SUSTAINABLE DEVELOPMENT CHALLENGES FOR HOT DIP GALVANIZING PLANTS[1]

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Abstracts
Beyond the recent increase of the world demand for hot dip coated products, a major threat is coming concerning the existing and the newly implemented hot dip galvanizing lines (HDGL). The context of economical operation has changed with many issues such as the cost of energy, raw material and transportation. In the same period, new concerns related to the product life cycle, Health-Safety-Environment have surged. The challenge for HDGL designers is to now ensure the profitability of the future plant in spite of the continuous shrinking of the product added value. The objectives, both in terms of process improvements and plant management are now condensed in a newly developed concept : “Smart HDGLs”.
Key words: Hot dip galvanizing line; Coating; HDGL

DESAFIOS DO DESENVOLVIMENTO SUSTENTÁVEL PARA PLANTAS DE GALVANIZAÇÃO

Resumo
Com o aumento recente da demanda mundial por produtos galvanizados, inicia-se uma grande ameaça às linhas de galvanização a quente (HDGL) existentes e às recentemente implantadas. O contexto de operação econômica mudou devido aos custos de energia, matéria prima e transporte. No mesmo período surgiram preocupações relacionadas ao ciclo de vida do produto, Saúde-Segurança-Ambiente. O desafio dos projetistas de HDGL é agora assegurar lucratividade da futura usina, independente da continua diminuição do valor agregado do produto. Os objetivos, em termos de melhorias de processo e gerência da planta estão agora condensados em um conceito desenvolvido recentemente: “Smart HDGLs”.
Palavras-chave: Galvanização; Recobrimento; HDGL

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INTRODUCTION

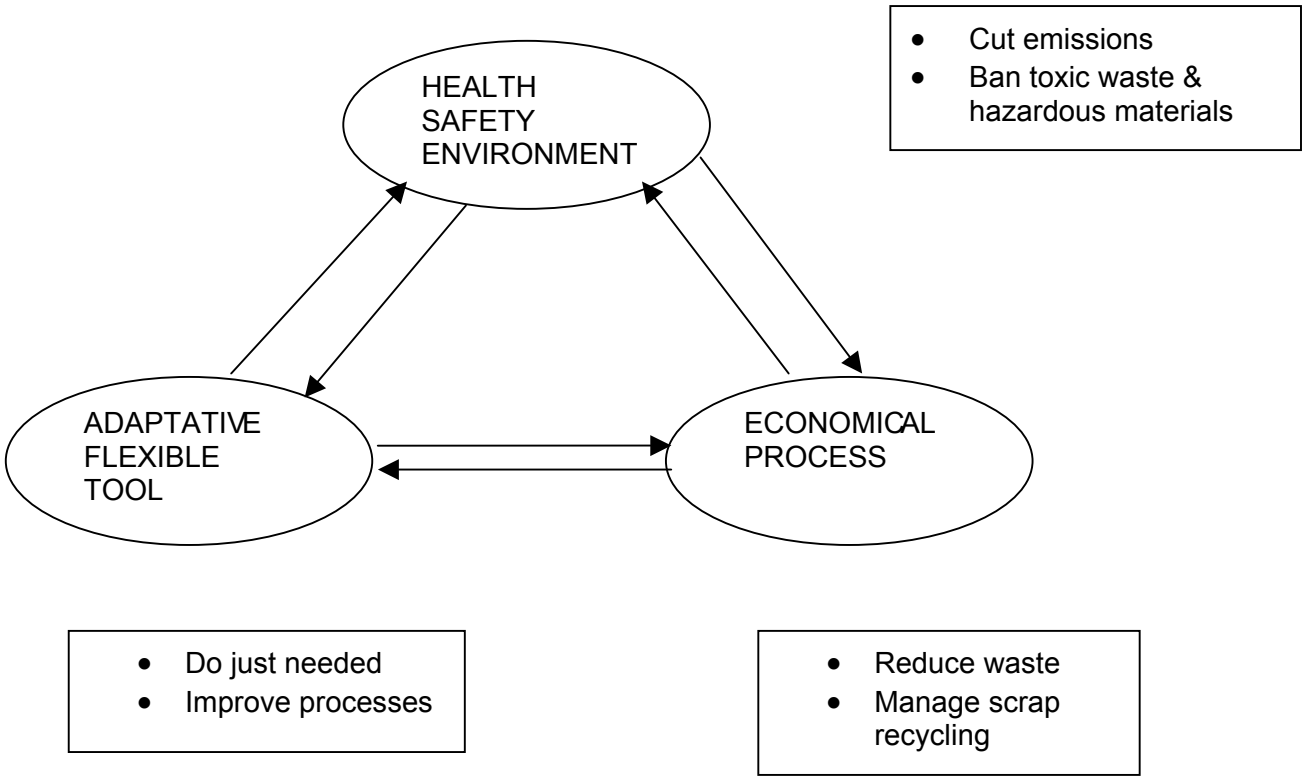
Beyond the recent increase of the world demand for hot dip coated products, a major threat is coming concerning the existing and the newly implemented hot dip galvanizing lines (HDGL). The context of economical operation has changed with many issues such as the cost of energy, raw material and transportation. In the same period, new concerns related to the product life cycle, Health-Safety-Environment have surged. The challenge for HDGL designers is to now ensure the profitability of the future plant in spite of the continuous shrinking of the product added value. The objectives, both in terms of process improvements and plant management are now condensed in a newly developed concept : “Smart HDGLs”.
This idea integrates the following features :

- Health Safety & Environment (HSE) as a driving force for reducing wastes, energy consumption, increasing the product life and managing the by-products by efficient recycling
- Versatility of the market and consumers habits which leads adaptative tool design
- An economical operation of the plant which results in a continuous improvement of the coating /annealing process

SMART HDGL CONCEPT, A GLOBAL APPROACH

Obviously, those features are to be treated simultaneously since they are closely linked together in a virtuous loop :

- Designing a flexible and environmental friendly plant leads to process improvement and easy operation
- Improving process induces waste reduction
- Reducing wastes increases profits
- Profits will fuel future improvements



KEYS FOR A SUSTAINABLE DESIGN OF HDGL PLANTS

The Health Safety & Environments issues are to be anticipated especially :

- ban bio persistent fibres
- removal of lead and hexavalent chromium
- prevent injuries by ergonomically designed work stations
- reduce Nox and CO2 emissions to levels lower than actual EPA regulation prevent the pollution of scrap yard by tramp elements such chromium, molybdenum detrimental to the up-stream steel making processes
- minimize zinc in the scrap recycling stream
- control the waste water dumps.

Those targets are matching together with the cost reduction focuses such :

- zinc application to the “just in spec” level
- fuel consumption minimized at the annealing furnace
- reduction of chemicals (soda, passivation product, anti finger print)
- reduction of fresh water consumption.

Solutions are to be implemented, watching the new market trends of galvanized product such :

- The development of advanced high strength steels using the HDGL route, Dual Phase, TRIP
- The substitution of Cold Roll by Hot rolled galvanized product where applicable
- The management of various surface texture for improving a further coating process
- Development of new post treatments such anti finger print, self lubricating.

SOME ELEMENTS OF THE SIEMENS VAI APPROACH

1 The Design of a tool suitable for the wider range of galvanized products

A Hot dip galvanizing line can be designed with different approach depending on the production and market context. One is to build a specialized line dedicated for a specific product; the other way is to process the wider range of the product mix with the same plant. At first this basic consideration cannot be solved without a serious survey of the production context.

A multipurpose Hot Dip Galvanizing line **(MP)** would be suitable to supply a market from a single plant but would require a more sophisticated tool. On the other hand a single purpose line **(SP)** is easier to operate but need to be complement by another line (s) for fulfilling the whole market demand. The decision is in fact, dictated by the position of the galvanizer on its geographic market and its existing production tools. This has to be solved using a market analysis. For that, it is recommended to study the product under its various aspects for correlating the product grades, sizes together with the capacity of the equipment. Generally, the following criteria are watched :

- Size range (width, gauge)
- Annealing grades and substrate quality
- Coating material (zinc, aluminium, aluminium-zinc, galfan, galvannealed)

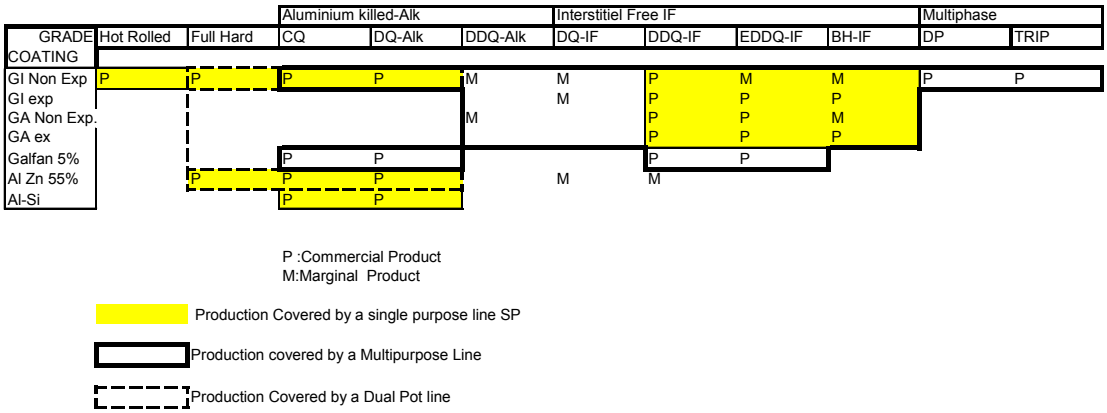


Fig-1 GRADE Versus COATING TYPICAL REPARTITION

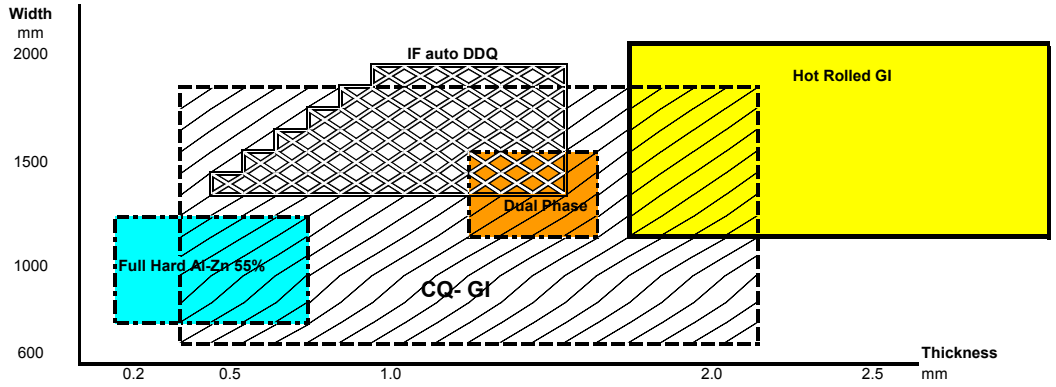


fig-2 **GRADE Versus Size: TYPICAL REPARTITION**

Referring to the Figure 1&2 it looks that current commercial product have some common parameters that predetermine a primary classification. In view of that, we can identify some product that can be treated in a specific line as soon as the commercial context allows it ; for instance :

- Line dedicated to galvanisation of Hot rolled material only
- Line dedicated to Zinc-aluminium coating exclusively
- Line dedicated to automotive product draw able grades.

As said, the production management would be much easier if the work load of each plant is sufficient to ensure the profitability. In other situations, it may be recommended to dispatch coils from different sources on the same line.

One might notice that a significant portion of zinc aluminium production is for construction in agricultural & marine atmosphere. Those products are sold un-annealed with a minimum hardness and the substrate is similar to the traditional Full hard galvanized for corrugated sheets. The two products are very similar with a slight difference on the gauge range. Then, both could be produced on the same line providing the implementation of a dual coating system.

By extension, a Multipurpose plant is designed by processing other types of product on a line where characteristics are such that a compromise is possible with various operating practices. Generally speaking, those lines need a more sophisticated equipment and must exclude some products not compatible with the equipment. The capability of each component of the line is to checked, the figure 3 shows the various parameters involved in a compatibility study. Among the major criteria, are selected at first :

- maximum process speed
- furnace capacity (constant thickness x speed)
- coil size
- strip size
- size range

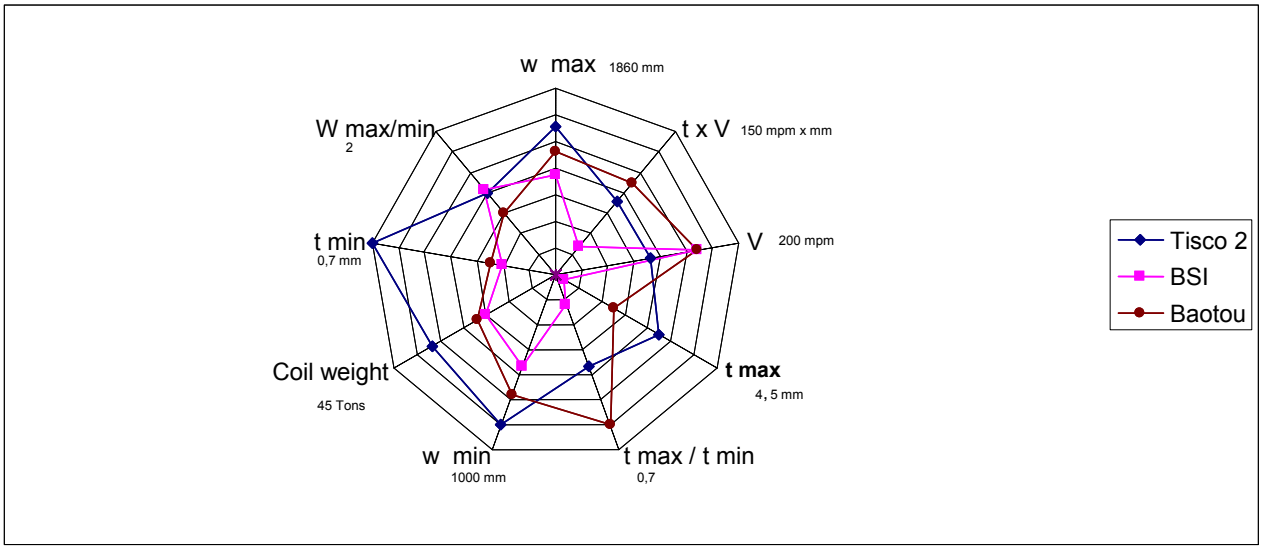


Figure 3. Terminal & Drives

2 To follow the trend of the galvanized products

The trends of the past years are mostly :
- Increasing segment of high strength material such dual phase
- Substitution of CR by HR products

3 To develop new devices for improving processes and reduce consumptions

➢ Ergonomy of work station

Thanks to the 3D design a considerable enhancement is done just by simulating the tasks and visualisation of workers sight. This has given proven gains in the Coil handling system, zinc ingot management and loading accessibility for maintenance etc …

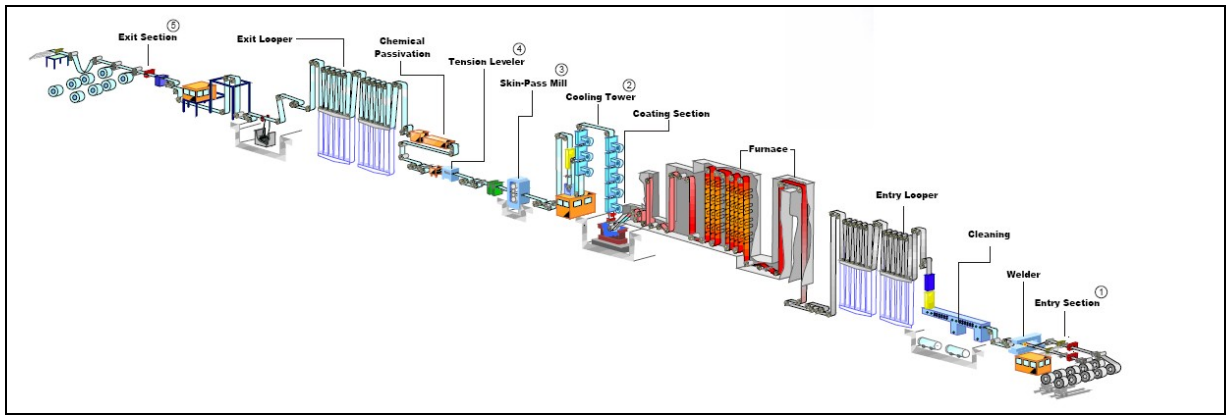
➢ Cleaning section

Significant reduction of waste water disposal by implementation of :
- Ultra filtration of cleaning solution
- High gradient magnetic separator

Any gain in cleaning efficiency improves the zinc wetting process and consequently increase the production yield

➢ Furnace

Among the different alternatives solutions for a multipurpose HDGL, the smart combination of the Direct fired furnace with a radiant tube soaking and a rapid cooling has brought many advantages at the Voest Alpine CGL#3 of Linz.



- Significant reductions of the NOx and CO2 emissions
- Smooth strip tracking with low tension
- Reduced risk of buckles
- Ability to trigger the internal oxidation of the tramp elements of high strength steel thus easing the zinc wetting

In other sites, this combination with a DFF :

- improves the process of full hard material by reducing the risk of the un wanted sub critical annealing
- allows the process of Hot roll GI strips

➢ Zinc Pot Area

The zinc pot area (**Figure 5**) is the critical process area of the line, where equipment and operation must be dedicated to the production of a zinc coating which is uniform, free of defects and of consistent thickness, both across the strip width as well as along the length of the strip. This ability to control the quality of the zinc coating must be repeatable and is paramount to meet the quality requirements of automotive product.

Figure 5. Zinc Pot Area

Zinc Pots :

- Two zinc pots, moveable across or in-line, are usually practice in operation to give more flexibility of coating. At the present stage, it seams, that only one zinc pot is requested according to the range of strip coating
- Ceramic lining for best quality and long life

- Heating by channel type inductors.

Bath Management :

Control and management of the constituents of the zinc bath, particularly the aluminium content of the bath, is very important.

High quality chemical analysis of the bath is necessary in order to enable control over the bath constituents. Additionally, Voest Alpine Stahl have utilised a proprietary software package to improve the management of the bath chemistry, and in-bath aluminium sensors have been used for specific investigations.

The main goals in respect of the zinc bath are :

- Constant aluminium level during zinc (Z)
- Constant bath temperature
- Low dross formation
- Low corrosion or dross pick up at zinc bath rolls
- No entrapment of dross into the coating

Automatic zinc bath surface cleaning could be operated through a robot.

Zinc Wiping (Coating Knives) and Pot Rolls :

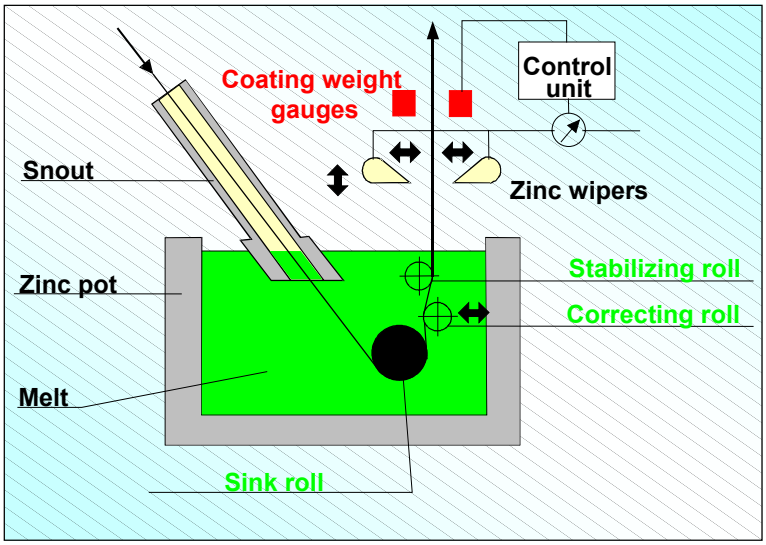


Figure 6. Schematic of Zinc Wiping Knives and Pot Rolls

High quality coating knives and pot roll systems (**Figure 6**) are essential for consistent coating both across and along the strip. Correct operation of the coating system is necessary in order to achieve uniform coating weight and good coated surface appearance, as well as to maintain acceptable bath dross formation. Features include :

- Wiping pressure and knife position control related to line speed and required coating weight
- Wiping normally using air, but also using nitrogen gas for the best coated surface quality
- Edge baffles in order to prevent edge overcoating
- 3-roll pot system required for elimination of strip crossbow and for stable strip in the coating knife gap
- Pot rolls are coated (tungsten carbide in cobalt matrix) to reduce dross pick up and increase service life

- Improved bearing materials are under investigation (e.g. ceramic ball bearings)
- Sophisticated coating knife system with on-line nozzle gap adjustment is now available with the VAI Dynamic Air Knife, DAK (**Figures 7 & 8**). This coating control system is unique ; it enables automatic control of the coating in the transverse as well as the longitudinal direction, by using on-line dynamic lip gap profile adjustment. This offers better zinc coating distribution along and across the strip which results in :
  - Enhanced surface quality
  - Minimized coating deviation and zinc savings (**Figure 9**)

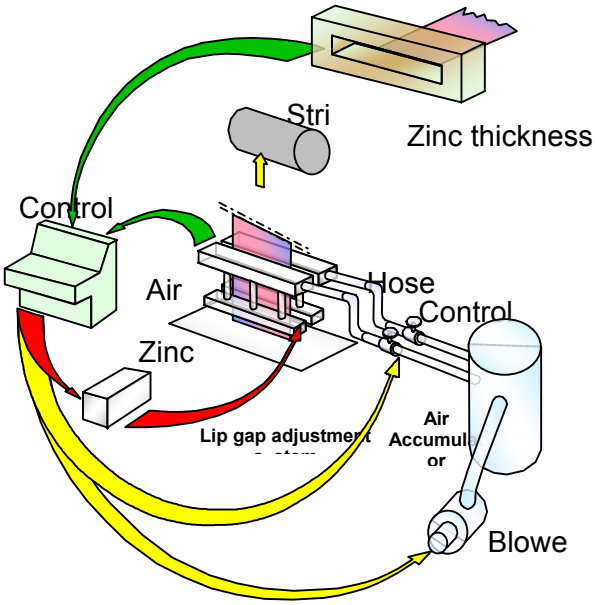


Figure 7. Schematic of VAI Dynamic Air Knife (DAK) System

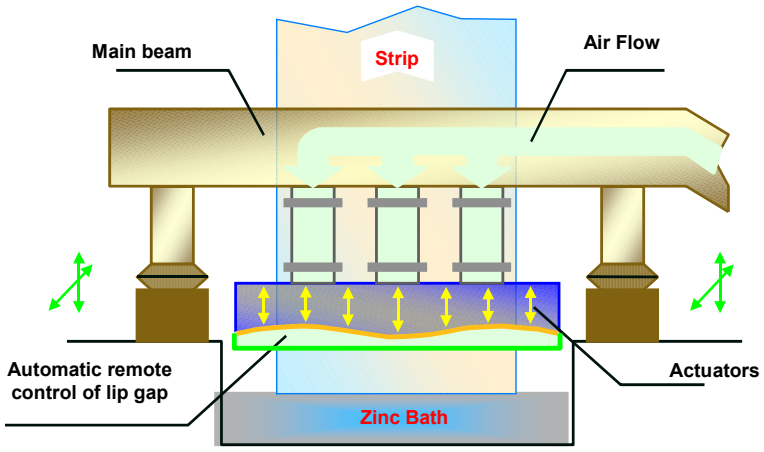


Figure 8. Schematic Cross-Section of VAI Dynamic Air Knife (DAK)

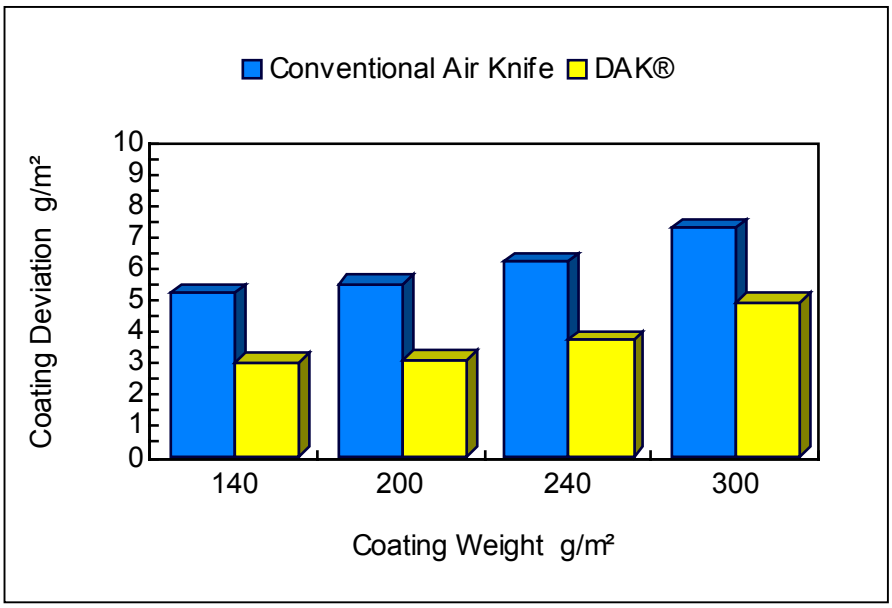


Figure 9. Coating Weight Comparison - VAI Dynamic Air Knife (DAK)

Coating Gauge

The coating thickness on both sides of the strip is measured by X-ray traversing type coating weight gauge for best accuracy (**Figure 10**). The coating weight control can be operated in closed loop mode with the coating knives.
Possible locations of the Coating Gauge are :

- "Hot gauge" - close to coating knives - fast response time, but difficult environment and access
- "Warm gauge" - top of cooling tower - medium response time, better environment, inconvenient access
- "Cold gauge" - after final quench - slow response time, best environment and good access

The majority of galvanizing line applications currently utilise coating gauges located either in the "warm" or "cold" positions.

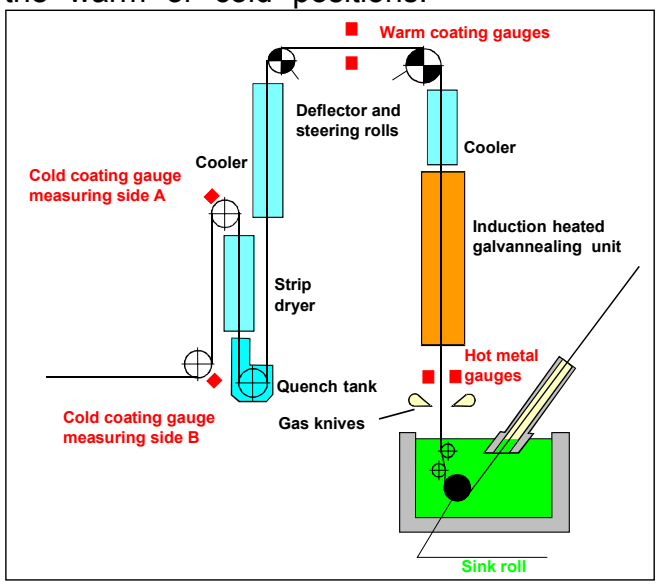


Figure 10. Alternative Positions of Coating Weight Gauges

➢ Skin-pass Mill and Tension Leveller

Skin passing and tension levelling are essential for the production of exposed automotive strip and other high quality applications (**Figure 11**).
The skin-pass mill and tension leveller equipment serves to meet the very strict specifications for surface roughness, mechanical properties, yield point suppression and flatness of the final product.
The large number of different material and surface specifications, as well as the different behaviours of the various coatings underscores the difficulties in properly designing the skin-pass mill. Indeed, the demands placed on the strip are sometimes even contradictory, such as when high surface roughness is required with a simultaneous demand for low tensile strength and therefore low elongation degree.

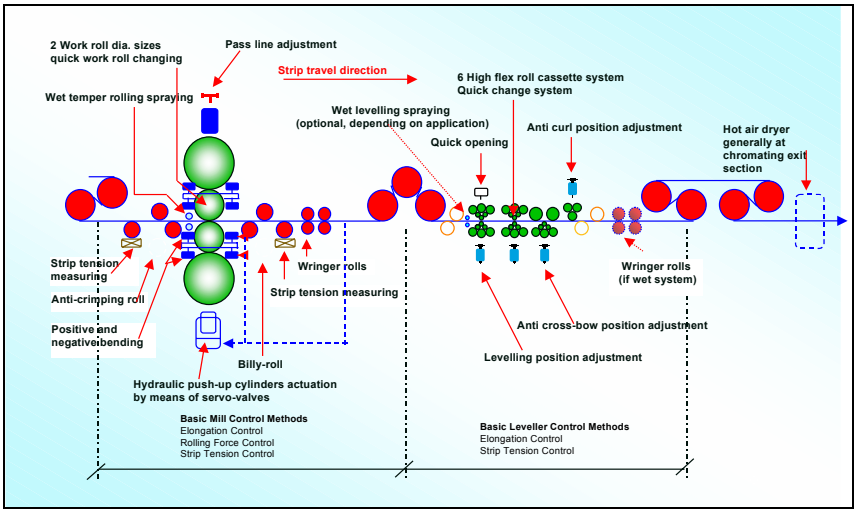


Figure 11. Skinpass Mill & Tension Leveller Schematic

Operation of a four-high mill, with positive and negative roll bending system, enables the work roll gap to be adjusted in order to achieve homogenous distribution of roughness across the entire strip width and also to improve the degree of flatness.
Very soft materials, such as extra deep drawing IF steel grades used for some automotive materials, can tolerate only small deformation forces in order to preserve their low yield point. Only very small rolling forces can therefore be applied to these

steel products, and this can lead to low-load control problems as well as limited possibilities to control strip surface roughness and flatness. Indeed, this dichotomy with the relatively high rolling loads required for thin and/or hard material grades has led to some skin-pass mill installations with dual work roll diameter size capability in order to enable larger work roll diameters to be used for the extra deep drawing steel grades.
Strip marking can be caused by zinc pickup on the rolls of the skin-pass mill and tension leveller. VAI adopt special wet skin-passing techniques with roll cleaning, allied to a sophisticated torque control system, to minimise the possibility of such surface defects occurring.
Wet skin-passing operations together with the installation of a neutral point control system and high pressure roll cleaning in the Hot Dip Galvanizing Line No.2 of Voest Alpine Stahl resulted in a considerable reduction of unscheduled work roll changes (**Figure 12**).
Work roll changes due to zinc contamination were reduced to less than 10% of the total number of scheduled and unscheduled work roll changes.
The number of scheduled work roll changes due to varying product requirements for surface roughness or changes in strip width according to rolling schedules cannot be avoided. However, a considerable cost saving was achieved by these implementations.

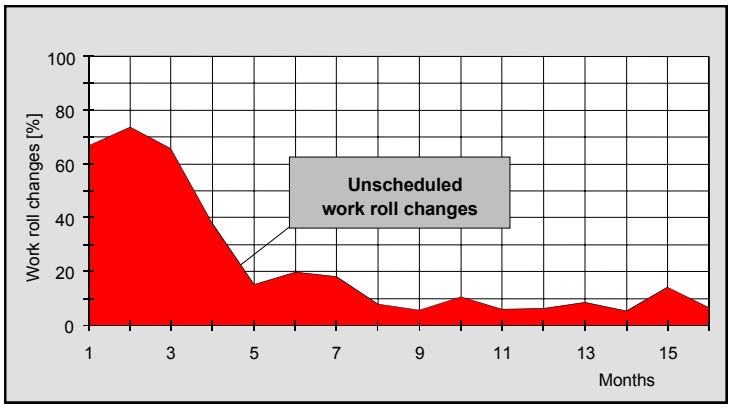


Figure 12. Reduction in Unscheduled Work Roll Changes at SPM

With regard to the layout of the skin-pass mill and tension leveller area (**Figure 13**), the equipment should additionally include :

- Intermediate bridle to enable independent control capability in respect of strip elongation, rolling load and strip tension at the mill and leveller
- Fast work roll change
- Work roll and back-up roll change without stopping the strip. That means, it is necessary to install an intermediate accumulator able to store strip length for 90 seconds work roll changing time.
- Automatic control system for system parameters set-up and control, including system to maximise prime material yield during weld seam passage through the section

➢ Post Treatment

The classic chrome no-rinse treatment by spray application for protection from “white rust” is still in use, but alternative application methods and other treatments are gaining favour or are under development, such as :

- Application by chemical roller coater for precise coating control and improved working environment
- Chrome free chemical solutions to meet requirements of stricter environmental limits
- Phosphating on-line as a paint pre-treatment
- Anti-fingerprint coatings prevent unsightly surface marks being created during subsequent handling of the product
- Some of these new coatings require sophisticated (and expensive) application equipment, involving chemical coating, heating/curing and subsequent cooling treatments

➢ Surface Inspection

Surface quality control is one of the key features for production of best surface quality (exposed automotive panels) on a hot-dip galvanizing line.
The operational requirements for inspection are :

- Both sides (top and bottom) should be inspectable at the same time by one person
- 5 metres of strip length should be observable (corresponds to approx. 1.5 m roll diameter)
- Light source should be optimised and variable in power due to different reflectance of products
- High level of acceptance by inspection operatives

VAI SIAS has developed high technology equipment for strip inspection surface and will be proposed for CORUS CGL.

➢ Automation and Process Control System

The efficient and cost-effective operation of a modern, high quality, hot-dip galvanizing line requires a sophisticated automation and process control system which integrates and controls the process automation of the various equipment elements of the line. All the automation and process control system can be supplied by VAI Automation.
The main benefits of such a system include :

- Reproducible and consistently high product quality
- High yield through application of optimised production strategies
- Consistent operation by automated entry and exit coil handling, feed-up and automatic welding
- Accurate weld tracking enables optimised process set-up changes to suit the new strip as it passes through the line
- Exact annealing furnace temperature control with process model
- Reduced zinc and energy consumption
- Achievement of high level of elongation accuracy at the skin-pass mill and tension leveller for uniform mechanical properties and surface roughness aspect
- Reduced maintenance with automatic diagnostic systems

CONCLUDING REMARKS

In this paper, the hot-dip galvanizing line requirements to serve the highest quality market have been considered.
The ever increasing quality demands of the automotive market has lead to hot-dip

galvanizing line installations of increasing complexity and specialisation, together with implementation by the operating companies of line operating regimes which are dedicated to reaching the highest quality demands of the marketplace. Summarising some of the factors pertaining to a hot-dip galvanizing line for the automotive market:

- Consistent, high quality, cold rolled substrate
- Line design optimised and with specialised equipment to meet the highest quality market needs
- Vertical annealing furnace and other process equipment designed to process the full range of automotive product grades and ideally with capability or retrofit flexibility to process new steel grades which will be introduced in the future
- All equipment to be operated and maintained at the highest levels of quality in order to consistently meet the product requirements
- Flexibility to serve other markets whilst qualifying to supply highest quality automotive product

VAI, a major supplier of strip processing lines, offers attractive technological and investment solutions for all types of process lines, including highest quality cold rolled strip galvanizing lines for the automotive market. In addition to the high levels of expertise and experience in the supply of galvanizing lines, VAI has identified and developed in-house key components including Laser welder, Mash Lap Seam Welder, Cleaning Section, Dynamic Air Knives (DAK®) and In-Line Skin-pass Mill, Tension Leveller and Roll Coater to state of the art for modern reliable and profitable, high quality Continuous Hot Dip Galvanizing Lines.