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Furnace combustion and control renovation to improve the productivity of a continuous annealing line

Hai Wu[a,]*, Bertie van Benschop[b], Omar Ben Driss[b], Ferry Frinking[a], Ramon Speets[a]

[a]*Research & Development, Tata Steel, P.O.Box 10.000, 1970 CA IJmuiden, The Netherlands*
[b]*Downstream Operations, Tata Steel, P.O.Box 10.000, 1970 CA IJmuiden, The Netherlands*

Abstract

The investigated annealing line was constructed in late 1980s with a design capacity of 350,000 t/y. After many years of service the annealing furnace was in an unsound state and renovated in a number of steps in three years time. A furnace survey was firstly conducted to fingerprint the conditions of the combustion system and to identify opportunities for improvement with a quick return of investment. Burner tests were carried out to better understand the combustion process and identify the critical conditions for component design and improvement. Furnace mathematical model was developed to study the energy balance and deficiency of the process. The model was further explored in the designing and implementation of a new control automation system using Model Predictive Control. Production results over the recent years were collected and analyzed. The data after the renovation showed some significant improvements with a reduced specific energy consumption below the benchmark of World Steel Association, a 4% increase in monthly production throughput, over 10% increase in production volume and an advance to a highly automated process.

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1. Introduction

Steel strip goes through a complex process including pickling, cold rolling, annealing, temper rolling and electrolytic tinning to become tinplate before it is dispatched to can manufacturers. The annealing is a crucial step to heat-treat the full hard strip to produce the right mechanical properties. Continuous annealing is a very efficient

* Corresponding author. Tel.: +31-251-496-833.
E-mail address: hai.wu@tatasteel.com

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process for this purpose, which conveys strip through a number of consecutive furnace sections providing the required heat treatment in a continuous manner. The annealing processing line investigated in this paper is one of the two continuous annealing facilities at Tata Steel's IJmuiden site. The line was commissioned in late 1980s with a design capacity of 350,000 t/y. The annealing process consists of heating, soaking, cooling, over-aging and final cooling, as illustrated in Fig. 1. After the annealing, the strip is temper rolled or double reduced up to 30% to produce various qualities.

The heating furnace is the critical part of the annealing process. The furnace has many radiant tube units installed to provide the heating and furnace rolls to transport the strip. The furnace inside is filled with protective gas, a mixture of nitrogen and hydrogen, to prevent the strip from oxidizing at elevated temperature. As the heat source, every radiant tube unit is equipped with a burner on one end to fire the natural gas and a recuperator on the other end to recover the waste heat to preheat the combustion air, as shown in Fig. 2. The radiant tube has a maximum service temperature of 950°C as specified by the supplier, which is monitored by a thermocouple attached to the metal tube. The tube is subjected to thermal degradation as the 'normal' process and also thermal shocks in emergency situations when the furnace needs to be cooled down fast to avoid strip overheating and potential breaks [1]. Experiences show that the life time of the radiant tube can vary between 2 and 10 years depending on its service temperature history. The availability of the tube units has a direct impact on the furnace capacity and performance, and consequently the annealing process. Periodic inspection and maintenance are carried out to maintain the installation condition. Furthermore, improvements are sought to meet the plant ambition to reduce the natural gas consumption and hence CO_2 emission, and further to maximize the line output in volume and quality in a sustainable way.

Due to the economy recession back in 2008, large capital investment and furnace revamp incurring long production stops were certainly out of question. The improvements largely based on the existing installation were defined and executed in a number of consecutive steps: renovating the defected radiant tube units to improve the installation availability, refining the combustion control to maximize the combustion efficiency, and implementing an advanced control system to optimize the furnace operation and hence the productivity. The investigations and obtained results are highlighted in the next sections.

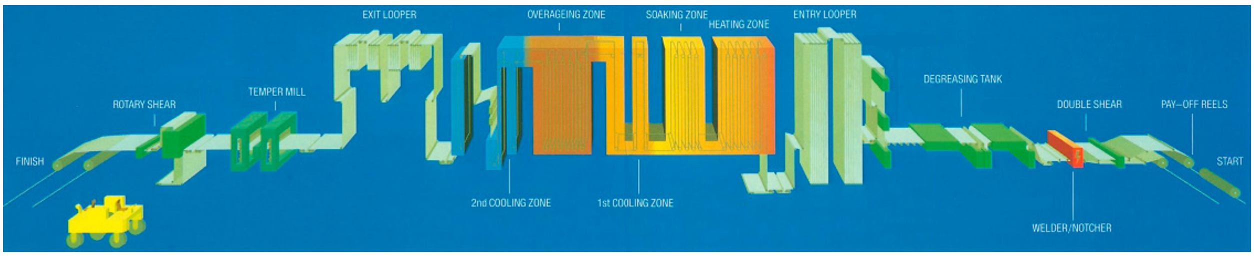

Fig. 1. Continuous annealing line.

2. Furnace condition diagnosis

Apart from the tube failures as routinely seen, the inspection revealed unexpected damages on a number of recuperators (Fig. 3) and sealing gaskets between the mounting flanges. Analysis led to believe that the deterioration was primarily due to an enduring exposure to high temperature during service. The higher than normal temperature can be triggered by the following and propagate by their combining effects.

- Insufficient insulation leads to a high heat flux to the structure of the recuperator.
- The supply of combustion fuel and air is out of balance with either too much fuel or too less air to the individual burner units, which prolongs the combustion reaction beyond the radiant tube and further inside the recuperator.