Revamping of treatment furnace with Tenova FlexyTech® TLX burners

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1. INTRODUCTION

As a result of US market requirements for a new Ultra Low NOx burner, Tenova started in 2002 the Flexy-Tech® research program in co-operation with CSM in order to definitely lower NOx emission of the previous generation burners.
Based on promising results of R&D work performed, successfully applied for NOx abatement in the big steel reheating furnace, the family of FlexyTech® burners has been enlarged with small size burners (TLX). First application of this burners has been done in the revamping of the furnace for austenitizing treatment of seamless tube at TenarisDalmine. The main goals of the revamping was decrease of NO_x emissions at furnace stack of one order of magnitude and increase the productivity up to 20%.

2. TENARISDALMINE ORIGINAL HT FURNACE

TenarisDalmine HT furnace performs an austenitizing treatment, followed by a tempering. It was a 40t/h (nominal) walking beam furnace, 9.2m length and 16m width, equipped with Tenova high speed flame burners HS4 and HS6, supplied with natural gas. Furnace was designed with a tunnel, where is placed the charging door, a reheating section and a soaking section. Two rows of burners were placed in frontal way. Total combustion air flow rate was 14500Nm^3/h, natural gas 1510Nm^3/h. Combustion air is preheated by a centralized heat exchanger by using the flue gas taken from the furnace at the exit of tunnel: the mean temperature value at burner inlet is about 300°C.
Tubes are moved by beams, there are 34 saddles, having 234mm pitch, with a beam pitch of 134mm
As first step of revamping activities, the assessment of working conditions of the furnace during the six month before the modifications, has been performed. Original HT furnace operation has been also analyzed using both thermal and fluid dynamic model.

2.1 Thermal and CFD model

A mathematical model has been developed by CSM to calculate the thermal profile of the tubes reheated in the furnace using the zonal method, The thermal distribution in the tube during the treatment, is simulated dividing the whole circumference of the tube in 120 circular sectors and the tube thickness in 10 parts. In such a way it is possible to have the temperature field in a entire section of the tube, taking into account the difference of reheating conditions in the different position of the tube. The thermal model calculations were validated with the temperature profiles measured with thermocouples placed in the tube during the treatment cycle.
Fluid dynamic model based on FLUENT code, developed for single burner simulations, has been applied to the simulation of HT furnace. CFD calculations assume temperature of tubes formerly calculated by the thermal model. The discretization of the furnace, including the 50 burners, requires a very high number of computational cells. To overcome this limitation in the furnace model, the burners have been represented as “holes” having the diameter of each burners quarl exit. The boundary conditions for the “holes” are set-up using the profiles of the main variables at the exit of burner quarl (temperature, velocity, species mass fraction, etc.) obtained by the simulation of the single burner installed in a lab furnace working at the same conditions of HT furnace. This approach has been validated for the simpler configuration. Following this approach the volume of the entire furnace was discretized by 4,925,444 cells. Analysis of simulation results has been focused on velocity and temperature field.

3. TENARISDALMINE REVAMPED HT FURNACE

Previous analyses pointed out that productivity limitation at 40t/h is due to the length of furnace, that affects the time needed to reheat tubes, and to the limitation of temperature in the tunnel, necessary to prevent recuperator damage. From an energy point of view productivity of 50t/h can be achieved. Therefore, to increase the productivity, the furnace geometry has been modified eliminating the tunnel and moving back burners to the charging wall.
In order to reduce NO_x emissions, flameless Tenova Flexytech Burners TLX6 and TLX8 have replaced HS4 and HS6 burners in reheating and soaking zone respectively.

3.1. FlexyTech® TLX burners family

TLX burners (figure 1) is based on the same combustion technoloy of the biggest size TSX burners and are developed mainly to be installed on Heat Treatment and Roller Heat Furnace for direct rolling of thin slab and on Rotary Heart Furnace.

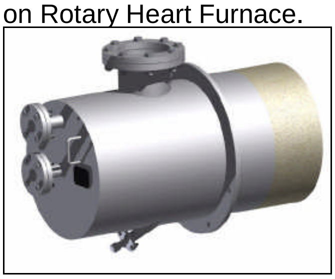

figure 1 - Tenova TLX burner

The separated injection of combustion air and natural gas allows to reach flameless combustion regime (lateral gas injection) with consequent extremely low NOx emission level in comparison with traditional flame regime (central gas injection). The results of tests performed at CSM for the pre-series TLX6 burner (280kW size) that have confirmed the characteristics of flameless Tenova Flexytech® burner family as shown in the graph.

- NO_x emissions below 40 ppm @ 3% O_2 in DFG
- Ultra low CO emissions (below 5 ppm)
- No valves on hot air for air staging
- Least excess air operations for maximum fuel efficiency
- NOx emissions not affected by air temperature
- NOx emissions not dependent on turn-down
- Air preheating up to 550 °C

Serie family of TLX burners (TLX6-130kW and TLX8-450kW) has been designed to be used in the HT furnace.

Due to lowest value of furnace temperature (920°C vs. 1250°C) and preheated air temperature (300°C vs. 450°C) lower NOx emissions are expected in comparison with single burner measurements.

3.2 CFD simulation of revamped HT furnace

In order to quickly verify effects of new furnace geometry and combustion system a section of the furnace corresponding at 1/10 of the total furnace width has been modeled (figure 2).

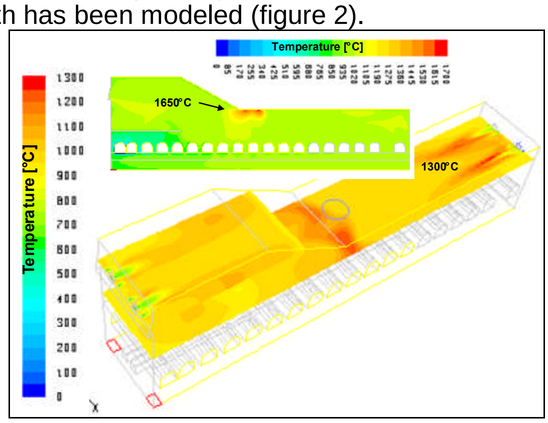

figure 2 - Heat treatment furnace CFD model

Accordingly, the simulation included two TLX8, two TLX6 working at the new operating conditions.

The fluid dynamic model of the single burners and of the furnace module confirms that flameless combustion considerably reduces the temperature peaks. In the furnace zone interested by TLX, gas temperature doesn't exceed 1300°C. This indicates a strong potential for very low NOx emission level. The comparison of surface heat flux (kW/m^2) from the flue gas to tubes between original and revamped furnace configurations showed that the new configuration set up guarantees a more effective heating process. In particular, heat exchange with cold tubes on the baking side is enhanced while the one with hot tubes, on the side exit, is reduced. This means that with the same thermal input and with the same production the tubes reach the desired surface temperature more quickly, confirming the results of thermal model calculations.

4. COMMISSIONING PERFORMANCE

Commissioning of revamped TenarisDalmine HT furnace was performed by Tenova in September 2006.

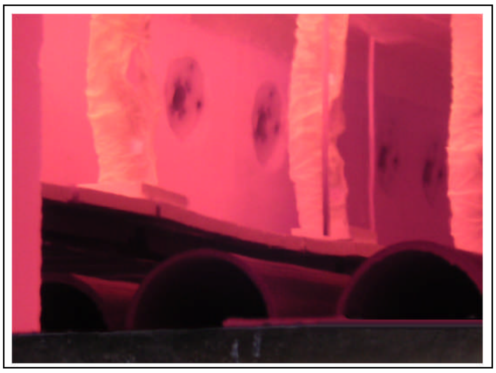

figure 3 - Heat treatment furnace after revamping

During this period the flameless condition has been demonstrated for the side burners in over the whole furnace turn-down. This allows to reach NOx emissions well far below the guaranteed value: from NOx level about 100 ppm @3% O_2 in dry flue gas of original furnace, to about 20 ppm @3% O_2 of revamped one. Values obtained during the commissioning phase were also confirmed by measurement performed by TenarisDalmine in the year 2007 (figure 4). Moreover productivity increase between 15 to 20% has been monitored during the same period.

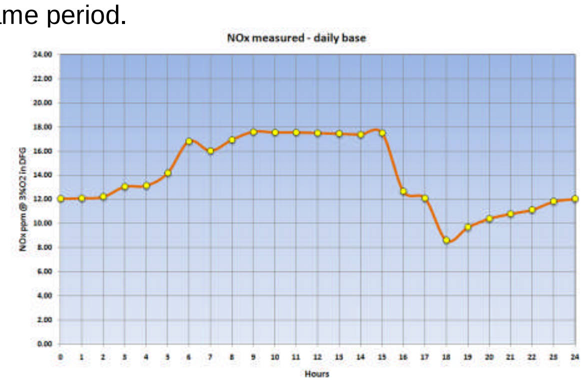

figure 4 - Operating results

The improvement is mainly due to the new configuration of the furnace coupled with a new concept of zone temperature control:

- the burner moving back in reheating zone has allowed to anticipate tubes reheating and to increase tube velocity inside the furnace;
- placement of control thermocouples at the level of the furnace top wall instead of inside the chamber, has allowed the signal to be not affected by hot jets produced by high momentum burners, when impinging on the thermocouples. Since the thermocouples are also used for control burner switch from flame to flameless mode and vice versa this is an important aspect to take into account for the proper working condition of flameless furnace.