Water Injection in the Fluewalls of an Anode Baking Furnace to Reduce Nitrogen Oxide Emissions

Sandra Besson[1], Solène Bache[2], Julien Maugain[3], Arnaud Bourgier[4], Guillaume Vergouwen[5] and Thierry Conte[6]
1. Process Engineer
2. Process Engineer
3. Process and Operation Expert
4. Manager Carbon
Rio Tinto Aluminium, Voreppe, France
5. Process Engineer, Aluchemie, Rotterdam, The Netherlands
6. Technical manager, CFD-Numerics, Solaize, France
Corresponding author: solene.bache@riotinto.com

Abstract

In the aluminium industry, the carbon anodes are baked in the anode baking furnace by means of the combustion of both the volatile matters emitted by the green anode and the extra fuel injected. The baking process generates pollutant emissions, most of them being treated by fume treatment centers. However, some of them persist, such as nitrogen oxide, one of the main sources of acid rain and acidification of fresh water.
Nitrogen oxide emissions are regulated in most countries and limits for this type of emissions tend to decrease. Therefore, it becomes challenging for some plants to operate their anode baking furnaces in compliance with new regulations. End of pipe solutions exist to treat nitrogen oxide emissions, but their implementations are often expensive. This makes source reduction of nitrogen oxide formation very interesting.
One method of source reduction is injecting water into the refractory fluewalls of anode baking furnaces, upstream from the combustion zone. In this article, the principle of operation as well as the implementation and effects of water injection on the anode baking process will be presented.

Keywords: Anode Baking Furnace, Nitrogen oxide, Water injection, Energy consumption, Anode cooling.

1. Introduction

The process of baking carbon anodes in an open-type anode baking furnace (ABF) produces fumes resulting from the combustion of gas or heavy fuel oil in the heating zone, and from volatile matters in the preheating zone. These combustion fumes containing several pollutants are collected via a ring main and sent to a fume treatment center to be treated, especially for soot and fluorinated gases. However, the most widespread treatment centers cannot remove all polluting emissions: nitrogen oxides (NO_x), for example, are not treated and typical concentrations of 20 to 150 mg/Nm^3 can be measured at the stack. Those gases contribute to the air pollution and the local regulations vary considerably from one plant to another. For instance, the local limit in Aluchemie is currently 150 mg/Nm^3 at the stack.

Due to growing environmental concerns, regulations relating to nitrogen oxide emissions are becoming more and more restrictive and some smelters must find urgent solutions to reduce NO_x emissions and maintain their authorization to operate. Smoke reprocessing solutions such as selective catalytic reduction exist; but, they are generally expensive and difficult to set up and maintain, which makes the reduction of NO_x generation at the source highly valuable.

The NO_x formed in the ABF are principally created during the combustion of natural gas and oil, their formation depends mainly on two parameters: the oxygen availability and the temperature of the combustion zone (Figure 1).

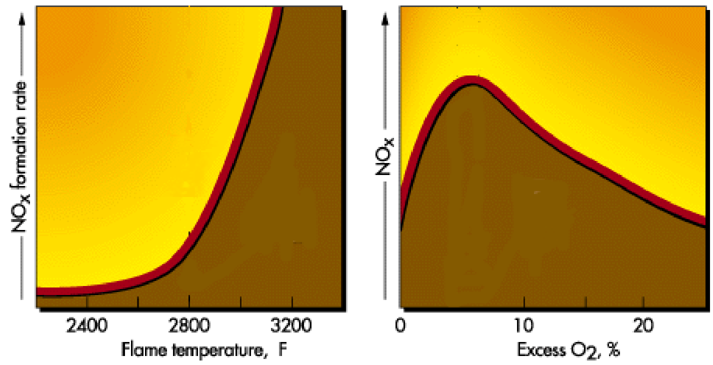

Figure 1. NO_x formation, from [1]

The measurements and modelling done in the past on ABFs have shown that the NO_x are mainly generated in the last heating section (HR3 or HR4), where the O_2 availability is higher (fresh air coming from the blowing area) as well as the temperature of the area.

Thus, to limit the formation of NO_x, the temperature along with the amount of oxygen of the fumes entering the 3rd heating section must be reduced. Experience shows that there is little lever to play with the burner design as the NO_x generation reduction is often coupled with a reduction of combustion efficiency and higher CO contents. The water injection in the fluewalls located in the blowing area of ABFs on the contrary has shown promising achievements together with other benefits.

Aluchemie is a carbon anode plant operating in Spijkenisse (The Netherlands) and producing 216 kt anodes of several formats each year. With the operation of 4 ABFs over the last years, the plant has seen an evolution of the local restrictions regarding the NO_x emissions and has tested several solutions. In this article, the operating principle of water injection will be described as well as the result of water injection tests carried out in Aluchemie.

2. Water Injection to Reduce NOx Generation

2.1 NO_x Generation in the Anode Baking Furnaces

NO_x is a generic term for the nitrogen oxides and refer mainly to nitric oxide (NO) and nitrogen dioxide (NO_2). These gases are atmospheric polluants that are harmful for immune and respiratory function and are contributors to acid rain, smog, and ozone depletion.

The primary source of NO_x production in the industry is related to combustion processes. In the ABF process, where natural gas or heavy fuel oil is burnt, the thermal NO_x is the most relevant source.

There are three factors influencing NO_x formation: high temperature, high O_2 content, and high residency time at high temperature. Two ways to control NO_x formation in our standard industrial furnaces is to control excess oxygen or control flame temperature, as the residency time at high temperature is relatively short and difficult to control.

Table 3. Effect of water injection for different flow rates

	NO_x (%)	**Anode temperature in BL1 (°C)**	**Energy consumption (%)**	**O_2**	**CO**	**Cold spot temperature (°C)**
Nozzle 1, 0.5 L/min, peephole 1	-9	-15	/	no impact	no impact	275
Nozzle 1, 1.0 L/min, peephole 1	-30	-23	-5,50	no impact	occasional peaks	<200
Nozzle 1, 1.2 L/min, peephole 1	-38	-54	-5,50	no impact	occasional peaks	<200
Nozzle 1, 1.0 L/min, peephole 2	-30	-	-6,50	no impact	occasionalp peaks	335
Nozzle 2, 0.5 L/m, peephole 1	-16	-	-6	no impact	no impact	490

5. Conclusions

The trials carried out in Aluchemie with the injection of water in Blowing 1 have confirmed the benefits regarding the reduction of NO_x generation with reductions up to 38 %. The NO_x concentration decreases as the water flow rate increases in the studied range (0.5 to 1.2 L/min) without reaching a thershold effect. The design of the nozzle affects the percentage of NO_x generation, and the finer the droplets, the lower the NO_x.

The trial has also shown that the water injection enables the cooling of the fumes more efficiently during blowing, thus to improving the anode cooling efficieny, with expectations of up to 54 °C anode temperature decrease at the end of the first blowing section.

Trials also showed that a reduction in gas consumption by 5.5 % can be expected for a water flow rate ≥1 L/min. The change of nozzle type only slightly improved this reduction. Water injection has no impact on the percentage of oxygen supply to the preheating zone and doesn't impact the combustion in this area but some peeks of high CO values could be observed for higher water flow rates.

The thermal camera pictures show that water injection creates cold spots on the fluewall and on some tie-bricks: this could affect the refractory condition on the long term. Some further trials should be carried out on a longer term to evaluate this impact more precisely and identify possible mitigations.

6. References

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