ArcelorMittal Belgium produces 3rd Generation AHSS incl. Q&P on the unique annealing furnace from ANDRITZ Metals

Karim Kahoul, Martin Hamman – ANDRITZ Metals, France
Brecht Caekaert, Ann De Boeck, Chris Bollaert, John Gijs – ArcelorMittal Belgium, Belgium

Abstract

“ArcelorMittal Belgium is one of the first steel suppliers to have invested in a fully versatile furnace with the objective to produce a high amount of third generation Advanced High Strength Steels, such as Q&P steels. ArcelorMittal chose the ANDRITZ group to supply the necessary equipment, in particular the ANDRITZ Selas furnace, to ensure that the specific thermal and process cycles needed for these steel grades can be realized.

The furnace performances allowed to produce new grades such as Q&P steels after 12 weeks of operation, respecting specific heating paths and extreme cooling patterns, necessary for these high-end products, without jeopardizing coating quality”

Key words
Galvanizing, Innovation, Annealing Furnace, Q&P, 3G AHSS, Automotive
INTRODUCTION

In 2015 ArcelorMittal decided to speed up the time to market for the 3rd generation of Advanced High Strength Steels (3G AHSS) for cold stamping so that those products, part of the Fortiform® family, would be integrated by the OEM car makers as essential materials for the body in white (BIW) of the next 10 - 20 years car design. Following a long-term strategy to achieve these goals it became clear that only a new annealing and galvanizing production facility would be able to answer that question. ArcelorMittal R&D and the management of ArcelorMittal Belgium received the objective to specify the requirements needed to meet all challenges given by the 3G AHSS, phase transformation, temperature homogeneity over the width of the strip, coating adhesion and coating qualities.

An out of the box solution was required in order to achieve the company goals by means of a two-stage strategy. First the problems of the heat treatment and coating issues of the 3G AHSS steels had to be solved, this as to receive that acceptance of the car manufactures. The second step entailed a production on a mass scale. Thus allowing the ArcelorMittal group to make the right decisions beneficial to the group future revenues and market leadership for innovative products.

1. AM Belgium strategy behind the concept of SIDGAL 3.5

Moving from a lab environment to industrial production is a difficult process. To smoothen this transition ArcelorMittal Belgium decided to take a two-step approach. The first step was the construction of a state of the art process section to develop the newest AHSS grades. This enabled the protection of the service levels towards our main automotive customers during construction and production ramp up. Before building a full dedicated line, the product and customer needs will be better known.

Building a stand-alone process section entails that the entry and exit facilities of another installation is needed. To fulfill these needs ArcelorMittal decided to build the new SIDGAL 3.5 processing part...
adjacent to the existing SIDGAL 3 line. This concept has a number of engineering consequences. Figure 2 shows the principle of the SIDGAL 3.5 concept. Figure 2 - Concept of SIDGAL 3.5

As the two furnaces are not located in the same hall, the steel strip needs to be deviated at the entry and exit of both furnaces. This for all gauges and at all line speeds. As the current product mix has a big variation in width, thickness and yield strength, precautions had to be taken to prevent strip deformation or creation of defects. An extra challenge for the engineering of this part is that the galvanized strip with a spectrum of very low to very high yield strengths, also has to be deviated without any influence on mechanical properties or causing any defects.

The relationship between roll crown, roll distance and angles between the different rolls was calculated in order to achieve an equal strip tension all over the strip width. To maintain the strip tension and strip centering, adjusted bridle and steering rolls also had to be foreseen. The principle of twisting towers already existed, however ArcelorMittal Belgium did not have knowledge of a similar case for galvanized strip with exposed quality. Figure 3 offers a view on the turning towers.

A second issue addressed was how to safely and smoothly switch between the two furnace sections. The strip needs to be cut and connected in the entry and exit part to follow a different route. ArcelorMittal had to invent a mechanical/electrical part. This at an acceptable cost as for a possible later full line, this part will become unnecessary.
For this purpose the project team introduced a specific cutting and rewelding system of the strip. The strip connection is made by means of a welder. These welds can withstand conveying the strip through the preheated furnace.

![Figure 4 - 3D image of the switching tables](image)

The operator interventions are made near to the strip, rolls and moving tables. To ensure safety, the use of a locked stop is obligatory before the operator is allowed access to the zone for cutting and welding. The entrance via the electrical door is only allowed when all electrical power for conveying the strip is shut off, the pneumatically pressure has been released, snubber rolls are keeping the strip fixed and all gravity parts have been locked by pins. This process is completely controlled by a safety PLC. Only then will the operator be able to start with his semi manual interventions for cutting and spot welding of the strip. Both systems are comparable at the entry and exit.

The installation was made for a switch from one furnace to the other to be completed within 4 hours. In the meantime the operators were able to however optimize the way of working and overcome some technical issues, resulting in a switch in less than 2 hours.

For the supply of the process section, ArcelorMittal Belgium have worked with the following main suppliers.

<table>
<thead>
<tr>
<th>Scope</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furnace and APC tower</td>
<td>ANDRITZ Metals</td>
</tr>
<tr>
<td>Induction Heaters</td>
<td>Inductotherm</td>
</tr>
<tr>
<td>Twisting Towers</td>
<td>John Cockerill</td>
</tr>
<tr>
<td>Zinc Pot</td>
<td>Induga</td>
</tr>
</tbody>
</table>
2. Furnace design and features to cope with the Q&P family products and future trends

2.1 Furnace description

For the construction of this 3G AHSS furnace, ArcelorMittal Belgium selected ANDRITZ Metals as supplier, based on their advanced furnace technology and knowledge.

The ArcelorMittal Q&P furnace includes the following sections:

- **Direct Fired Furnace (DFF)** including pre-oxidation capability and temperature control over the width. This furnace includes the ANDRITZ Selas specific technology: Pre-mix burners to control the strip surface quality, trimming of the strip width to control the temperature homogeneity, nozzle mix burners operated with hot air to decrease the fuel consumption, separated post-combustion chamber to limit oxidation of the strip.
- **Radiant Tubes furnace (Heating RTH and Soaking RTS)** designed for high strip temperature and including humidification facilities for control of the dew point.
- **Slow Cooling Section (SC)** specially designed for very slow cooling rates and capable to hold the temperature as high as the soaking temperature. The particular design of this chamber allows simultaneous heating and cooling which provides a flexible operation and homogeneous strip temperature.
- **Fast Cooling Section** including the ANDRITZ Selas specific **Differential Rapid Jet Cooling (DRJC)** technology. The design has been adapted in order to meet the specific cooling requirements of Q&P metallurgy: provide a high cooling rate to promote residual austenite and maximize the heat transfer where the martensitic transformation occurs.
- **Partitioning Section (PS)** specially designed for 3G AHSS metallurgy including a holding section and capable to hold the strip at any temperature well below the zinc bath temperature and two longitudinal inductors of Inductotherm to reheat the strip before and after this zone.
- **Snout with Overflow** for automotive exposed surface quality as per ArcelorMittal patented technology.
- **After Pot Cooling (APC)** facility using the ANDRITZ Selas specific cooling technology.

2.2 Particular design for 3G AHSS

Specific attention was payed to the metallurgical requirements of 3G AHSS: e.g. High annealing temperature, flexible cooling and long holding cycles, control of the furnace atmosphere and homogeneity of the strip temperature. These topics will be discussed more in detail.

2.2.1 High temperature annealing

Annealing temperatures up to 870-920°C are reached by combination of a DFF up to 750°C and a RTH and RTS section up to 870-920°C. Although the technology is quite standard, the equipment needed to be properly sized for this purpose. Particular attention was paid to the choice of the materials (furnace rolls, cladding, refractory). Furthermore ArcelorMittal selected the bubble tubes technology of Bisson.

2.2.2 Flexible cooling cycles
The combination of a very slow cooling and holding chamber with an ultra-fast and flexible cooling equipment provides a multitude of cooling cycles, from common cycles for drawing qualities to the very fast cooling rates for AHSS. All cycles being operated at a low H2 content of 5% even the special cycle for austenitic martensitic grades requires a high cooling rate. The Andritz patented system can deliver a cooling rate of more than 100°C/s/mm. This is realized with the DRJC at maximum capacity. In between a multitude of cooling cycles are possible. The fast cooling section is capable of cooling the strip well below the zinc pot temperature.

For this project a special control philosophy of the cooling was developed allowing the high cooling with retained austenite.

2.2.3 Flexible holding cycles

With an inductor installed at the entry and the exit of the partitioning section, the holding temperature is quickly adjustable between low/high temperatures, providing a wide range of cycles that can be produced.

2.2.4 Control of the oxidation

To prevent the selective oxidation of elements Mn, Si, Al... of the highly alloyed steel grades, and thus to guarantee the adherence of the zinc coating, the control of the oxidation is key. Several oxidation tools are available in SIDGAL 3.5. Preoxidation in the DFF is possible by modifying the air /gas ratio in the last zone(s) of the DFF. The technology of ANDRITZ Selas based on pre-mix burners arranged in front of the strip provides a good tool to control the thickness and the homogeneity of the iron oxide layer over the width. Humidification of the heating chambers is another concept.

2.2.5 Control of the atmosphere

The control of the furnace atmosphere is of first importance for the 3G AHSS grades. It is possible to adjust for instance the hydrogen contents in each chamber. For this the flow rates of nitrogen/hydrogen are controlled separately as well as the HNx flow extracted from each chamber. The flow rates are determined in real time by means of an atmosphere control model which takes into consideration the aimed atmosphere chemistry but also the contraction/expansion of the atmosphere caused by the operating conditions (HNx temperature and pressure in the cooling modules and the chambers). The model acts as a feed-forward to the furnace pressure control providing each chamber with the quantity of HNx required to keep a stable pressure and thus preventing transfer of HNx from one chamber to another.

![Figure 5 - H2 control in the furnace (different H2 contents in different chambers)](image-url)
2.2.6 Temperature control over the width

Several tools are provided to control the temperature over the width of the strip:

- Burner trimming in the DFF
- Cooling trimming in the DRJC.

In addition, the particular design features of ANDRITZ Selas furnaces tend to promote a homogeneous temperature distribution over the width of the strip: power load distribution in the radiant tubes, simultaneous heating and cooling in the slow cooling section, nozzle design in the DRJC, ...

![Figure 6 - T Strip Temperature over width DFF](image1)
![Figure 7 - T Strip Temperature over width DRJC](image2)

3. Commissioning philosophy, ramp up phase & performances achievements

For the commissioning a different strategy was applied compared to having to start a full CGL line. The aim was to start the line in a minimal timeslot taking into account the actual production schedule of our automotive line SIDGAL 3. For the first milestone, where basic grades were targeted, only 10 production days were foreseen. A small but highly skilled project team was formed, containing experts both from the suppliers as well as customer side. The different approach was steered by a detailed test plan. Moving the maximal amount of installation tests outside the production days was the target. Detailed IO test, full simulated software test and advanced functional testing were executed with a level of detail higher than for classical lines. On the product side, detailed product simulations were done before the commissioning.

From months in advance, short scheduled stops of the adjacent SIDGAL 3 line were used to gradually implement the needed mechanical, electrical and software changes. All these changes were implemented without any additional stop of the production line. On April the 25th 2018, the strip driving was tested for the first time for 16 hours. After three iterations of 8h, the stability was considered sufficient to go ahead and produce the first hot dip galvanized coil.

On May the 3rd 2018, the first production was started on the line. The commissioning was focused on delivering coated material with the correct mechanical properties. The production day was split in two parts. First and foremost, the project team commissioned the different installation functionalities and secondly verified the process stability of the different common steel grades. In a record time of only six days were needed to commission the major process critical installations. This was made possible only thanks to the highly qualified project team. Once parts of the installation were reliable, ArcelorMittal could start validation of the produced customer grades.

The high quality of the technical parts made it possible to produce very good basic qualities with perfect adhesion after a couple of hours. It took around 8 days to produce and validate the first products within the specifications of our automotive customers. At the end of the 10-day time slot the project team were ahead of schedule and started the industrial development of future products.
4. Product development from lab concept to customer coils acceptance

On the existing SIDGAL 3 line a wide range of hot dip galvanized steel grades are produced. The aim of the development team was to, as much as possible, use the same chemical analysis for both routes (SIDGAL 3 and SIDGAL 3.5), in order to maintain some flexibility in case of issues on one or another process section.

However, as the furnace of SIDGAL 3.5 is twice as long as the one of SIDGAL 3, ArcelorMittal Belgium needed to ensure that with the same chemical analysis, customer specifications regarding in-use properties (IUP), may be produced with both furnaces. Therefore, lab simulations were performed with the existing full hard steel grades – varying from HSLA and BH grades towards TRIP, DualPhase (DP) and ComplexPhase (CP) grades – to determine if, and how, the annealing cycles, currently used for these steel grades in the SIDGAL 3 furnace, had to be adapted for the SIDGAL 3.5 furnace.

In a second step, line trials were organized to validate the annealing cycles on an industrial scale. Certain steel grades and/or dimensions could more easily be galvanized on SIDGAL 3.5, for instance with respect to steel strip stability. During these trials, the process and quality teams also noticed a different sensitivity regarding the influence of the full hard surface state during production on SIDGAL 3.5 compared to SIDGAL 3 (DFF-RTH vs full RTH furnace). This also had to be taken into account during the trials. In some cases, modifications of chemical analysis are required after all resulting in significantly better IUP.

After validation by our ArcelorMittal R&D department, coils were sent to customers for acceptance trials. By the end of 2018 over 200 trial coils were galvanized on SIDGAL 3.5.

For most Quench and Partitioning (Q&P) and DP grades with better deformability (DP DH) of the Fortiform Family, line trials were organized based on lab-scale recommendations. The ramp-up curve is fast, thanks to a very close collaboration between R&D and line process people. Figure 9 shows a typical DH annealing cycle while Figure 10 shows a typical Q&P cycle, showing the possibilities of the SIDGAL 3.5 furnace.
5. Conclusions

ArcelorMittal has taken the new SIDGAL3.5 process section into service in a record time of 10 days and this without impacting the current service and quality level expected by our numerous automotive customers. SIDGAL 3.5 line is currently running on an average of once every three weeks. This is expected to increase towards more than 50% of the time in 2020.

The full commitment of both ArcelorMittal Belgium and ANDRITZ Metals made it possible to achieve the target set and to transform this two stage approach into a very robust concept for understanding the processing of the new cold formed steel grades of the future.

The following requirements have been successfully implemented

- Achieving the heat and cooling treatment homogeneity requirements.
- Obtaining the coating properties and decreasing coating sensitivity.
- Implementation of the best technology and product optimizations to enlarge the production spectrum in a more sustainable way.
- Making the facility ready to supply the car manufacturers with a higher service and prepare the overall logistic for serial production in early 2020/2021.

ANDRITZ Metals has proven that the developed technologies in heating and cooling are a reliable base for the production of the 3rd generation AHSS and repaid the confidence placed by ArcelorMittal into ANDRITZ Metals.

The processing of the coils in a full-scale furnace brought forth an incredible source of knowledge to speed up the optimizations to achieve the performance and to launch some new developments. ArcelorMittal will continue the original strategy for the product development and is preparing for the full AHSS line configurations.

Both parties have fully benefitted from this innovative project to improve their competitiveness and capabilities in process and product developments.