Revamping of reheating furnaces

by Massimiliano Fantuzzi

A considerable number of reheating furnaces erected in the last decades of the past century are still in operation today. Such furnaces can’t often continue yielding acceptable throughput, product quality, fuel consumption, and pollutant emissions. According to the market demand comes the time to take a decision about the future of a furnace: continue squeezing the plant, stop or dismantle it, maybe building a new one or most likely restructuring. The answer is the result of an overall technical and economic analysis where the market demand is fulfilled only by a profitable and sustainable production.

Revamping of the furnaces is in many cases the best choice for increasing the production profitability in accordance with criteria of sustainability. For one new furnace from five to ten old furnaces are revamped. According to the type of furnace and to the works carried out the investment cost for a revamping ranges from 10 to 20 times less than the cost of a new furnace.

The modern design techniques and the solutions adopted for the realization of new furnaces can be applied to give new life to old plants. Tenova through its experience makes possible to carry out efficiently furnace revampings by means of consolidated procedures and the application of the ultimate products of the research and the technology. Revampings carried out by Tenova are relevant to any type of reheating and heat treatment furnace: pusher-type, walking beam, walking hearth, roller hearth and rotary hearth furnaces.

OBJECTIVES, OPERATIONS AND PROFITABILITY

According to the plant type and the expected improvement, different revamping requirements are pointed out. So limited operations are possible to be carried out in short time (typically an ordinary plant maintenance stop: about 2-4 weeks) as well as more complex works.

In the revamping operations the following main objectives are identified:
- Increase of furnace productivity,
- improvement of product quality,
- energy saving,
- pollutant emissions reduction.

The greater number of these objectives is complied; the best result is achieved. Different specific operations comply with each objective. The common case is that each operation brings benefits in many areas.

According to the expected benefits four main areas are interested to the revamping operations:
- Combustion system,
- charge support and movement system,
- furnace structures and devices,
- automation.

Due to the limitations of time necessary for the revamping it is common practice to carry out some works preliminarily while the furnace is still in production before the shutdown e.g. pre-assembling plant components. Table 1 shows how objectives and operations can be related according to the level of benefits achieved. Any operation carried out should lead to an increased production profitability which is acceptable only if it is achieved according to the criteria of sustainability as represented in the ideal set of equations of Fig. 1.

Production profitability is directly affected by the productivity, the product quality and the overall production costs. However increasing the productivity and/or improving the product quality and/or reducing the production costs it is not sufficient in many cases. It is necessary also to comply with some constrains such as:
- Safety issues (no negotiation on this point is allowed),
- environmental regulations,
- availability of energy,
- finance, budget and return of investment,
- external factors.

OPERATIONS: COMBUSTION SYSTEM

Technical interventions on the combustion system are aimed to improve the efficiency of the heating process by means of new modern burners, to increase the thermal power of the furnace (and consequently the production), to reduce the fuel consumption, to improve the final qual-
Heat Treatment

The improvement of product quality means: more strict compliance of the heating specifications, better temperature uniformity of the product, lower thermal gradients, lower scale formation, lower decarburization.

Hereinafter it is assumed the skid mark as reference parameter of the product quality. The main revamping operations concerning the combustion system are:

- Replacement of the existing conventional burners with high-performances low NO\(_x\) (e.g. flameless burners) and/or regenerative new burners. In addition to better combustion efficiency due to the higher combustion air preheating temperature (above 1,100 °C) a strong reduction of NO\(_x\) emissions is obtained (Fig. 2). This operation can be generally applied to any type of fur-

### Table 1: Objectives versus operations map

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Operations</th>
<th>Combustion system</th>
<th>Charge support and handling system</th>
<th>Furnace structures and devices</th>
<th>Automation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase of furnace productivity</td>
<td>XX</td>
<td>XXX</td>
<td>X</td>
<td>XX</td>
<td></td>
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<tr>
<td>Improvement of product quality</td>
<td>XX</td>
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<td>Energy saving</td>
<td>XXX</td>
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<td>X</td>
<td>XXX</td>
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<tr>
<td>Pollutant emissions reduction</td>
<td>XXX</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
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</tbody>
</table>

Expected benefits: X = Low         XX = Medium            XXX = High

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### Fig. 1: Production profitability versus sustainability

![Production Profitability Equation]

### Fig. 2: Replacement of the burners

![Burner Replacement Image]
nace and it is in many cases required a modification of the combustion control system software (Level 1).

- Replacement of the central heat recovery system. Modern heat recuperators fabricated in high temperature-resistant steels are able to preheat combustion air above 600 °C thus improving the furnace efficiency.

- Installation of new control zones at the charging side with new burners and related equipment. A more intense heating of the charge is performed and a production increase is obtained. If the new zones are equipped with regenerative burners the production increase can be achieved with a lower specific consumption. This work can be carried out for the furnaces with a convective zone sufficiently long. It is necessary to modify the software of the control system (Level 1 and Level 2).

- New combustion control mode. A localized control of the charge temperature is obtained by means of a cyclical pulse firing implemented as a function of the production schedule and of the charge position. A reduction of the fuel consumption and of the NOx emissions is also achieved. The best performance is achieved for top and bottom fired furnaces. It is necessary to modify the software of the control system (Level 1).

**OPERATIONS: CHARGE SUPPORT AND HANDLING SYSTEM**

Technical interventions on the charge support and movement system are aimed to improve the heat exchange between the charge and the combustion chamber finally improving the product quality through a minimization of the skid mark effect.

This condition can be achieved with the following works:

- Installation or replacement of special alloy riders, insulated from the water-cooled skids to support the charge. This solution substantially reduces the heat transfer from the slabs and minimizes the beam shadow effect reducing consequently the skid mark. The riders are mounted onto the skids by means of a mechanical coupling able to assure a solid support with no need of welded joints that may determine maintenance problems. This intervention is limited to walking beam and pusher type furnaces. (Fig. 3)

- Replacement of the external lining of the skids with new high-insulation refractory. Also the shape of the refractory around the skid is arranged to increase the overall view factor charge-furnace and consequently improve the heating efficiency. This intervention is limited to walking beam and pusher type furnaces.

- Partial or total replacement of the skid pipe system used to move the charge through the furnace. The round pipe is replaced with rectangular pipe in order to improve the heating efficiency. This intervention is limited to walking beam and pusher type furnaces.

- New skid layout (fixed and/or movable skids). The skids are shifted so as minimize the skid-mark effect on the charge. Deep care has to be taken to locate the offset position in order to guarantee the best performances and at the same time a good maintainability. The optimization of the skid layout is performed by means of mathematical models. This intervention is limited to walking beam and pusher furnaces.

**OPERATIONS: FURNACE STRUCTURES**

Technical interventions on the furnace structures include a wide range of works. Product quality improvement, reduction of heat losses and production increase are the main expected results.

The revamping operations concerning the furnace structure and devices are:

- Replacement of the wall/roof refractory lining with new high-insulation materials. In order to reduce both thermal losses and high temperature on the external walls, the furnace equipment and components will be lined with refractory castable, plastic refractory, anchor bricks, standard bricks, shape bricks and other insulating material. The following features have to be taken into account when design furnace refractories: operational conditions, working temperatures, anti-abrasive factors, resistance to spalling, correct insulating values, method of installation,
replacement of the existing soaking hearth with new high-insulation materials. The main results of this solution are a reduction of the heat losses and an improvement of the product quality. This operation can be carried out on the pusher furnaces.

- Widening of the furnace. This may be obtained by forming the internal walls with a suitable niche. A production increase derives from the possibility to load longer slabs. This operation can be carried out for walking beam and pusher furnaces. Alternatively, widening of the furnace is possible also by moving one of the side walls and restoring the roof and the hearth. Also in this case the production increase is obtained by the longer pieces charged.

OPERATIONS: AUTOMATION

Technical intervention on the automation and control equipment are aimed to improve the overall efficiency of the furnace. The interventions on the field instrumentation can be carried out during a normal maintenance stop while the activities related to a level 2 control system can be implemented with the furnace in production.

Revamping operations concerning the combustion system are:

- Replacement and/or tuning of the existing field instrumentation. This operation can be applied for any type of furnace.
- Installation and/or optimization of a level 2 process control system. The system, based on the use of an on-line mathematical model computing the thermal profile of the charge in the furnace, determines, in comparison with the traditional control of the plant, the main following advantages:
  - More compliance with the specifications required by the material during the heating process. This is obtained with any variation of both in heating equipment and production figure.
  - Automatic management of planned and unplanned delays thus to discharge the pieces at the required temperature without overheating.
  - Quicker adaptation of the heat distribution in the furnace due to the better knowledge of the actual thermal status of the charge.
  - Lower fuel consumption and minimization of the scale losses and of the steel decarburization as result of a better control.
  - More uniformity in the furnace operation due to the elimination of the human factor with the "style of management" of each single operator.
  - Less risk of troubles and delays at the mill as result of more uniform discharging temperature.

This activity can be implemented for any type of furnace. A preliminary condition for the installation of a new Level 2
control system is the presence of a reliable and effective Level 1 control system.

ANALYSIS OF THE OPERATIONS
The experience achieved by Tenova Italimpianti in more than 40 years of reheating furnaces manufacturing is the best tool to guarantee the expected results to the customers. Nevertheless, in order to evaluate the result of a revamping it is necessary to use a reliable mathematical model for simulating the different operating conditions and understanding the effect of each intervention.

Tenova Italimpianti uses the mathematical model TFM that is a 3D simulator developed for the thermal design of the furnaces. TFM is validated with the feedback data of each type of furnace. TFM calculates the temperature distribution of the charge (Fig. 4) taking into account the charge characteristics (shape and size), steel grade, type of fuel, and the boundary conditions (furnace temperatures and fuel flow rates, geometrical parameters).

Any single intervention of the revamping is analyzed as it was the only one carried out. Applying the superimposition of the effects it is possible to evaluate the final result of the operations and to guarantee the performances of the restructured furnace. Each intervention is compared with the reference condition (current performance of the furnace). A parallel cost evaluation is carried out for each solution in order to produce an overall analysis.

EXAMPLES
Here follow some details about some revampings of furnaces performed by Tenova Italimpianti.

Example 1: Walking Beam Furnace for Pipes
This is the case of a walking beam furnace for austenitizing process of seamless pipes. The required improvements were production increase (up to 20 %) and strong NOx emission reduction (one order of magnitude).

Analyses carried out by means of mathematical models pointed out that productivity limitation of 40 t/h was
due to the length of furnace, that was affecting the time needed to reheat tubes, and to the limitation of temperature in the tunnel, necessary to prevent any damage to the recuperator. From the energy point of view productivity of 50 t/h could be achieved. Therefore, to increase the productivity, the furnace geometry was modified eliminating the tunnel and moving back burners to the charging wall.

In order to reduce NO\textsubscript{x} emissions, TLX6 and TLX8 Tenova Flexytech\textsuperscript{®} Flameless Burners replaced THS4 and THS6 burners in reheating and soaking zone respectively. Moreover a new row of Tenova TR4 roof burners was installed at the middle section of the furnace.

TLX burner is based on the flameless combustion technology. Lateral gas injection allows reaching flameless combustion regime over the whole turn-down field with consequent extremely low NO\textsubscript{x} emission level in comparison with traditional flame regime with central gas injection. Commissioning of the austenitizing walking beam furnace was performed by Tenova in two weeks. Productivity was increased up to 20 % due to the new furnace profile and NO\textsubscript{x} emissions were far below the guaranteed value: from about 100 ppm at 3 % O\textsubscript{2} in dry flue gas of original furnace, to about 30 ppm at 3 % O\textsubscript{2} of revamped one.

**Example 2: Rotary Hearth Furnace**
The complete revamping of the 215 t/h FTM pipe mill rotary hearth furnace for seamless pipes at the TenarisDalmine factory was an important industrial application of the energy and environmental benefits of Tenova Regenerative Flameless technology.

The TenarisDalmine rotary furnace revamping was an extremely demanding project completed in a very short time (seven weeks) considering the complexity of the works carried out.

The furnace was enlarged (towards the center in order to charge longer blooms (up to 5,300 mm). All the existing burners were replaced installing 55 TRGX Tenova regenerative flameless burners in the first three reheating zones and 200 TRX Tenova roof flameless burners in the final five zones. The operating data collected in the years after the revamping confirm that specific consumption was improved (about 15 %) from 45 to 38 Nm\textsuperscript{3} of natural gas per tonne of blooms produced, while average guaranteed NO\textsubscript{x} emissions are under 60 ppm well below the legal limits. The furnace expansion also allowed for blooms weighing up to 5,800 kg be used and, consequently, the production capacity increased 35 % from 160 to 215 t/h. The heat regenerator ceramic elements on burners were made up of high density aluminum based materials which, after two years of intense use, did not show signs of either deterioration or dust accumulation. **Fig. 5** gives for the above revamping operations a qualitative representation of the ranges among the plant shutdown time, the complexity and the subsequent cost.

**Table 2** contains some indicative benefit achievable through different operations based on the revampings carried out by Tenova Italimpianti.

**CONCLUSION**
Tenova Italimpianti experience shows how it is possible to carry out efficiently furnace revampings by means of both
In any case an old furnace can never become more efficient than a new one, but in many cases it can be again profitable for a long period with low investments.

**LITERATURE**


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**Objectives**

- **Increase of furnace productivity**: 5-20 %
- **5-20 %**
- **5-10 °C**
- **5-10 °C**
- **5-8 %**
- **2-5 %**
- **10-15 %**
- **2-4 %**

**Table 2: Expected benefits**

- **Energy saving**: 7-20 %
- **10 -15 %**
- **2-5 %**
- **5-8 %**
- **2-5 %**
- **10 -15 %**

- **Pollutant emissions reduction**: 10-60 %
- **3-8 %**
- **2-4 %**

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