THE LATEST TRENDS IN COKE OVEN TECHNOLOGY FIELD APPLIED TO A MODERNIZATION PROJECT *

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Abstract

Arcelor Mittal Asturias coking plant at Gijon works, Spain, is undergoing a complete modernization of the whole coke making complex.

In this context, Gijon has to be considered a brownfield project, where Paul Wurth has been awarded with the engineering, supply of key equipment as well as erection and commissioning supervision services for the rebuild of two coke oven batteries the modernization of the adjacent by-product and relevant waste water treatment plants.

Main objective of this paper is to present the technological improvements introduced by Paul Wurth in the rebuild of a modern plant focusing on fulfilling all the recent environmental regulations.

Keywords: Coke oven battery design; Emissions; Coke oven gas treatment design; waste water treatment design.

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1 INTRODUCTION

The modernized coke making plant of Arcelor Mittal in Gjion, will produce 1.1 million tons of dry coke per year. The following table reports coke making plant main production data:

Number of battery	2	
Number of Ovens each battery	45	-
Coke Production	1,1	Mt/y
Clean Coke Oven Gas Production	55.000	Nm^3/h
Tar Production	144	t/d
Sulphur production	9.5	t/d

The project consist of two main units, coke oven batteries with quenching facilities and gas treatment plant with waste water treatment plant.

The coke oven batteries is a so called “pad up” project which means that existing battery civil foundation and nozzle deck are reused. Paul Wurth is acting as technological provider offering engineering and supervision services plus the supply of key items as the complete refractory package and the main heating up equipment. The coke and coal handling facilities will remain existing, while coke quenching will be refurbished in order to achieve the current environmental emission target of PME < 25 g/t coke.

The gas treatment plant is a so called “modernization“ project with the revamping of some existing units and introducing completely new process units in order to be in compliance with the more stringent environmental regulation like desulphurization units and relevant Sulphur production. Paul Wurth together with DMT GmbH & Co. KG will be in charge of the whole engineering, supply of key equipment and responsible the turnkey installation of a Claus plant for sulfur removal and a strong water plant.

First coke will be produced on 1st January 2019 after 3 months of heating up.
In the below figure it’s reported the current situation of the site:

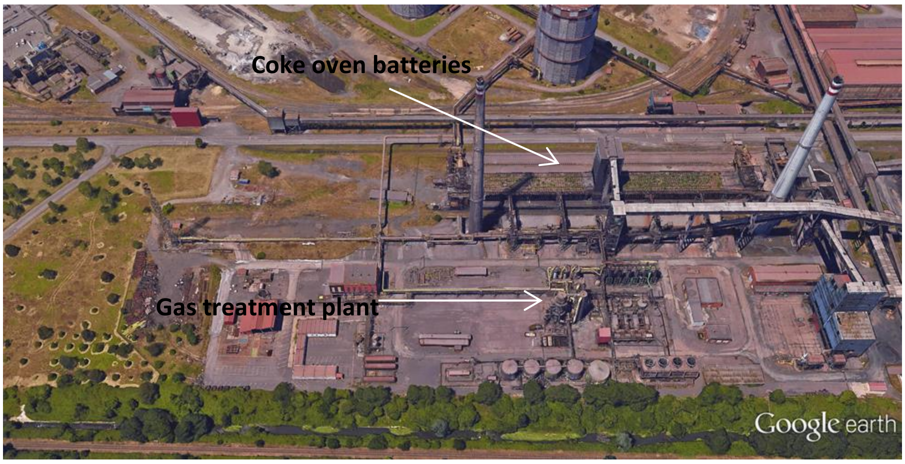

Fig 1 Arcelor Mittal Asturias: Existing facilities

2 MATERIAL AND METHODS

2.1 Coke oven battery

In the table below are reported main coke oven data:

Number of Ovens	45 +45	
Oven length (hot)	15050	mm
Oven height (hot)	6550	mm
Oven width (hot)	420	mm
Oven pitch	1375	mm
Useful volume	39,5	m^3
Coking time h	16,6	h
Daily coke production	3044	t/d

The battery was constructed in the past based on Car Still half divided design. Please refer to the below figure for the process scheme.

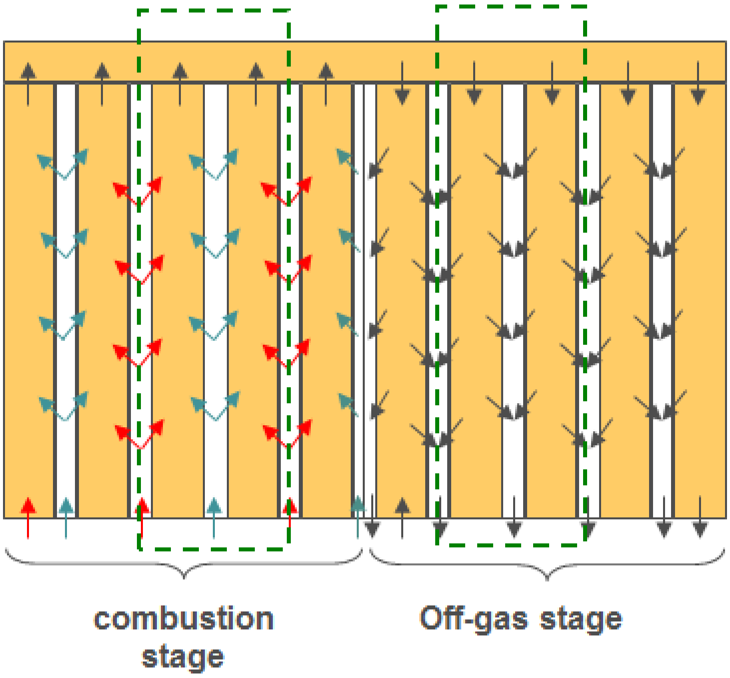

Fig. 2 Half divided process scheme

Arcelor Mittal has decided to keep the half divided configuration asking Paul Wurth to provide improvements regarding some weak points of such design.
In particular the following points have been deeply analyzed and studied

- High graphite build up
- Horizontal channel weak structure
- Low bracing forces applied to the refractory

Moreover Paul Wurth has modernized the coke oven battery design in order to be in line with the latest safety European standard.

2.2 Gas treatment plant

In the table below are reported main gas treatment data:

Clean Coke Oven Gas Production	55000	Nm^3/h
H2S in coke oven gas	≤ 0,05	g/Nm3
NH3 in coke oven gas	≤ 50	g/Nm3
Sulphur production	9,5	t/d
Sulphur purity	≥ 99,5	%
Tar production	144	t/d
Water content in the tar	≤ 3	%

Gas treatment plant project of Gijon is divided into two main parts: brownfield areas, modernized with the introduction of important technological improvements and green field areas plants in order to accomplish the environmental regulation.
Based on the constrains of existing layout and keeping the existing coke oven gas line the following areas have been redesigned:

- **Primary Gas Cooler**: refurbishing the existing equipment with the implementation of chilled water circuit and tar emulsion cleaning system.
- **Electrostatic Tar Precipitator**: new high performances tar fog precipitators will be installed on existing foundations.
- **H2S-NH3 Scrubbing System**: existing old NH3 scrubbing shell will be converted, by modifying washing liquor circuit and internals, to combi H2S-NH3 Scrubbing system introducing desulfurization treatment.
- **Naphthalene Scrubbing System**: existing Naphtalene scrubber will be modernized, by keeping existing shell and introducing new internals.
- **Tar decanting**: new horizontal decanters with connected new tanks, new filters and new sludge treatment will be integrated with existing tar centrifuges and old redesigned storage area, making this unit modern, efficient and tight with low water and solid content in tar

Next to the brown-modernized field areas, new part of the layout will be dedicated to:

- **Distillation area**: new columns and related set of pumps, heat exchangers and tanks will be introduced for H2S/NH3 recovery
- **Claus Plant**: completely new sulphur recovery plant for producing high purity liquid sulphur will be designed
- **Strong water Plant**: new column and related tank and facility will be located next to Claus Plant to ensure a backup during sulphur recovery plant maintenance
- **New waste water plant** with a design capacity of 70 m^3/h.

3 RESULTS AND DISCUSSION

3.1 Coke oven battery

On the basis of its consolidated know-how in coke oven battery design, Paul Wurth has applied technological improvements in order to achieve performances and life time targets of a modern concept coke oven battery.

3.1.1 Process and Refractory improvements of Carl Still Design

Paul Wurth has analyzed the relative position of the horizontal channel in order to reduce the high graphite build up in the "Car Still half divided" oven design.
The lowering of horizontal channel position has led to a new combustion configuration in the heating wall deeply studied by Paul Wurth by means of the in house developed FAN (Flame analysis software).
FAN is a Paul Wurth software based on Fluent code which has been used to finalize the combustion configuration minimizing unburnt and NOx formation and ensuring an optimum and homogeneous temperature profile.

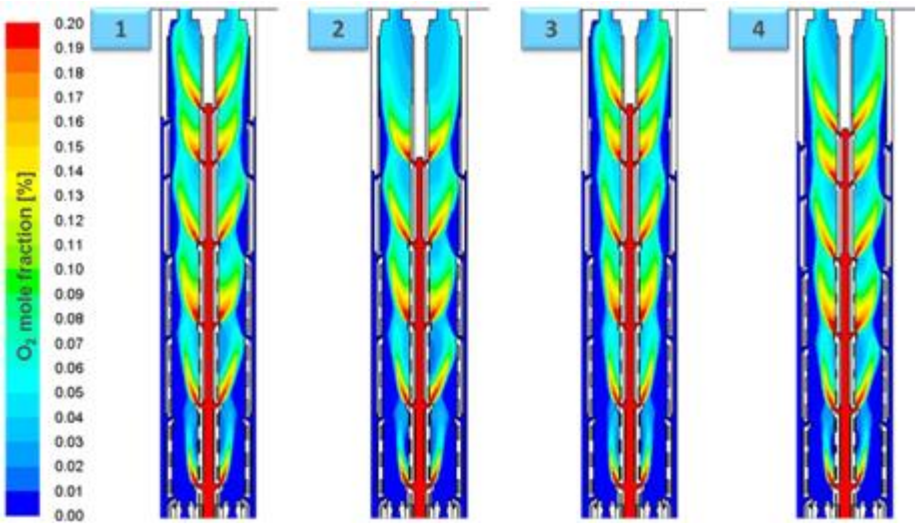

Fig. 3 FAN simulation of different Car Still Half divided oven configurations.

The new arrangement of the horizontal channel and the relevant combustion configuration will improve the old "Car Still half divided" design minimizing graphite formation in the oven and NOx production.

Paul Wurth has completely re-engineered all the refractory of the "Car Still half divided" oven.
In particular the new brickwork has been reinforced and strengthened with the aim to ensure long operational life.
Several changes have been adopted in the new design as layer overlapping, application of special mono-block shape for mixed and combustion air outlets, proper

application of thermal shock resistant material, joints with labyrinth configuration in order to avoid straight line geometry.
Furthermore thickness of liner bricks have been reduced to achieve optimum heat transfer and keeping stronger liner structure in more stressed layers at the same time.

Fig. 4 Special mono block shape

Labyrinth configuration for joints have been adopted in order to delete straight line geometry and consequent possible gas leakages. Furthermore thickness of liner bricks have been reduced to achieve optimum heat transfer and keeping stronger liner structure in more stressed layers at the same time.

Paul Wurth has implemented several improvements also in refractory material quality with relevant technical solutions for Waste Gas Channel, chimney, bench galleries, coke wharf and quenching tower with a target to allow long and stable operation with high performances.

3.1.2 Bracing system and oven closure improvements of Carl Still Design

As per refractory and process, also mechanical design has been analyzed by Paul Wurth in order to ensure important and crucial technological improvements.
Wall protection plate and door frame connection has been modified allowing door frame easier maintenance, also ensured by the installation of hammer head bolts as junction elements.
A modern bracing system have been designed with larger forces distribution profile in order to reduce tensile stresses in the brickwork ensuring heating wall stability under critical conditions such as pushing and coal swelling pressures.
The verification and optimization of the whole system has been performed by using a customized finite element simulation based on Ansys software in which all mechanical components have been analyzed under thermal condition with new forces distribution.

Fig. 5 FEM simulation for bracing and oven closure system.

3.1.3 Safety requirements

Paul Wurth design and technological improvements were also focused in the application of all the necessary safety requirements for the new modern concept battery.
As main enhancements infrared barrier for valves opening/closing detection has been included in reversing winch new engineering.
Isolating and stand pipe lid valves will be equipped by pneumatic actuation, avoiding the manual operations of the old concept plant for more safety operations and environment.
Coke oven and mixed gas underfiring system have been designed considering all safety requirements actually recommended by EN-746. For example automatic nitrogen purging in the gas line have been considered in case of low pressure in the manifold.

3.2 Gas treatment plant

Paul Wurth together with DMT GmbH & Co have re designed completely the whole gas treatment plant with the implementation of latest technologies considering existing lay out constraints and re-usable process equipment.

3.2.1 Process scheme

In the figure n° 6 is reported the main gas treatment plant process block diagram.
The crude gas from gas collecting main is driven towards downcomer inside gas treatment plant, while flushing ammonia liquor and tar collected in the bottom part are evacuated from it with separate lines and sent to tar decantation unit.
Leaving downcomer, gas is directed to the primary gas coolers (PGC) where coke oven gas (COG) is cooled down within six existing indirect equipment.
Paul Wurth / DMT has adapted the existing design in order to ensure better performances, provided that efficient gas cooling is a key factor for the entire gas treatment plant operation and performances.
For this reason chilled water stage has been added together with tar emulsion cleaning system, that will ensure a continuously operated cleaning system based on spraying of light tar emulsion coming from tar separation plant, able to remove

naphthalene sticking on the cooling tubes in order to guarantee long operation between two intensive PGC cleaning.

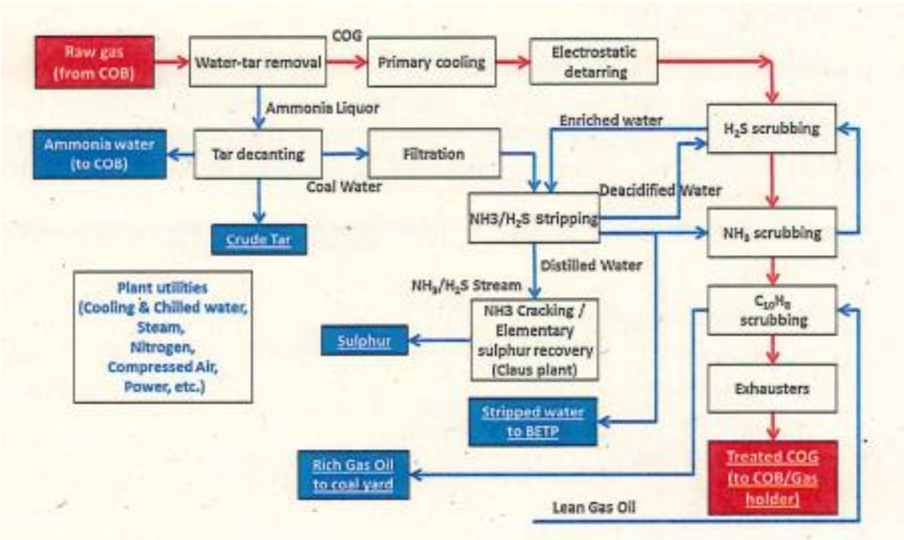

Fig. 6 Gas treatment plant process block diagram

Tar rich ammonia water leaving gas collecting main is directed to tar separation plant that includes 3 double chamber new horizontal tar decanters.
From tar decanter, once separation with tar and solids will be accomplished, flushing liquor is returned to battery gas collecting mains for flushing of raw gas from coke ovens, while excess coal water is pumped via a buffer tank to the gravel filter plant for final tar removal required by ammonia still plant. Entire amount of coal water will be treated inside a complete new set of gravel filters.
Production crude tar is extracted from tar decanter bottom and pumped to storage tanks. Tar emulsion is produced by mixing ammonia flushing liquor and light tar in dedicated unit, in order to achieve the right light tar content required by PGC continuous flushing system.
Coming from the primary gas coolers, cooled COG is supplied to electrostatic tar precipitators (ETP) for reducing tar content to ensure proper operability of the subsequent units, reducing as much as possible tar for content in COG.
COG is then supplied to a scrubbing system with integrated internal cooling stages for reducing H_2S and NH_3 concentration down to the required levels (fig 7 lefts side).
Scrubbing liquor for the H_2S/NH_3 removal consists of stripped (low NH_3 content) and de-acidified water (low H_2S, high NH_3 content) returning from the distillation plant.
As final gas cleaning stage, COG is supplied to Naphthalene scrubber in order to reduce naphthalene content of COG.
Scrubber shells will be reused, internals (structured metal packing) will be completely new in order to achieve the target performances ensuring high specific surface.
Enriched wash oil is then regenerated in existing plant.

Enriched scrubbing liquor coming from the H2S and NH3 scrubbers is regenerated in a distillation plant consisting of two combined distillation columns with the capability to handle the entire scrubbing liquor by mean of steam. Excess coal water, coming from gravel filter plant, is stripped under the presence of caustic soda (NaOH) within ammonia stripper to remove fixed NH_3 compounds. Excess stripped water flow (consisting of coal water and stripping steam condensates) with reduced free and fixed NH_3 content is led to the waste water treatment plant.

Acid gas leaving distillation plant, mainly consisting of H_2S, NH_3, HCN, CO_2 , is supplied to a combined NH_3 cracking/elementary Sulphur plant (Claus Plant) for Sulphur recovery (fig 7 central part). In the process, NH_3/HCN are cracked down into N_2, while H_2S content is converted to liquid Sulphur. Tail gas from Claus Plants is returned to the crude gas mains upstream primary gas coolers.

Fig 7 Gas Scrubbers (left), Claus unit (central) , 3D modelling (right)

In case Claus plant is out of operation an Ammonia Strong water plant has been foreseen. Acid gas coming from distillation unit is directed to strong water column, flowing bottom-up. Acid gas is cooled by sprinkling with strong water in counter direction in order to enrich strong water and absorb mainly the H2S and NH3 and remove the heat from the solution. Strong water is buffered in a storage tank and can be added to enriched water in case of Claus plant back in operation.
Ammonia Still, Strong water and Claus plant will be totally new.
COG suction is ensured by existing gas exhausters.

All plant has been completely modelled using latest 3D software tool.

3.3 Environmental requirements

Environmental protection aimed at minimizing fugitive emissions and accomplish the target of emissions required by European Norms also plays a vital role in this project.
For this reason, in the context of modernization all battery boundary items have been designed in order to minimize pollutant emissions and gas leakages (i.e. waste gas boxes connection to embedded framework, regenerator upper plate, double sealing for waste gas plug etc.).

Wet quenching plant has been reviewed with the target of PME < 25 g/t coke implementing an upper de-dusting system and a steam washing in the new design.

In the gas treatment plant it has been implemented the **"Zero emission concept".**
New and existing equipment will be provided by a new pressure controlled respiration system, which will provide nitrogen as respiration gas in a closed circuit to coke oven suction pipes.

Tanks are grouped together in different independent loops to avoid any possible product contamination. This will ensure ‘zero emissions' to the atmosphere (fig 8).

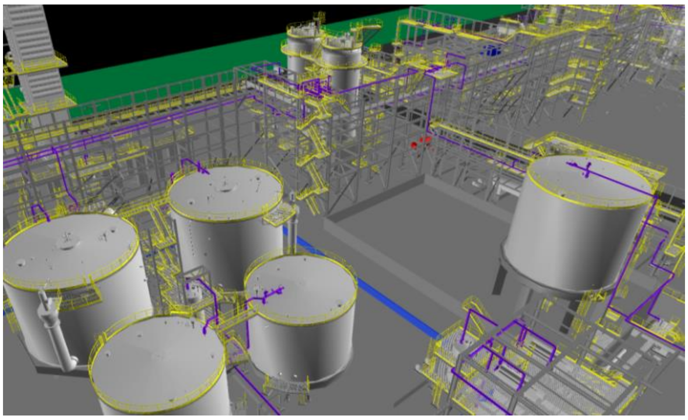

Fig 8 3D Model of respiration system

4 CONCLUSION

The implementation of state of the art technologies in the existing facilities considering original configuration design, equipment reuse and layout constraints, leads to a new concept of plant modernization.
Arcelor Mittal Asturias project is a perfect example of this new concept in which Paul Wurth has improved old technology coke making plant with latest improvements in terms of long operating life, efficiency, environment and safety.