Update on FlexyTech® Level 2

Tenova FlexyTech® furnace is the framework which encompasses all these innovation activities as applied to reheating furnaces; FlexyTech Level 2 is one of the company's technological kernels, as it can be easily integrated in any reheating furnace typology in the context of existing customer automation.

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Tenova Loi Italimpianti has been a world leader in the market of high capacity reheating furnaces since the early 1960s

Tenova Loi Italimpianti has gained considerable experience over the decades since it was founded – in design, erection and commissioning of furnaces – by continuously investing considerable resources into R&D projects with a particular focus on combustion control techniques, high performance burners with very low emissions burners [1,2] and automation systems.

Its FlexyTech furnace is the framework which includes all its innovation activities as applied to reheating furnaces.

FlexyTech furnaces (**Fig 1**) are engineered in order to assure top performance under any conditions, particularly for baseline efficiency and thermal quality, with special focus on low environmental impact.

One of the most advanced performance features of these furnaces is the level 2 automation for the furnace control. This paper describes Tenova FlexyTech Level 2 automation architecture with a particular focus on the more recent innovative features implemented such as communication protocols, advanced 2D model, predictive control logic, Tenova ICS® fuzzy logic and statistical cooling model

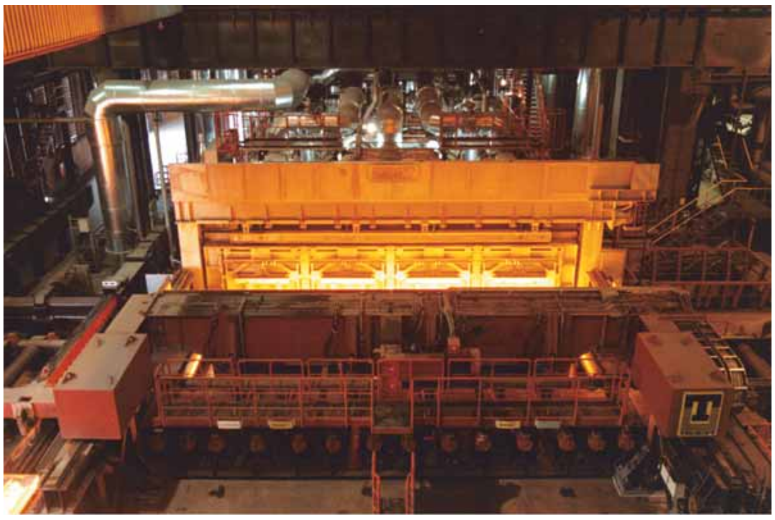


Fig 1 Techint FlexyTech® slab reheating furnace

FLEXYTECH LEVEL 2

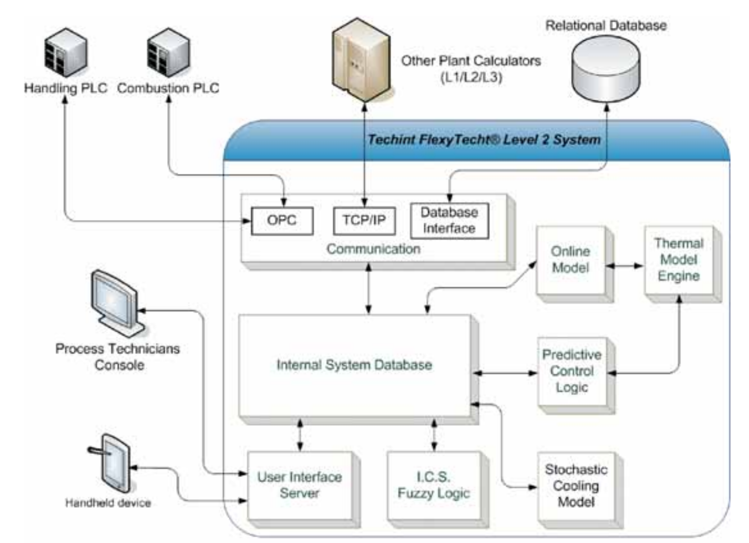
FlexyTech Level 2 [3] can be easily integrated in any reheating furnace typology in the context of the existing customer automation. It is a computer-based system that can be built on various hardware and software platforms such as Windows Server, OpenVMS, HP-UX, etc.

As shown in (**Fig 2**), all FlexyTech Level 2 modules store and retrieve data to or from an internal system database; those modules are:

- Communication layer, from and to the other devices on the plant;
- Mathematical model to compute the thermal profile of the slabs;
- Control logic to compute the pacing and the set points of the furnace;
- Statistical model to estimate the cooling from the furnace discharge to the exit of the roughing mill;
- Fuzzy Logic to drive the Tenova ICS system upon the heating distribution in the furnace;
- User interface with real-time and historical data stored by the system;
- Technological editor;
- Remote diagnostic and assistance.

All the topics covered below will reference the Windows Server version.

Fig 2 Architecture of the Level 2 system



However, the same concepts apply, with minor changes, to the other platforms.

COMMUNICATION LAYER

FlexyTech Level 2 needs to be integrated in the existing customer network in order to exchange data with the other computers of the plant automation system. Combustion and handling systems are usually driven by industrial PLCs. Nowadays any PLC provides support for the OPC protocol. Tenova is a member of the OPC foundation [4] and this protocol has been integrated into the communication layer of FlexyTech Level 2 so that it can be easily integrated into any PLC-driven system, regardless of the model and brand.

While OPC is the standard communication path for PLCs, the TCP/IP protocol is the universal transport layer for communications among PCs or Workstation. FlexyTech Level 2's communication layer has a set of basic functions that can be easily integrated with any of the several possible non-standard protocols used on the various plants.

Sometimes the communication is also carried out via database tables; Oracle and Microsoft SQL Server are the most popular relational databases used by industrial plants – therefore FlexyTech Level 2's communication layer also integrates support for relational databases.

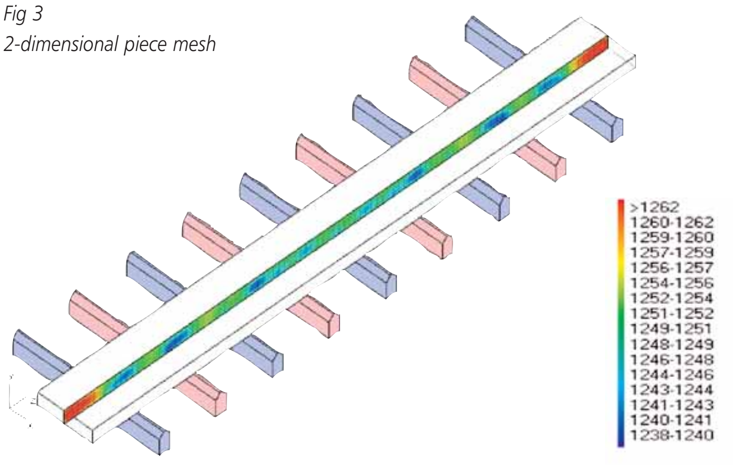
MATHEMATICAL MODEL

The FlexyTech® Level 2 integrates an accurate on-line mathematical model of the charge heating process in the furnace. Its model, first developed in 1981 and improved and validated through years of applications, is aimed at calculating the thermal status of each piece inside the furnace.b The same model is also used in the off-line Tenova thermal tools used by process engineers for furnace design (aka TFM) [5].

The main features are:

- 2D mesh of each piece in the furnace according to the typology of the charge (**Fig 3**). The temperature is calculated for each point of the mesh for all the pieces in the furnace on a fixed time basis;
- Supports devices modelling (skids, hearth, rollers, …) with skid mark calculation;
- Oxidation and decarburisation kinetics;
- Temperature dependent thermo physical properties of the material database;
- Tuning of FlexyTech model obtained with specific tests done with an instrumented piece.

Fig 3
2-dimensional piece mesh



PREDICTIVE CONTROL LOGIC

The FlexyTech model is also used in a predictive way by the control logic function to determinate the optimal furnace temperature set-points for each control zone and the discharge pacing. This allows the charge to be heated in the best way to assure that the target discharge temperature will be reached with the best temperature uniformity minimizing fuel consumption and scale formation.

The control logic considers the actual product mix in the furnace, critical steel qualities (if any), heating constraints of the steel (thermal gradients, oxidation and decarburisation), and the operating limits of furnace and waste gas temperatures.

Delay information is also taken into account in order to minimise fuel consumption during the delay while having the fastest restart time.

Moreover, there is an adjustable priority factor that can be used to increase or decrease the priority that a steel grade may have over the others.

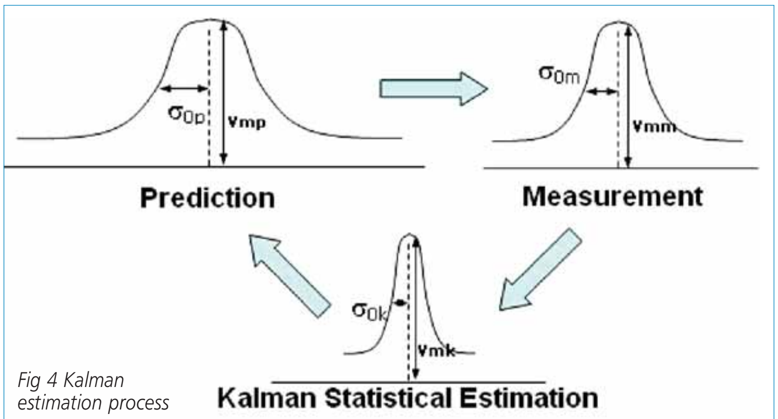


Fig 4 Kalman estimation process

STATISTICAL COOLING MODEL

The control logic, with its predictive feature, can drive the furnace in order to reach the requested slab discharge temperature. However, if the given target is the bar temperature after the roughing mill instead of the slab discharging temperature from the furnace, it is necessary to estimate the piece temperature drop from the furnace exit till the roughing mill exit.

A determistic model for such a task requires the knowledge of several parameters whose set-up is particularly complex and can be carried out only over a very long period. To overcome this problem, Tenova has developed an adaptive statistical cooling model (**Fig 4**) based on a modified version of the Kalman filter [6]. This model gets feedback from a pyrometer installed at the roughing mill exit and adapts the cooling coefficients of the piece on a statistic base in order to estimate the real temperature drop, thus allowing the system to calculate the correct furnace discharge temperature from the bar temperature after the roughing mill.

ICS FUZZY LOGIC

The model, the control logic and the cooling model operate synergistically to determine the optimal control of zone temperature set-points. Depending on the charge temperature and distribution in the furnace, each zone could have an unbalanced thermal load; therefore the burners in the control zone must be

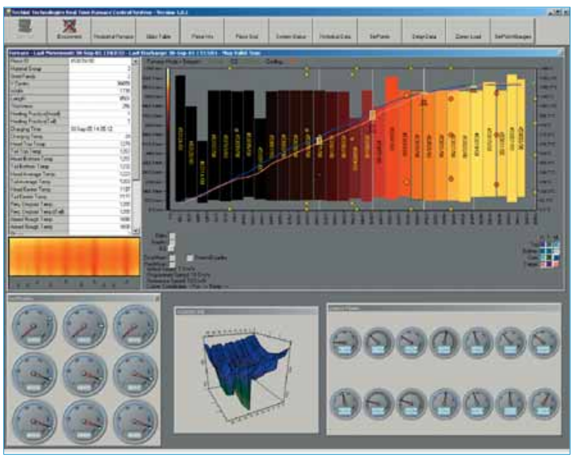


Fig 5 User interface

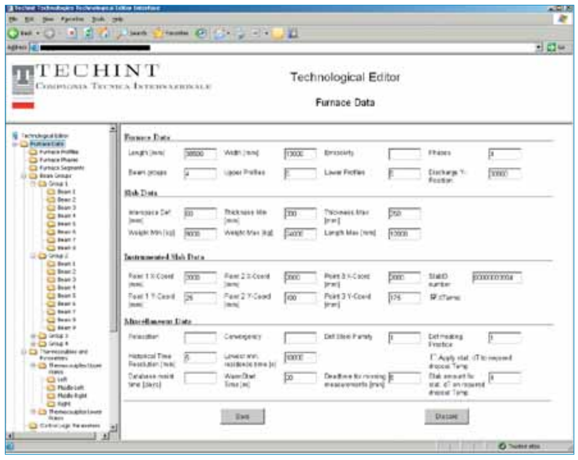


Fig 6 Technological editor

driven in order to compensate the unbalanced load. This is achieved by varying the duty cycle for each burner and the ignition sequence: this system is called ICS (innovative combustion system) [3].

In order to fulfil this task, the ICS relies on Fuzzy Logic that, if given the charge layout in the control zone and its temperature, evaluates the best power 'unbalancing' for the burners according to a set of practical rules assigned to the system during the commissioning phase.

Such rules, as in any fuzzy logic system, are expressed in a qualitative 'human-like' way as "IF <expression1> AND/OR <expression2> … AND/OR <expression n> THEN <output action>".

The power of fuzzy logic is to achieve best results with quantity that cannot be measured but only expressed in a qualitative way. The thermal load 'unbalance' is one of those quantities.

USER INTERFACE

Tenova and customer process technicians can monitor the furnace using the Real Time Furnace Control Client utility. The programme allows monitoring in real time all through the thermal process by means of a graphical representation of the charge in the furnace, a three-dimensional graph of the heating profile of each slab, delay information, production rate, gas flows and so on (**Fig 5**). This interface communicates with the Level 2 system using TCP/IP; this allows the Real Time Furnace Control Client to be run on any machine on the network.

All the geometrical data of the furnace and process control parameters necessary for the model, like steels thermo physical properties, customer steels classification as well as statistical data for cooling model are stored in a database and can be viewed, updated or added using a web interface from any computer that can reach the server. This interface (**Fig 6**) is also a useful tool for a basic diagnostic of the system and of the furnace.

REMOTE DIAGNOSTIC AND ASSISTANCE

Even after the commissioning phase of the system is completed, it can sometimes be necessary to carry out modifications of the system, for example in order to match new production requirements, to change some control parameters, or to configure the communication addresses due to changes on the customer network.

In order to obtain the fastest response time and to give the best assistance to the customer, a remote diagnostic and assistance architecture **(Fig 7)** was developed. This system allows Tenova specialists team to monitor, analyse and perform diagnostics on the furnace – in real time – without any stoppage of normal production. Any corrective and optimisation action can be performed online if needed, without any downtime of the system.

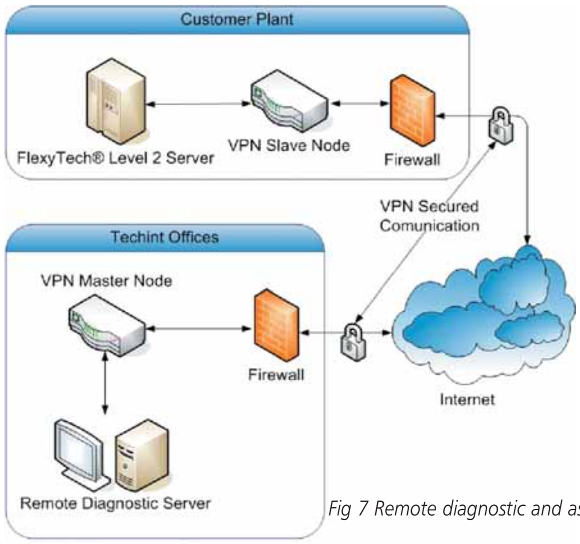


Fig 7 Remote diagnostic and assistance

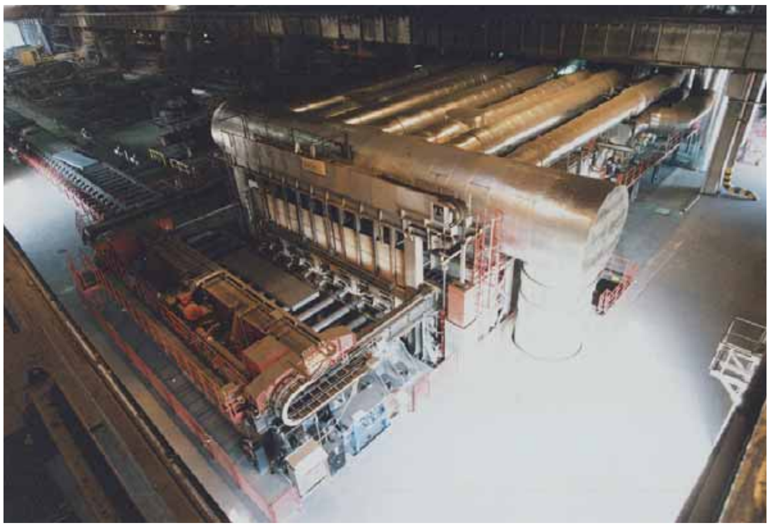


Fig 8 TKS 380t/h walking beam furnace

The system is composed of a central node (located in Tenova's Genoa office) and by a slave node (located in the customer's plant). These nodes establish an encrypted VPN (Virtual Private Network) so that all the communications taken between central and slave nodes are guaranteed to be secure.

INDUSTRIAL APPLICATION

All the new features of FlexyTech Level 2 system described in this paper have been applied in the 380 t/h Walking Beam Furnace of ThyssenKrupp Stahl at the Beeckerwerth Works in Duisburg, Germany (**Fig 8**).

The commissioning of the FlexyTech Level 2 system was recently completed.

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