ISSN 1983-4764

IMPLEMENTATION OF HIGH CAPACITY CONTINUOUS ANNEALING LNES WITH HIGH QUALITY MANUFACTURING[1]

Philippe Podda [2]
François Mignard [3]
Stéphane Georges [4]

Abstract

Within the last 10 years, Chinese steel producers have invested in Continuous Annealing facilities leading to a high install base capacity. Each of these plants is sized for approximately 0, 6 to 1 million tons per year to serve massively the construction, industrial and automotive market with various product sizes and grades such: Low carbon Al killed steel, IF steel for drawing qualities, High strength steel, Advanced high strength steel, DP,TRIP. The Continuous Annealing Line process is now facing several challenges taking place at the same time, namely: Serve Automotive demanding Industry, Development of new steel grades especially AHSS and Be responsible towards Health and Safety Environment by reducing energy consumption and emissions. These challenges are manageable through a very high Quality Manufacturing aiming down-grading reduction prime quality yield enhancement. For this purpose, Siemens is offering SIROLL PL, a set of powerful tools issued from years of research and development. Both from the Mechanic and Electric & Automation point of view, these solutions can be advantageously use by Steel Producers.

Key words: Continuous annealing lines; Processing line; China; Automotive.

[1] *Technical contribution to the 47th Rolling Seminar – Processes, Rolled and Coated Products, October, 26th-29th, 2010, Belo Horizonte, MG, Brazil.*
[2] *Vice President Cold Band, Siemens VAI MT*
[3] *Technical Sales Director, Siemens VAI MT*
[4] *E&A Product Lifecycle Manager for cold mills and processing lines, Siemens AG*

ISSN 1983-4764

1 INTRODUCTION

Fuel prices and general concern about environment is motivating steel makers to elaborate higher quality steel grades with even higher productivity and quality ratio.
In P.R. China, where accelerated industrialization is lifted by the development of the manufacturing industry, steel consumption is strongly increasing.
At the same time, steel is a product with high-energy consumption, meaning each rejected ton at any step of the metallurgical elaboration amounts to high waste, directly impacting environment. Applied to the Automotive Sector which is addressing the highest standards, manufacturing quality of lines processing flat carbon steel is of the utmost importance to limit environmental impact.
This document is dealing with root factors for reducing environment impact of Continuous Annealing Lines supplying the automotive industry.

2 METODOLOGY

2.1 Market Trends

Iron and steel application and utilization are increasing along with the development of the manufacturing industry.
Steel production is tremendously demanding in energy consumption giving to the product, at every step of the steel route, more and more value-added. P.R. China controls export steel products by enhanced tax-levy, encouraging exportation of the highest value-added products but also to response to their domestic demand.
According to "Chinese Market Analysis"[1] China consumption shall be over 20Mtpy of automotive steel by 2015 (Figure 1).
Average consumption of steel per vehicle is considered approx. to be 550 kg/car where the half of it would be cold rolled product and the other half galvanized product.

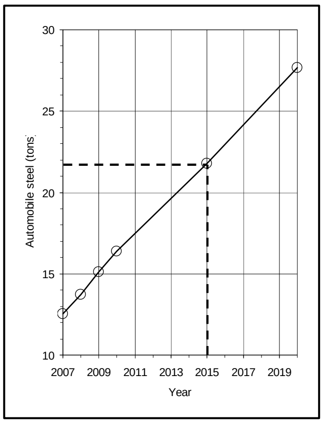

Figure 1. Chinese Steel Market Analysis – June 2008.

As developed next chapter, automotive steel grades are of the highest metallurgical complexity with specific design to exhibit various functions like deep-drawing ability, energy absorption, ultra-high-tensile strengths or bake hardening to be assembled in a vehicle.
To meet these challenging market trends, Chinese Steel Companies have already invested into 13 Continuous Annealing facilities during the last six years.

ISSN 1983-4764

2.2 Metalurgical processes

2.2.1 Energy consumption

Average total worldwide energy consumption is rating at about 16 terawatts. For the Iron and Steel industry it can be divided into 3 main source of energy:[2]
Coal is the largest energy share with over 95% of use by coke ovens.
The next largest fuel is Natural Gas used primarily in heating and annealing furnaces but also for blast furnace and oxygen injection, boilers and cogeneration (Figure 2).
Electricity third largest energy source and is used primarily in the electric arc furnaces. About 80% of electricity consumed is purchased; the rest is generated on site.

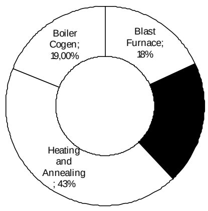

Figure 2. Natural gas use in the steel industry.

When focusing on the various metallurgical steps of elaboration of annealed products from iron making to continuous annealing processes, ones can observe that energy requirement for the annealing process is low compared to other processes (Figure 3).

ISSN 1983-4764

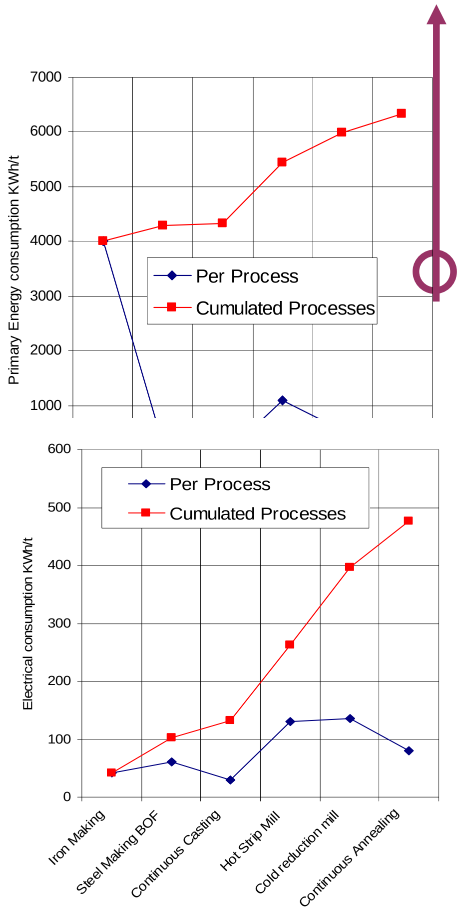

Figure 3. Primary energy and electrical.

- **Consumption per ton of product for various mill operations**

However, when considering the cumulated primary energy consumption to produce 1 ton of annealed material, it become obvious that each ton rejected is paying a large tribute to released wastes.

- **Emissions**

On average, 1.7 ton of carbon dioxide is generated for each ton of steel produced. Iron production is generating over 90% of steel industry emissions.
In Continuous Annealing Lines, recent development on cleaning section to reduce release of alkali solution, furnaces with modern burner technologies limiting fuel consumption and NOx generation, skin pass mills with fluid recirculation and modern drive solutions combined with more accurate process control are simple examples demonstrating how product development can reduce consumption and therefore impact of emissions. It is not questionable that the ever demanding regulation and concerning situation on emission will force further equipment development.
The table given hereunder (Figure 4) is giving typical consumption figures consolidated for process equipment of a continuous annealing line per ton of steel processed.
Annealing process representing only approx. 6% of the overall energy consumption for the elaboration of steel, the highest straight forward improvement

ISSN 1983-4764

to reduce environment impact would be the optimization of production facilities by metallurgical know-how and manufacturing quality best practices to enhance prime quality yield.

Table 1. Typical consumption and emissions by a CAL

Alkali Solutions	0,02	m³/t
Compressed air	14	Nm³/t
Instrument air	5	Nm³/t
Industrial Water	0,05	m³/t
Recirculated water	21	m³/t
Demi water	0,26	m³/t
Potable Water	0,02	m³/t
Steam	40	Kg/t
SPM Wet rolling	10	Kg/t
COG: LH 17 000 kJ/Nm³	66	Nm³/t
Nitrogen	42	Nm³/t
Hydrogen	0,7	Nm³/t
Electric Power	90	kW/t

NOx	250	mg/Nm³
Dust	0,5	mg/Nm³
Noise	85	dB(A)

2.2.2 Drawing application

Among the steel qualities required to be processed through a continuous annealing line, deep drawing qualities are necessary for the skin of car bodies.
Drawing ability is obtained by a minimum of free interstitial (C and N) to help dislocation displacements during drawing. Three major steel families are generally considered:
AlK: Aluminum Killed steels (C<500ppm, obtained by precipitation of C and N into iron carbides and aluminium nitrides).
ULC: Ultra Low carbon steels (C<30ppm).
IF: Interstitial Free steels (C<70ppm, by elimination of C and N thanks to precipitation of stable carbides and nitrides (TiC, NbC, TiN …).
Residual nitrogen (N) is treated by coiling temperature and residual carbon (C) is treated by the thermal process (cooling kinetics).
One shall notice that deep drawing qualities recognized by the automotive industry are mostly IF steel grades, mainly to avoid ageing concerns up to 6 months after being annealed. The use of AlK steel combined with rapid cooling facilities in a CAL can also provide deep drawing qualities. This thermal route withdraw the costly vacuum degassing process of the IF metallurgical route;[3] benefiting a saving estimated to about EUR 15/t.
Drawing mechanical properties with enhanced mechanical resistance is also demanded by the automotive industry. A controlled ageing behaviour can be desirable for some parts like Bake Hardening steels as illustrated figure 5. Both IF and AlK steel can exhibit bake hardenability effect during paint baking. This increases the yield strength of the formed part to approx. 40 MPa, provided sufficient cooling rate is integrated in the annealing line.

ISSN 1983-4764

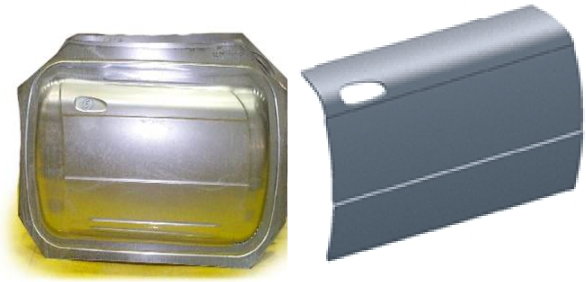

Figure 4. Final Calibration Step/Finished Part and Door outer panel resulting from ULSAC investigations.

2.2.3 High strength application

The arrival of the new millennium found automakers accelerating programs to reduce vehicle mass for better environmental performance while improving crash management and other safety features. Program goals required new steels with improved formability and major increases in strength. The global steel industry responded with a new family of Advanced High Strength Steels (AHSS). The main reason to utilize AHSS is their better performance in crash energy management, which allows one to down gauge with AHSS. In addition, these engineered AHSS address the automotive industry's need for steels with higher strength and enhanced formability (According [4] and referring to steel grades under Figure 6).
As a general tendency of this development:
Weight reduction will account for 25% percent of targeted fuel reduction.
10% growth rate per year is foreseen in the use of AHSS through 2020.
Approx. 300kg mild steel, high-strength steel and iron to be replaced with 160kg of dual-phase, martensitic, boron and other AHSS, to meet the new goal.

Table 2. Examples of Steel Grade Properties from ULSAB-AVC.W-1

Steel Grade	YS (Mpa)	UTS (Mpa)	Tot. EL (%)
HSLA 350/450	350	450	23-27
DP 300/500	300	500	30-34
DP 350/600	350	600	24-30
TRIP 450/800	450	800	26-32
DP 500/800	500	800	14-20
CP 700/800	700	800	10-15
DP 700/1000	700	1000	12-17
MS 1250/1520	1250	1520	4-6

Figure 5. ULSAB body front isometric view.

The achievement of Dual Phase microstructure dependants on strengthening alloying element content balanced by the thermal quenching kinetics.

Dual phase structural formation improves when Equivalent manganese Mneq is higher:

Mneq = Mn + 0.45 Si + 1.15 Cr + 2 P (+ 0.3 if B)

At the same time, welding ability is affected when carbon equivalent Ceq is higher:

Ceq = C + (Mn+Si)/6 + (Cr+Mo+Va)/5 + (Ni+Cu)/15

From this point of view, cooling rate is becoming of utmost importance to process AHSS as summarized in Figure 8.

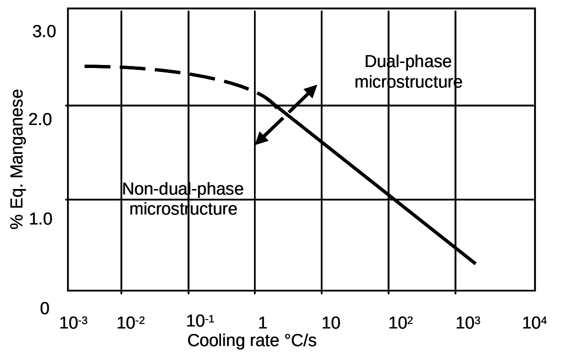

Figure 6: DP microstructure formation vs cooling rate.[5]

For instance, operational development of such equilibrium was conducted at Voest Alpine Stahl were benefits were demonstrated in term of Manganese and Chromium reduction (Figure 9).

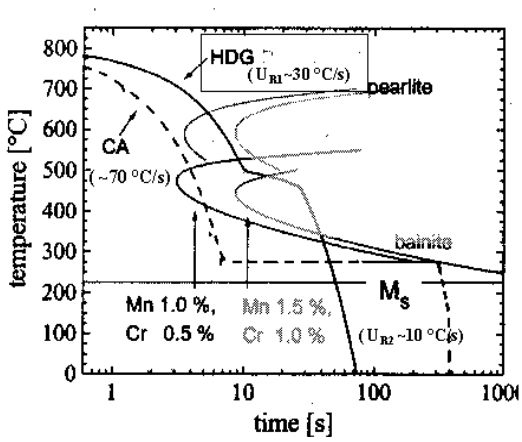

Figure 7. Mn, Cr content vs cooling rate for DP microstructure achievement.[6]

3 RESULTS AND DISCUSSION

3.1 Continuous Annealing Lines

3.1.1 Consideration for design

A Continuous Annealing Line is a succession of sequential processes, any of them having potential to be limiting factor. Therefore, the design of each of the processes shall be fit to purpose. As an example given Figure 10, balanced design between line maximum speed and furnace capacity shall be selected according steel producer mix-product. The thinner the products, the higher maximum speed shall be selected and vice-versa for thicker gauges.

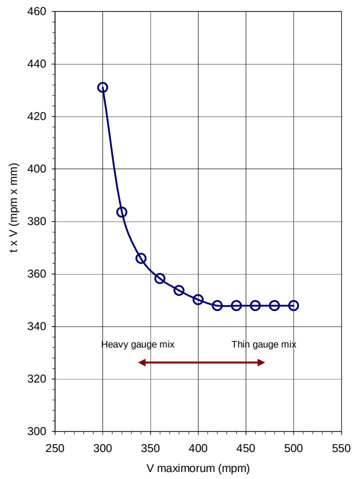

Figure 8. Furnace capacity Vs Process Speed.

Siemens, as responsible plant builder, provides steel makers with powerful tools for quality manufacturing to increase prime quality yield as completely integrated solutions materialized into:
Full liner: Mechanical, Electrical and Automation and Process Know-How,
Major references in Europe and in the USA,
Market leader in China with 60% market shares as full liner 80% market shares as E&A and furnace references with Majors Furnace Builders.

Figure 9. MaSteel continuous annealing line.

3.1.2 Automotive quality manufacturing

Know-how Providers
Looking back to the history of Know-How providers, three major periods can be identified:

- In the 80's – 90's: where mainly Japanese plant builders were supplying the European market,
- From the 90's Japanese and European steel makers supplying the Chinese market.

ISSN 1983-4764

- From 2008, Siemens Metallurgical Center was formed with the motivation of a full liner plant builder, new steel grades assessment, and increase market shares without providing conflict of interests to client benefits.

3.2 SIROLL Powerful Tools

Siemens has developed SIROLL powerful tools to provide steel makers solutions for manufacturing quality enhancement and therefore answer to automotive steel.

3.2.1 Sinamics – A modern drive solution

Siemens VAI offers the Sinamics family advanced technology frequency converters for AC drives to achieve excellent dynamic performance, requiring in processing line drive applications. The AC drives solution ensures high reliability, significant savings in maintenance costs combined with an increase of efficiency limiting environmental impact.

3.2.2 SIROLL PL automation platform

The efficient and cost effective operation of a modern, high quality continuous annealing line requires a sophisticated automation and process control system which integrates and controls the process automation of the various equipment of the line. Among its benefits, let' summarize the most important ones:

- High yield through application of optimized production strategies
- Direct tension control with and without tension measurements. All the drives are speed controlled with high accuracy and high dynamic response featuring a filter functionality for incoming tension variations
- High level of elongation accuracy at the skin pass-mill and tension leveller for uniform mechanical properties and surface roughness aspect
- Reduces maintenance with automatic diagnostic systems.

The modern drive solution combined with an accurate process control ensures immediate high quality avoiding thus reprocessing costs.

3.2.3 SIFLAT contactless flatness measurement unit

A contactless SIFLAT flatness measurement unit avoids any negative effects on the strip usually caused by measurement rolls, so that no additional spare measurement rolls need to be stocked. The device reliably measures the tension distribution in the strip and uses it to always ensure the best possible roll gap. The benefits of the SIFLAT approach include both process improvements and reduced operating costs.

ISSN 1983-4764

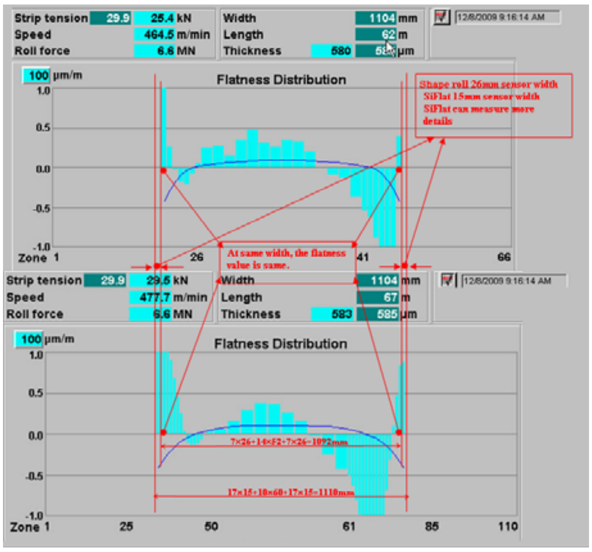

Figure 10. Comparisons between a shape roll and SIFLAT contactless flatness measurement unit (August 2009).

3.2.4 SIROLL Total Cost Optimizer TCO®

The TCO® Optimizer is an advanced level 2 module allowing better integration of manufacturing, maintenance, and quality management with local or distant efficient monitoring, will permit to reduce the Total Cost of Ownership (TCO) [7] of the plant through:

- A better control of consumables.
- The identification of the sources of yield & productivity improvement (OEE module).
- The on line Quality Control.

The development of this advanced module leads to:

- A plant ready for the starting up which includes all basic tools: process supervision, products qualification, scheduling, maintenance handling, and which uses homogeneous referential.
- A plant which give comprehensive and detailed information to the operator
- A plant which allows to do predictive diagnostic and to identify a problem before it creates a downtime or a decrease of the product quality.
- A monitoring which allows receiving the best know-how at this time.

3.2.5 SIROLL Overall Equipment Efficiency (OEE)

The goal of the SIROLL OEE module is to fight every loss (downtime, under speed and none quality) leading no more and no less to non stop production, top speed production and zero defect production. Most industries already monitor what is coming out of their tandem mills. The OEE module goes deeper and monitors what could have come out versus what has really been produced. Consequently, it can identify where the losses are.

Efficiently displayed in the HMI system, the OEE module not only informs the operator of the production efficiency but also give them the means to compare their actual performance with the past ones via records and graphs. With minimum manual inputs and fully customizable, the OEE module ensures better involvement of the operators as they will acquire a deep knowledge of the

ISSN 1983-4764

process, follow the indicators, qualify the stoppages and spread "Best Practises" within the teams resulting in a higher and constant product quality.

Figure 11. Typical OEE screen.

3.2.6 SIROLL SIAS® – Auto. Surface Inspection

SIAS® technology is applied to all flat-rolling operations:[8]

- Hot rolling
- Cold rolling
- Strip processing

Benefits can be grouped in generic categories:

Improved Product quality control and increased productivity: The introduction of SIAS® means replacing partial, random surface quality monitoring by constant, repeatable, systematic inspection of 100% of the production. SIAS users have a perfect knowledge of what is being produced.

The Coil Grading application is used to automatically assign a global quality level (grade) to coils, based on their surface quality as determined by the SIAS® Surface Inspection system on line. To achieve this, the application tests a given coil's surface inspection log with various user-defined defect tolerance rules. Based on theses tests' result, the coil's grade is determined.

With the coil grading application coupled to the SIAS® system, an immense reduction in the number of coils sent to re-inspection will quickly justify the system. The inspection line becomes an actual repair line as the system provides in advance all the information required to perform the removal of defects from the coil.

Process monitoring:

An indirect benefit of the SIAS® is that it provides an eye on production and hence can alarm users on process drifts. Defects such as stains from the process, roll marks are immediately detected; the cause of the problem can be quickly solved and subsequent production is not affected.

The benefit is tremendous when applied in situation where there is no alternative to automated surface inspection. This is particularly true of surface inspection at the hot mill where a defect like scale or a roll mark would be really hard to detect before several days until the next inspection downstream. Reciprocally, the impact of a change in process parameters can be observed on the product immediately and monitored, allowing an optimization of the same parameters to reach the right level of Quality at minimum cost.

ISSN 1983-4764

3.2.7 SIROLL SIAS® TRD

SIROLL SIAS® TRD is a management tool developed to track the evolution of defects along the metallurgical process of sophisticated steel sheets.
Main functionalities management tool are:
Predict how upstream defects will change on downstream line (disappear, increase, change…)
Check the turns, cuts from mother coils (HSM) to daughter coils (downstream line)
Deduce whether a HSM coil must be rejected or repaired for surface quality
Help to identify the line which created one defect

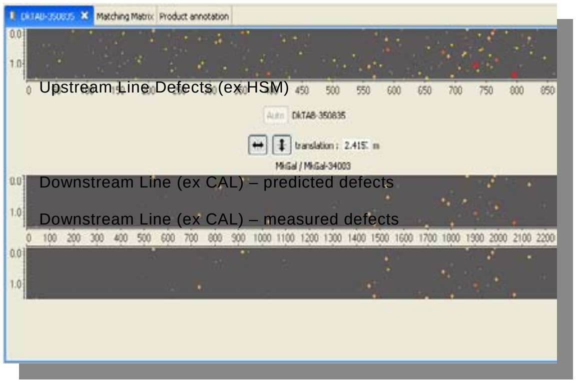

Figure 12. Defect measured at a CAL compared with defects predicted from HSM measurement.

3.2.8 Health and Safety Environment - HSE

Challenging situation of Continuous Annealing Processes to serve the demanding Automotive Industry shall not release Plant builders and Steel Producers from their responsibilities towards Health, Safety and Environment.
Siemens has developed with the support of Official Safety organisms APAVE and TÜV a standard and systematic safety approach for all projects including:

- A dedicated documentation for operator training and coaching,
- A safety Concept of the entire processing line,
- A Risk Analysis of the full processing line.

4 CONCLUSIONS

The Continuous Annealing Line process is facing several challenges taking place at the same time, namely:

- Serve Automotive demanding Industry,
- Development of new steel grades especially AHSS,
- Be responsible towards Health and Safety Environment by reducing energy consumption and emissions.

These challenges are manageable through a very high Quality Manufacturing aiming the prime quality yield enhancement. For this purpose Siemens is offering SIROLL powerful tools issued from years of research and development. These solutions can be advantageously use by Steel Producers.

ISSN 1983-4764

Figure 13. Xinyu CAL signing ceremony – April 28th, 2009.

REFERENCES

1 Chinese Steel Market Analysis, June 2008.
2 Energy Solution Center, Iron and Steel Overview: Energy Consumption, 2009.
3 The enhancement of continuous galvanizing lines by rapid cooling, F. Mignard, Steel Times, April 2000.
4 Advanced high strength steel (AHSS) application guidelines, Version 4.0, Edward G. Opbroek, Director, WorldAutoSteel, World Steel Association, March 2009.
5 Metallurgy of continuous annealed sheet steel, P. Mould, p. 3-33, TMS-AIME, Dallas, 1982.
6 41st Met. Work and Steel process. Cof.Proc., A. Pichler and al., ISS, vol. XXXVII, pp37-59, 1999.
7 An intelligent manufacturing system for CGL to produce more, better quality, and at lower cost, JF. Clavel, A. Tivolle, *Rolling and Conference '08*, Linz, Sept. 2008.
8 SIAS – From Solution to Value, M. Bailleul, *Rolling and Conference '08*, Linz, Sept. 2008.