge is installed after the side trimmer to check the cutting quality. The scrap is managed with an ingenious system of two bins and a sliding conveyor.

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2.11 Inspection Section[7]

Automated surface inspection systems have become standard tools for the manufacturing of steel products. Their benefits are two-fold as they allow monitoring both the quality of the product and the process. Siroll SIAS[13] has been developed to ensure that these two goals are met and design to exceed the demanding quality control requirements of the automotive industry. Based on technology from Space and Defense Industries, pioneer in image processing, the system has been adapted to the steel industry. With more than 15 years of experience and approximately 100 references all over the world, SIAS already convinced famous customers like Arcelor-Mittal, Salzgitter, ThyssenKrupp, Tata Steel, Wuhan Iron and Steel Corp and Anshan Iron and Steel Corp.

Figure 5. Siroll SIAS system.

Composed of an on-line sensor (light source and cameras) coupled with image processing hardware and software, the goal of the system is to replace partial and random surface inspection by constant, repeatable and systematic inspection of 100% of the production. Sophisticated in design, SIAS combines the use of highly efficient detection based on multidimensional convolution filters and highly praised classification algorithms – Coulomb Hyper Spheres – now reckoned as the most efficient available algorithm today. SIAS's exclusive and patented classification method comparable to a 2-layer neural network but with full traceability enables the system to detect and classify the most critical defect after generally 2 weeks of operation.
Fully integrated to the system, the "Coil Grading" application is an additional functionality that aids decision-making by automatically computing a global quality level based on final customer surface quality requirement and the product surface evaluation through SIAS. Although based on complex information such as defect map and user-defined defect tolerance rules, the result is a simple red/yellow/green light giving straightforward advice to the inspector.

2.12 Exit Section[8]

The exit section of the line comprises an electrostatic oiler, a shear and a tension reel.
The electrostatic oiler applies a precisely controlled protective coating of oil to the surface of the strip. Independently from an A or B-application, based on its proven reliability, Siroll Fara Electrostatic Oiler is used within the framework of Siemens VAI

[13] *SIAS: Surface Inspection Automatic System.*

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projects. The sturdy construction, simple mechanical design and PLC control system is specifically designed to withstand the environment of a galvanizing line.
The strip then goes through a shear provided for removal of the weld, sample cutting and dividing the coils for further processing. The cut sheets are guided into a sample tray or into a scrap bin. The design of the shear is fully dependent on the exit accumulator capacity and the maximum process speed. For a B-line with a process speed of 140 m/min to 150 m/min, a conventional up-cut shear is sufficient. On the other hand, for an A-line where the process speed can reach 180 m/min, the use of a rotary drum shear is preferred.
Finally, a tension reel ensures continuous winding of the finished strip. Once more, the design of this final section must take account of the type of end material to be produced. For an A-line handling large coils of about 30 tons, a single tension reel is most of the time sufficient. On the other hand, if the end customer requests smaller coils, then the coil change frequency will be higher and will impact the overall production rate. In such a case, it would be recommended to implement a second tension reel.

2.13 Automation System(9)

The entire galvanizing line is equipped with Siroll electric and automation concept that includes a matched basic automation, process automation, drives and HMI[14] for very accurate tension control, highly responsive drives, optimized sequences and intuitive diagnostic.
Automation is handled throughout the plant by Simatic S7 programmable controllers using standardized application modules as part of the integrated SIROLL solution, ensuring easier commissioning as well as maintenance and service work. The Level 1 basic automation uses Simatic S7 400 programmable logic controllers for the different functions such as sequential controls and the function module FM 458 for high-speed technological controls. This enables easy fault-finding through a clear division of tasks. Moreover, the online programmability allows avoidance of delay caused by rebooting the system. As a consequence, the design of the Siroll automation system ensures excellent reliability and high availability. The process automation system or Level 2 includes expertly designed tracking modules and process models which are a prerequisite for optimized production.

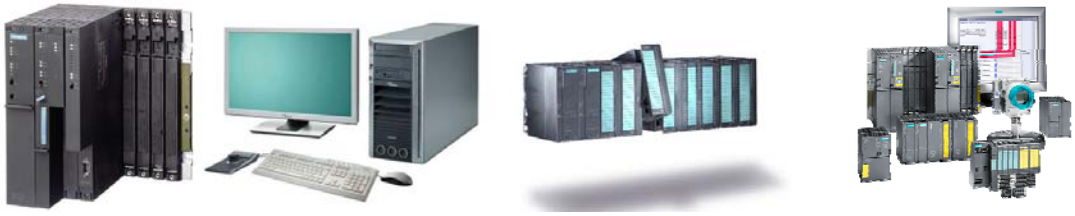

Figure 6. Simatic family (S7 400, PC, Remote IO, Safety components).

Although the whole automation system is quite independent of the type of line, the used functions may be different. For instance, the temper mill of an A-line will use the elongation control mode more extensively to suppress the yield point and ensure good stamping properties. On the other hand, the temper mill of a B-line will preferably use the roughness control to ensure a perfect surface quality for the strips dedicated to the domestic appliance market.

[14] *HMI: Human Machine Interface.*

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Sinamics, the advanced-technology frequency converters for AC drives, achieves the excellent dynamic performance required in processing-line drive applications. The AC-drive solution ensures high reliability, significant savings in maintenance costs combined with an increase in efficiency. The modular-voltage-source DC-link converter system has an innovative digital control system and uses common DC-bus operation for sections of the drive systems in the plant. The size of the drives is highly influenced by the material to be turned out. For comparison, an A-line handling hard material like AHSS requires on average three times more power than a B-line.
Integration tests using plant simulations are essential to success. Siemens VAI thoroughly tested the complete automation system, including all visualization systems, control consoles and the drive systems in the test facilities in Erlangen, Germany, before shipment.

2.14 Intelligent Manufacturing and Maintenance

Whatever the type of A or B-line is considered, the so-called TCOptimizer[15] software from Siemens VAI aimed at helping the line managers in the daily line handling can be implemented.
First of all, TCOptimizer collects data and signals not only from all parts of the line itself (entry area, cleaning section, furnace, zinc pot, temper mill, exit section, drives, etc.) but also from upstream (hot strip mill, tandem cold mill) and even from laboratory. Filtering all these signals using a multi-sources data correlation model, TCOptimizer transforms all related gigabytes of data stored everywhere within the plant into relevant manufacturing events and just-in-time alarms popping-up on a blank screen. These alarms are not only related to predictive maintenance (sensor drift, consumable tracking, etc.) but also to coil quality (mechanical properties estimation, coarse grain risk, etc.) and process conditions (out of range temperature, bad coating grip risk, etc.). The just-in-time feature allows almost immediate corrections leading to operational cost savings. In addition, all the data collected by the TCOptimizer software are easy to export for further analysis like developing some new grade qualities. Finally, using a remote access service, the Siemens VAI metallurgical team is in a good position to assist customers in their new developments.

3 CONCLUSION

The present article introduced the main components used to maximize the capacity and performance of a galvanizing line. Siemens VAI galvanizing lines stand out for their state-of-the-art achievement and their advanced technologies which will enable customers to meet the latest and future requirements.
Within the framework of this article, the authors wished to get the message across that a large spectrum of plant solutions exists. Choosing the adapted one is a matter of expertise! Acting not only as a supplier but also as an expert advisor for steelmakers, Siemens VAI undertakes to offer its customers tailor-made solutions derived from its standardized and well proven products. Whatever the market you intend to serve, Siemens VAI staff will always give a serious thought to the line design so as to make you stay one length ahead.

[15] *TCOptimizer : Total Cost of Ownership software.*

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