



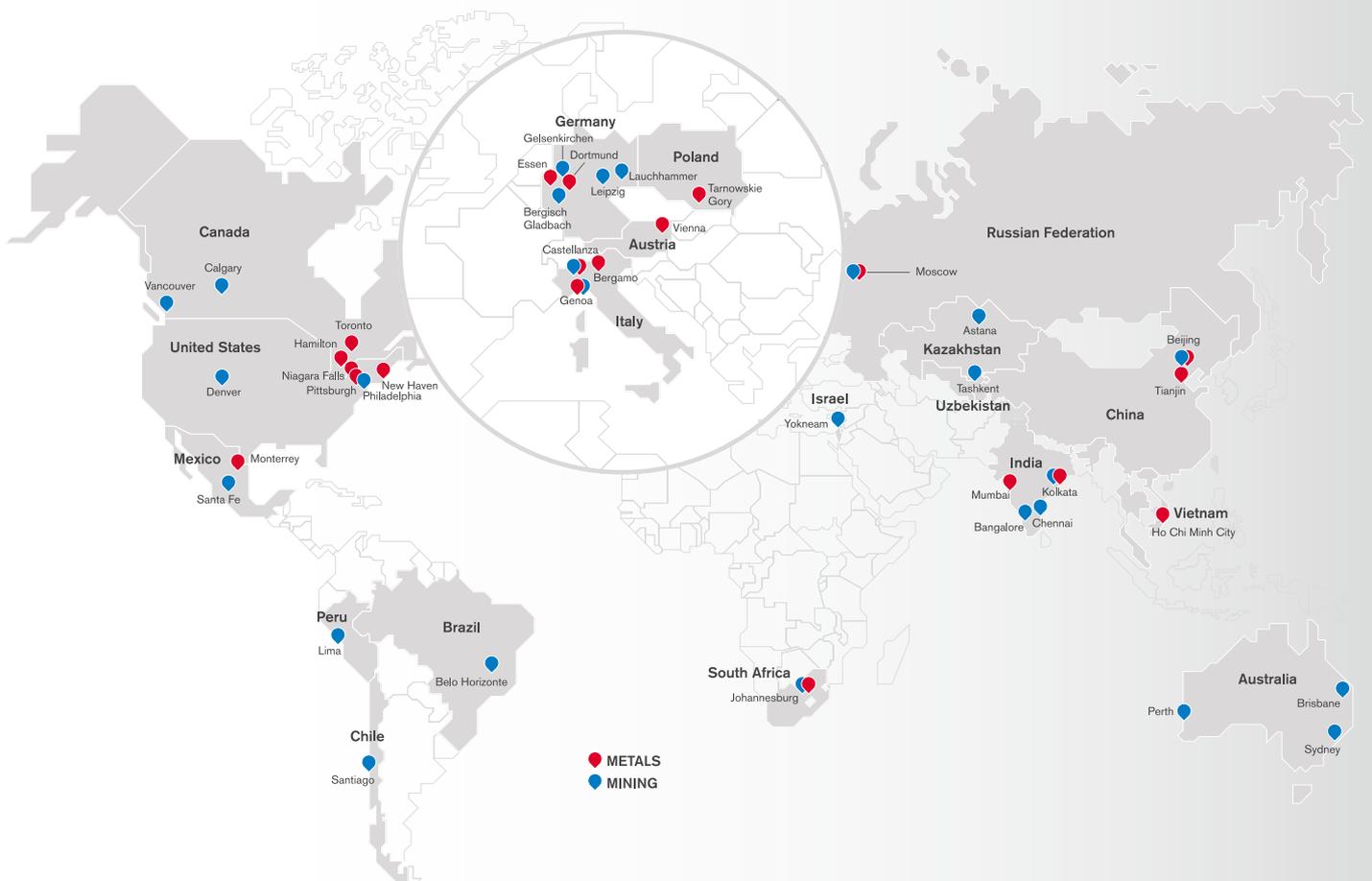
HEAT TREATMENT LINES

For Hot Formed Materials

TENOVA LOI THERMPROCESS

Tenova LOI Thermprocess is your global partner in the world of industrial furnace technology. Our clients appreciate our know-how and experience backed by hundreds of references and a history of about 100 years in the furnace sector. We offer highly advanced process technologies, high reliability, high-quality products and services, and a wide range of custom-tailored solutions for reheating and heat treatment plants for the metal industry.

Tenova LOI Thermprocess is a member of the Tenova Group, leveraging a total staff of more than 2,500 forward-thinking employees located in 19 countries across 5 continents. Tenova works alongside clients to design and develop innovative technologies and services that help mining and metal companies to reduce costs, save energy, limit environmental impact and improve working conditions for their employees.



Tenova and LOI – Since 1957 Leaders in Reheating Furnace Technology

CUSTOM-ENGINEERED REHEATING FURNACES FOR C STEEL, STAINLESS STEEL OR SILICON STEEL:

Tenova LOI Thermprocess and Tenova Italmimpianti are the world leaders in industrial furnaces for the reheating of long or flat products as well as for forgings. The companies' technical leadership is backed by

the long histories of Italmimpianti and LOI and confirmed by hundreds of reference plants in the following fields:

- Pusher-Type Furnaces for blooms, slabs, billets and forgings
- Walking Beam Furnaces for heavy-gauge plates, especially if quenching is required
- Roller Hearth Furnaces for slabs, tubes and plates
- Walking Hearth Furnaces, Rotary Hearth Furnaces and Chamber/Bogie Hearth Furnaces for blooms or forgings

Roller Hearth Furnaces

Special versions are available for reheating stainless steel up to 1,250 °C.

Chamber/Bogie Hearth Furnaces

used for large blocks or ingots to be forged and/or milled.



Car Bottom Pusher-Type Furnaces

for forgings, with high fuel efficiency and low NOx emissions as well as an overall process automation and handling concept.

Rotary Hearth Furnaces

for pipe production. Our proven rollers and guide systems ensure reliable furnace operation.

ADVANCED HEAT TREATMENT FOR PLATES & FORGINGS

New material grades and increasingly stringent specifications for strength, corrosion resistance and forming are the result of the market trend towards leaner steel constructions. Tenova LOI Thermprocess is the world leader in industrial furnaces for the heat treatment of plates and forgings.

We implement projects in these industries throughout the world. We supply custom-engineered, mathematically optimized heating and cooling systems that

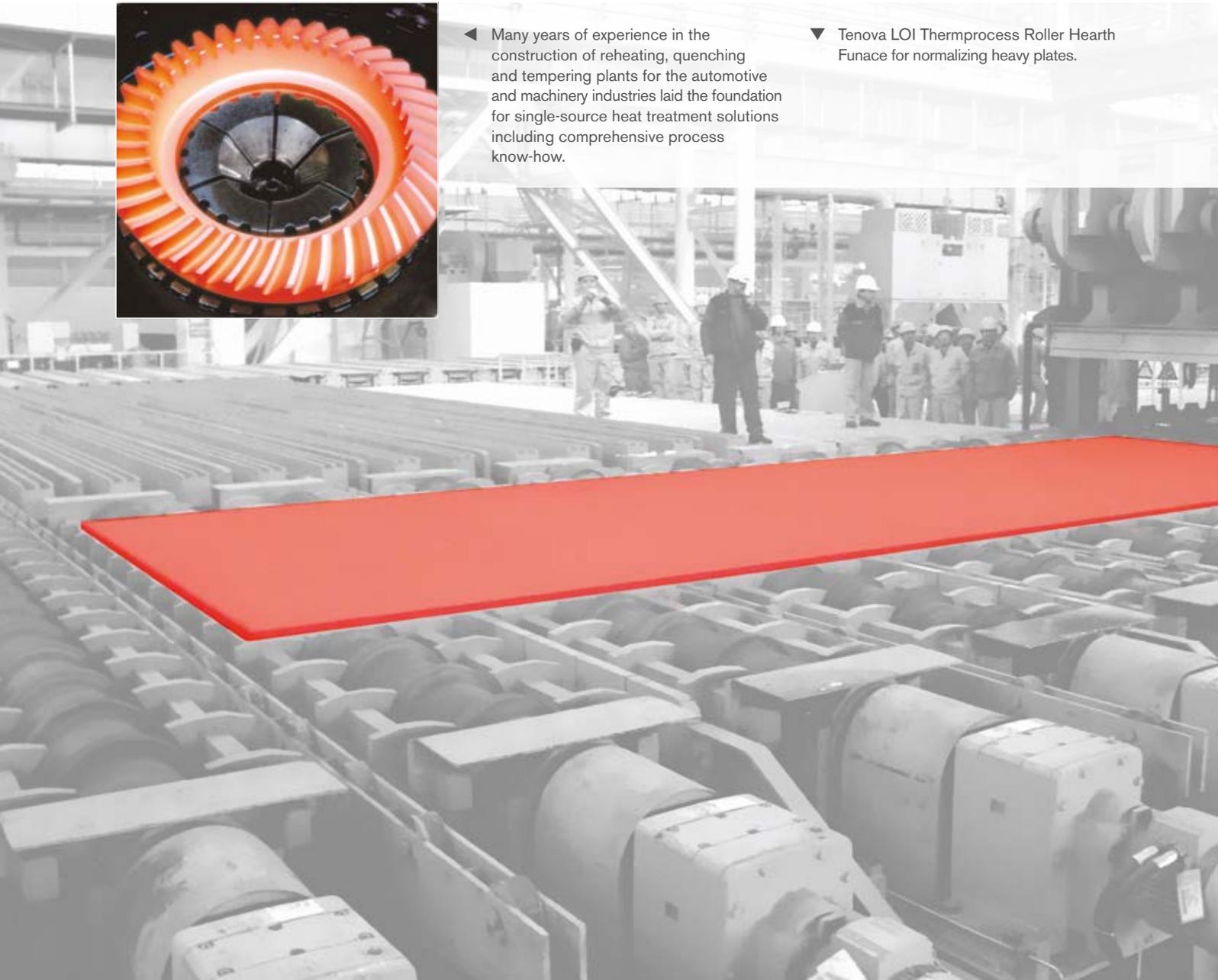
- precisely improve material properties and meet the requirements for microstructure changes defined in TTT diagrams

- achieve homogenous temperature distribution inside the parts
- reduce residual stress and distortion of the material and
- ensure defined surface quality.

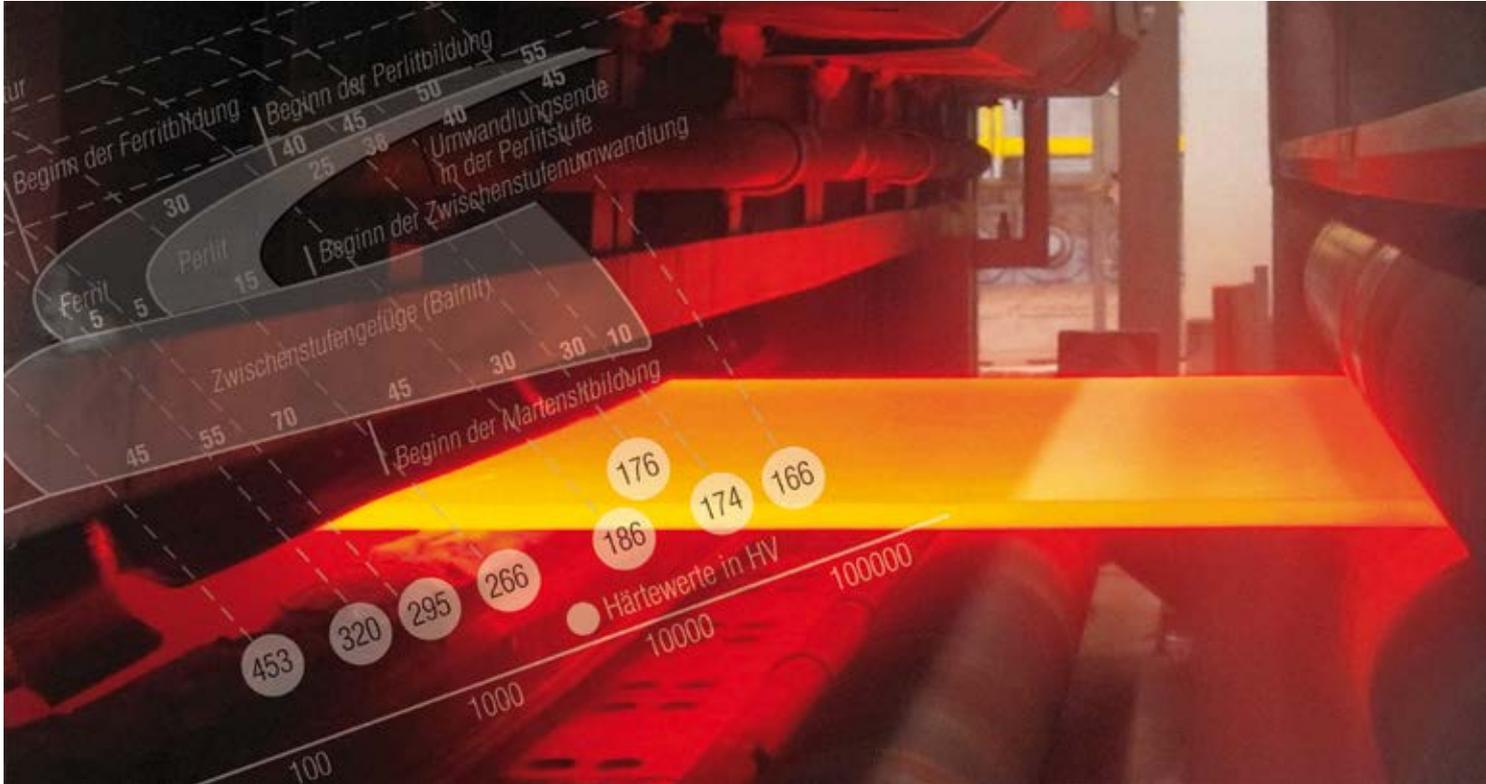


◀ Many years of experience in the construction of reheating, quenching and tempering plants for the automotive and machinery industries laid the foundation for single-source heat treatment solutions including comprehensive process know-how.

▼ Tenova LOI Thermprocess Roller Hearth Furnace for normalizing heavy plates.



Quenching and Tempering of Heavy Plates



GENERAL FEATURES

Numerous references

Tenova LOI Thermprocess has been the leading company in this field since the 1990s with more than 30 quench facilities and more than 50 furnace installations throughout the world.

Plates can be produced with widths up to 4.9 m, thicknesses from 2 mm up to more than 150 mm and lengths up to 25 m.

Tenova LOI Thermprocess Q&T lines for hardening, normalizing and tempering are ideal for mass producers as well as niche producers with small batches.

Everything from a single source

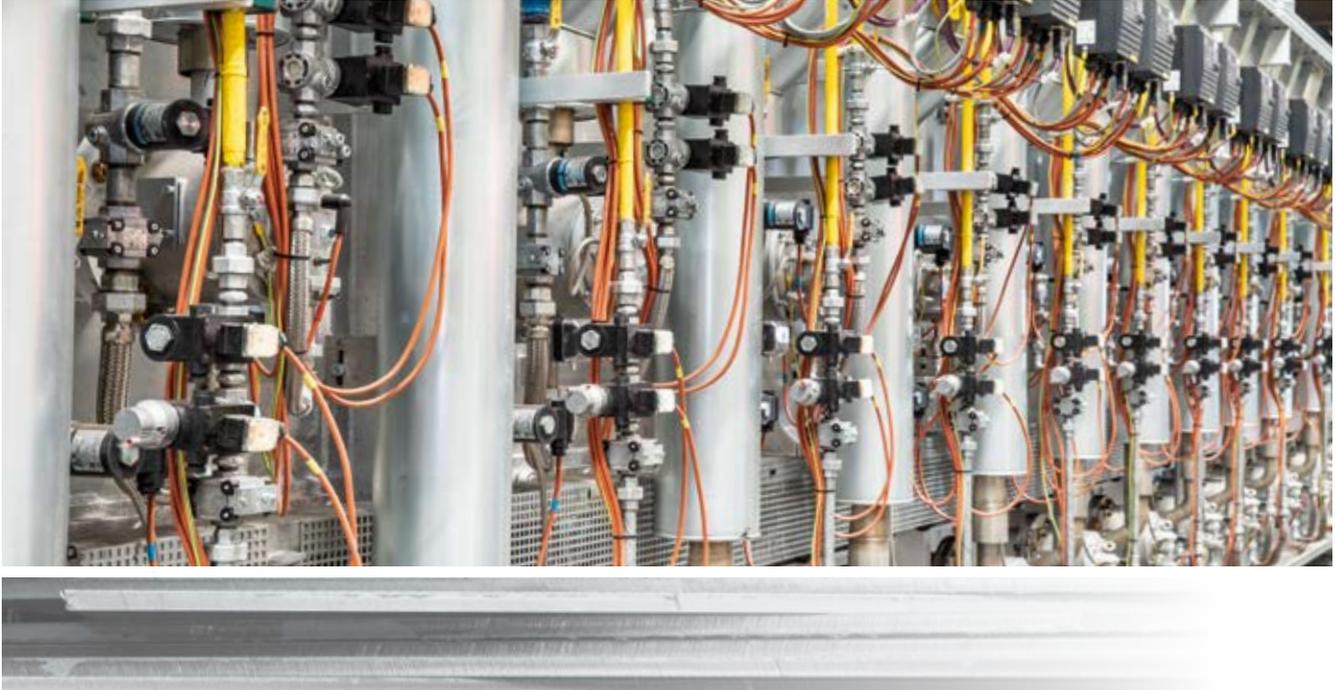
Comprehensive process know-how, design, automation, mathematical models, scheduling & installation as well as modernization, maintenance & service. Our Q&T technology is precisely tailored to customers' growing requirements for process security, quality and flexibility in heating and cooling processes for heavy plates.

Unique, powerful and intelligent technologies

like iQuench® including 3rd Generation MQM (Mathematical Quench Model) and PFM (Plate Flatness Model) together with our special HCT (High Convection Technology) for tempering guarantee high process reliability.

- ▲ Our stationary, continuous and iQuench® cooling systems include mathematical optimized water spray cooling processes for high plate flatness and microstructure changes defines in TTT diagrams.

Roller Hearth Furnaces for Normalizing (NF)



NORMALIZING FURNACES

Our normalising furnaces are the perfect supplement to Q&T lines in view of the rising demand for normalizing.

Normalizing is the easiest way to influence the mechanical properties of carbon steel. For heavy plate normalizing, the process involves heating to normalizing temperature in a furnace to completely dissolve the carbon, which is present in the steel in the form of carbides at room temperature.

Tenova LOI furnaces may be heated either by open burners firing directly into the furnace, or indirectly by radiant tubes. Our indirectly heated Roller Hearth Normalizing Furnaces (NF) provide a protective atmosphere to ensure the best possible surface quality. The use of nitrogen prevents scale formation on the steel surface. Nitrogen consumption and heat losses are minimized by rapid charging and discharging of the plate.

- ▲ We use state-of-the-art recuperative burners to ensure higher combustion efficiency, lower energy consumption and reduced carbon dioxide emissions.
- ▼ The photo shows a typical Q&T line for heavy plates consisting of a Hardening Furnace, a Water Quench, a Tempering Furnace and a Normalizing Furnace. Heat treatment lines from LOI Thermprocess are precisely tailored to customers' growing requirements for process security, quality and flexibility.



Stationary and Continuous Quenches



◀ High-throughput continuous quench for heavy plates.

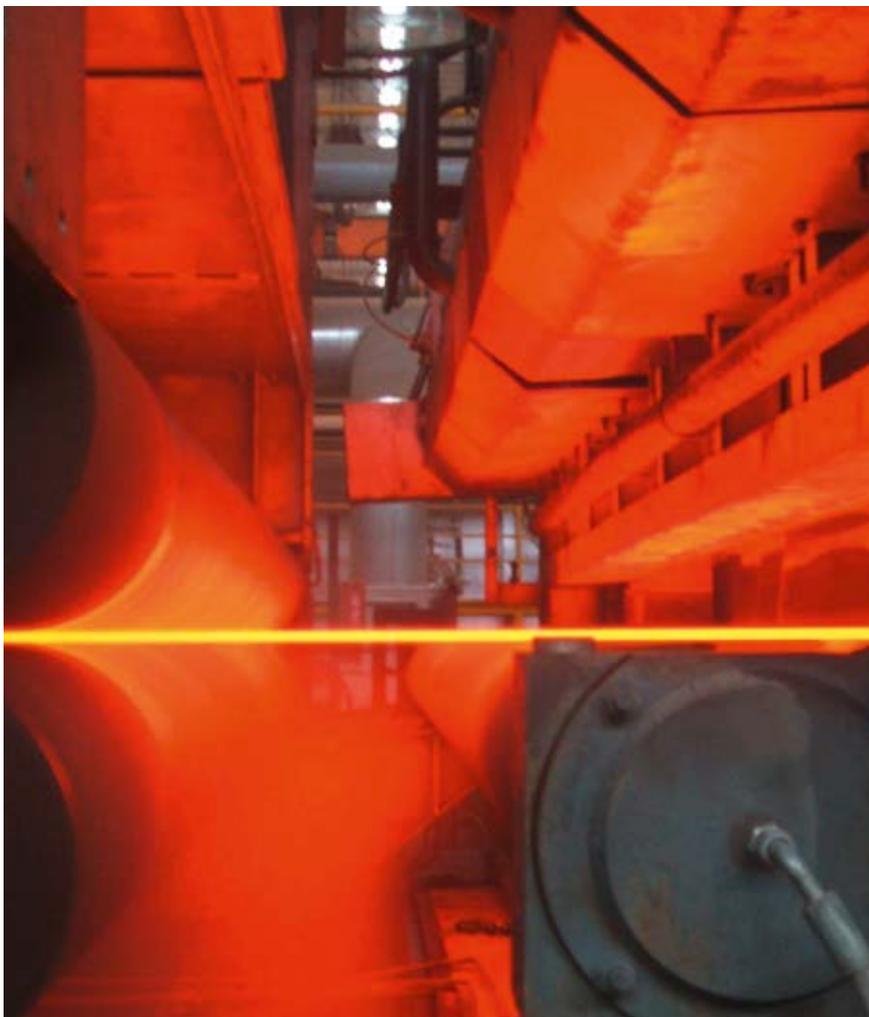
QUENCHES

The quenching facility is the key component of a LOI heavy plate Q&T line.

Tenova LOI Thermprocess offers stationary (throughputs of up to 10 t/h) and Continuous Quench facilities (up to more than 100 t/h).

A Stationary Quench can handle one plate at a time. This extremely short type of Quench can be combined for example with LOI oscillating Roller Hearth Furnaces.

The key advantages of a Continuous Quench are higher throughput, higher reproducibility and higher cooling uniformity. The mechanical properties required can be reached with far lower alloying additions. A combination of weldability, strength, bendability and flatness can be reached by individual cooling rates up to 200 K/s. Higher alloyed duplex or TRIP steels require specific cooling gradients.

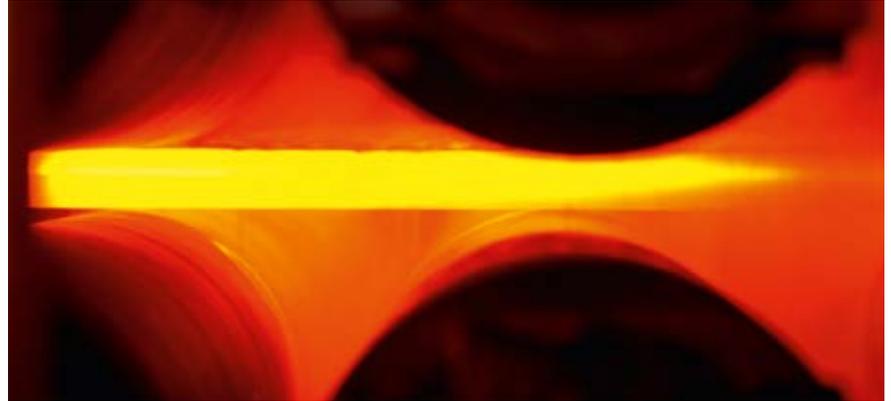


iQuench®

iQuench®

With its iQuench® technology, Tenova LOI Thermprocess offers a wide variety of quenching modes and a full range of heat transfer rates combined with a unique, powerful mathematical quenching model in an overall automation concept.

A patented system of slit, full and flat stream nozzles as well as full cone nozzles is arranged in a complex configuration in successive cooling sections. They are precisely controlled in dependence of flow rate, water pressure and distance from the plate to guarantee the best possible



mechanical properties and flatness over a wide range of thicknesses. Using dynamic parameter adaption during treatment and model-based

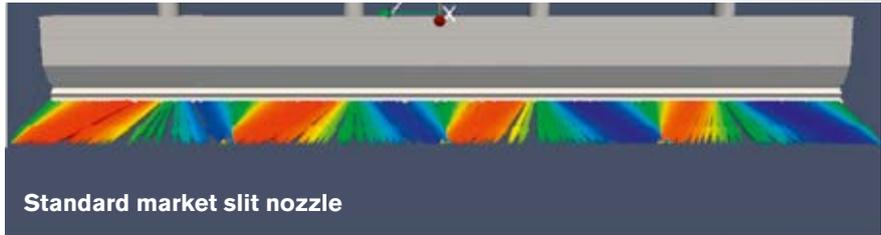
cooling processes, our Q&T lines with iQuench® technology can reach flatness tolerances tighter than those specified in the ASTM standards.



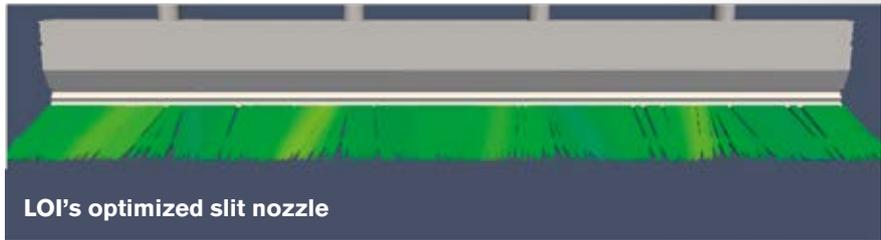
LOI PROPRIETARY SLIT NOZZLE SYSTEM

The patented LOI system of slit nozzles, arranged in a complex configuration in succeeding cooling sections results in homogenous flow rates over the entire width. The combination of precisely designed equipment with an intelligent model makes iQuench® a unique and powerful masterpiece of engineering.

The cooling system parameters are dynamically adapted during treatment to guarantee not only excellent mechanical properties but also high flatness even of thin plates.



Standard market slit nozzle

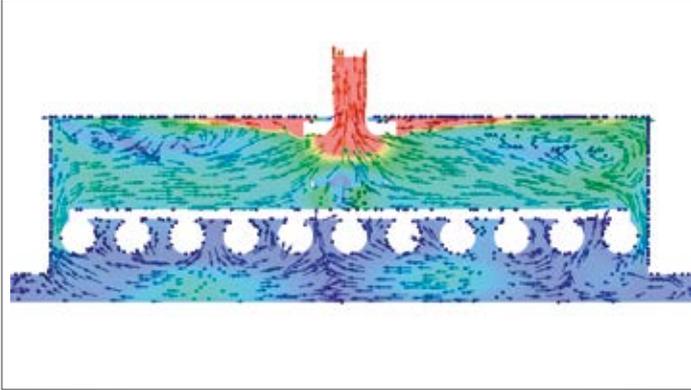


LOI's optimized slit nozzle



Roller Hearth Furnaces for Tempering (TF)

HIGH CONVECTION TECHNOLOGY (HCT)



The HCT consists of open-, fired burners and horizontal recirculation systems which transfers the heat from the mixed flue/furnace atmosphere by convection. This high convection allows a temperature uniformity of ± 3 K even at a material temperature of 200 °C.

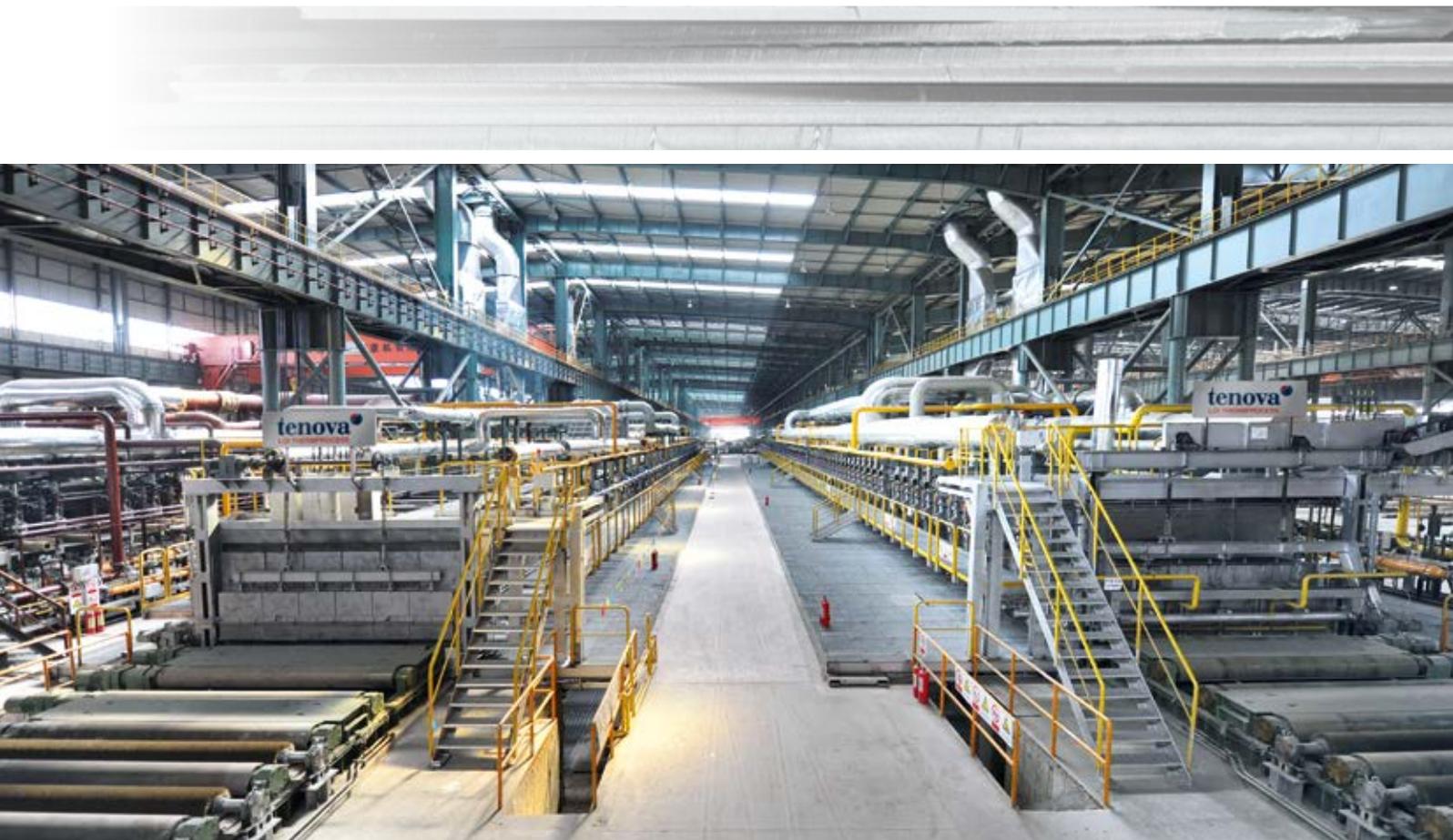
TEMPERING FURNACES

The tempering of carbon steel is the final step in the heat treatment process and influences the final material properties within a wide range. The precision of temperature control is the most important issue because there is only a small step between success and failure.

Tenova LOI Thermprocess supplies Roller Hearth Tempering Furnaces (TF) with advanced heating technology for short heating time to tempering temperature and excellent temperature tolerances. Our TF are designed for a temperature range of 175 to 750 °C and feature HCT (High Convection Technology) for higher heat transfer to the plate resulting in

- short heating times
- outstanding temperature uniformity
- excellent temperature constancy and reduced furnace length at the same throughput.

▼ Q&T line with NF, TF and Quench.



Rotary Hearth Furnaces



ROTARY HEARTH FURNACES

Tenova LOI Thermprocess is the world's leading supplier of Rotary Hearth Furnaces for a variety of process applications and product types (even up to 67 m in diameter). Computerized fluid dynamic simulation and lab tests are used for the effective design of waste gas systems inside the furnace for special applications including the reheating of forgings.



▲ Tenova LOI Thermprocess Rotary Hearth Furnace with zone separation for gas carburizing of gear parts and Q&T steels.

HEAT TREATMENT LINES FOR FORGINGS

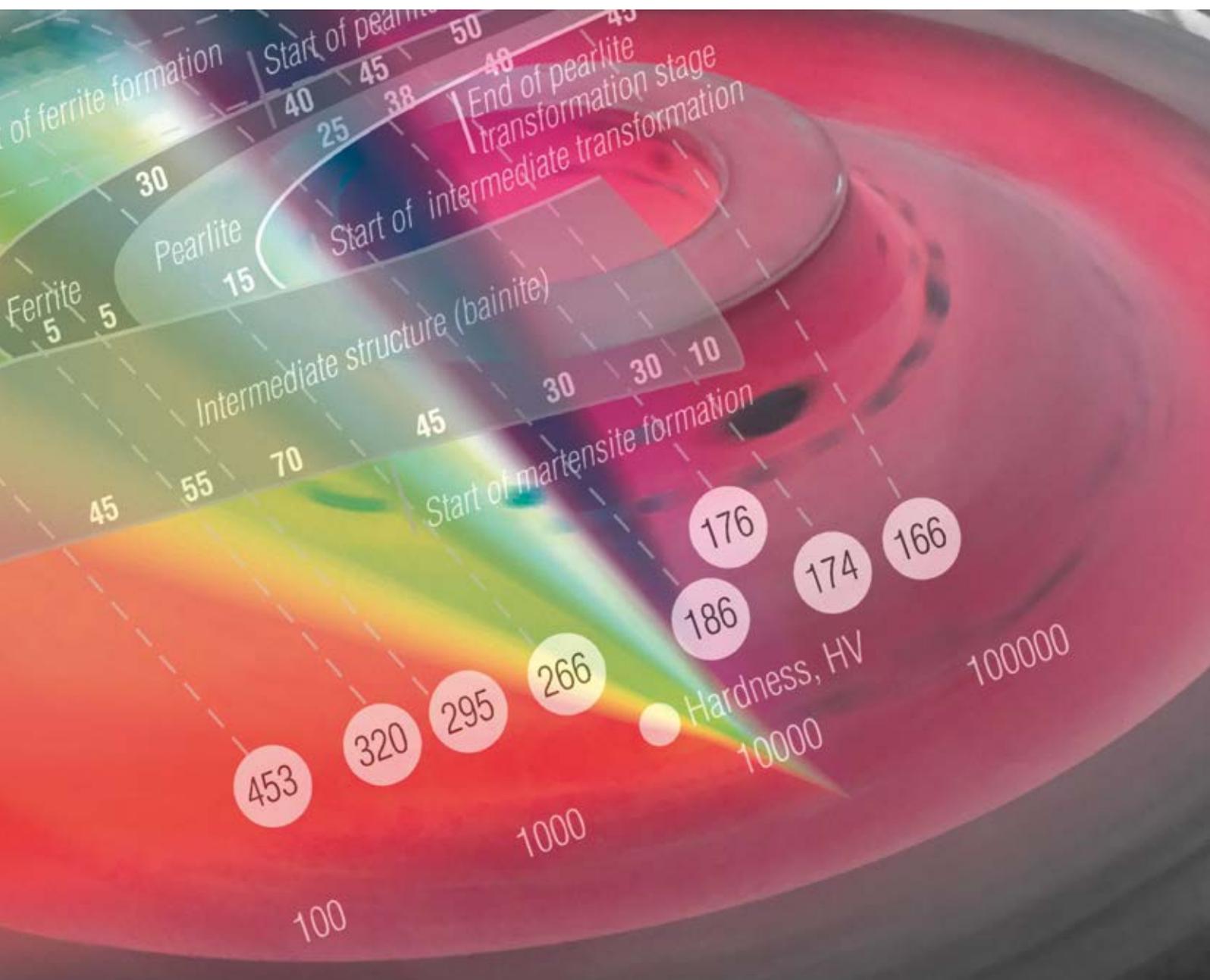
Continuous heat treatment lines are used to improve the mechanical properties of forgings. They ensure safe and long-term operation of the final product such as high-speed railway wheels or armatures of the oil and gas industry.

As the failure of a single product can already have disastrous consequences, reproducible process parameters within tight tolerances are crucially important. Tenova LOI Thermprocess guarantees

- highest available product quality and reproducibility achieved by most advanced production technology

- full understanding of the heat treatment processes and mathematical models, ensuring efficient equipment operation in everyday production
- high-quality, long lasting reliable equipment
- comprehensive visualization to allow a detailed documentation.

▼ The key to the definition of the microstructure of metals is the cooling of the material. This behavior is defined by TTT diagrams like the one shown below.



Heat Treatment Lines for High-Speed Railway Wheels

Tenova LOI heat treatment lines for high-speed railway wheels are combined with auxiliary transportation and quality assurance systems and are highly automated. Different heat treatment line configurations, furnace dimensions and numbers of Hardening Tables are possible, depending on the customer's needs.

The example below shows one furnace for austenitizing and two furnaces for tempering (with an overall length of approx. 100 m) combined with 8 Hardening Tables. It operates practically in-line with a forging press, which means that a typical output of 70 wheels per hour can be reached.

- ▼ Austenitizing/Tempering Furnaces and Hardening Tables operating in-line with a forging press. Different furnace dimensions and numbers of Hardening Tables are possible, depending on the customer's needs.



Compact Hardening Table

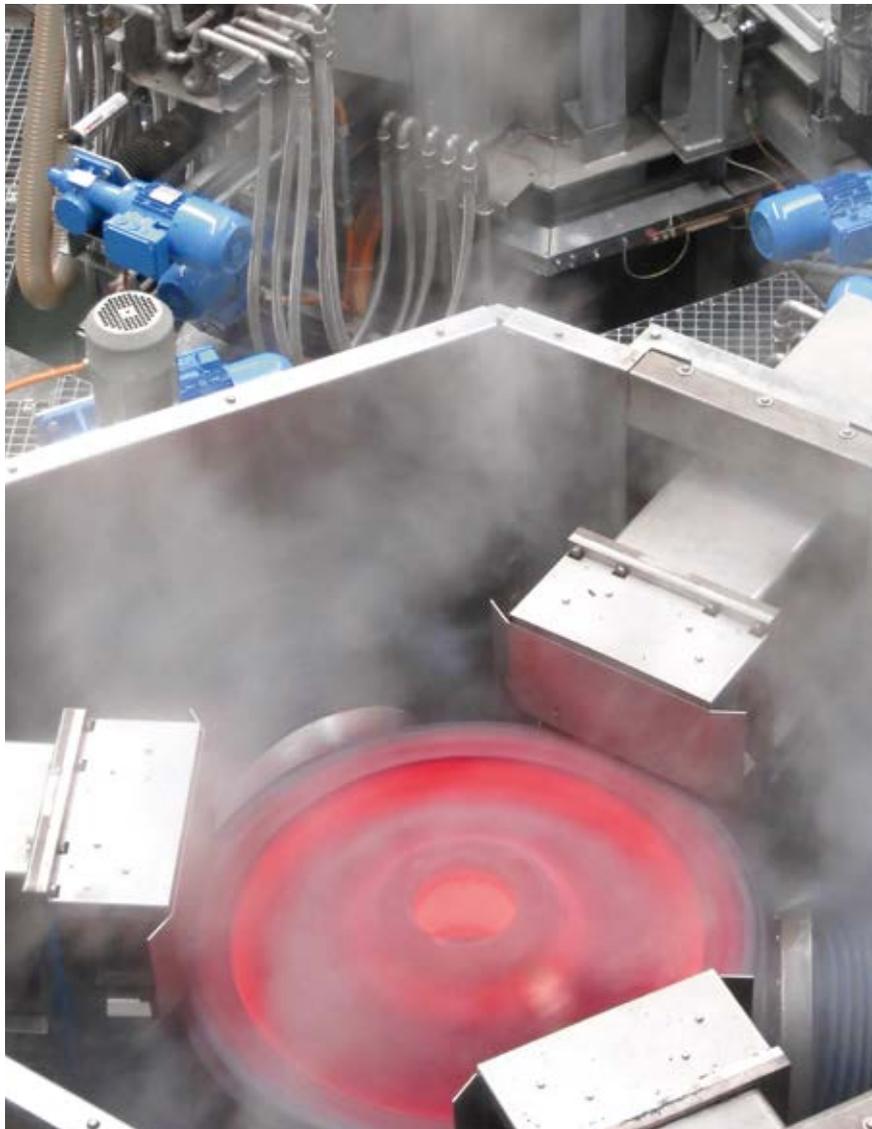


A highly complex quench process with a dedicated system of nozzles spraying water with different flows depending on position and time is essential for ensuring that the forged wheel has a long service life. ▲ ►

HARDENING TABLE

In order to reach a long service life, railway wheels must have a fine perlitic structure over a certain depth under the contact surface with the rails.

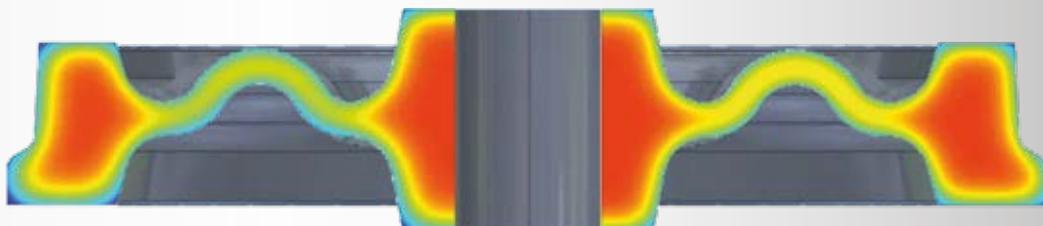
A highly complex quenching process is necessary with a dedicated system of nozzles spraying water onto the wheel with different flows depending on the position of the wheel and time. Compact Hardening Tables are extremely versatile and can be adapted to the required properties of a wide variety of wheels.



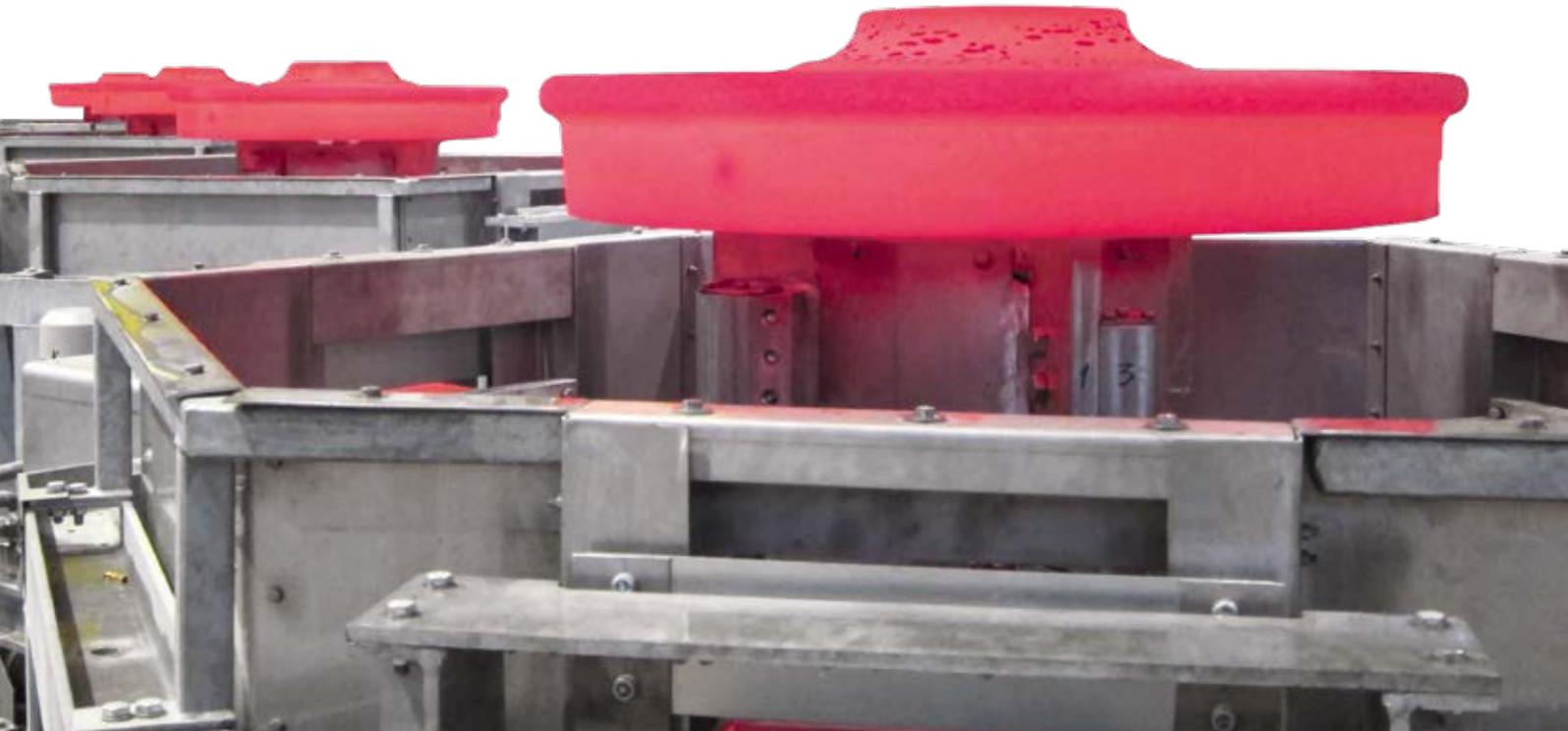
HARDENING PROCESS

In order to reach a long service life, railway wheels must have a fine perlitic structure over a certain depth under the

contact surface with the rails. A mathematical model adapts the hardening process to each individual type of wheel.



Handling Concepts



- ▲ Fully automated handling ensures high
- ◀ process stability and maximum use of production capacity.

Tenova LOI heat treatment lines for high-speed railway wheels are highly automated. During heat treatment the wheels are transported fully automatically by using a control system which comprises several PLCs (programmable logic

controllers) for transportation and processes. Comprehensive visualization and documentation possibilities – ranging from the display of the setpoints, via furnace charging to the actual wheel temperature – allow detailed

monitoring of the state of the process at any time. We guarantee extremely uniform heat treatment exceeding all international standards (e.g. EN 13262).

MQM (Mathematical Quench Model) for Railway Wheels and Heavy Plates

OUR DIGITAL SOLUTION

At many manual or semi-automatic plants, quenching is still dependent on the qualifications of employees. The development of "recipes" (plant parameters) for new products and the start-up phase have resulted to date in considerable waste of time and material. Individual theoretical models can offer considerable support. However, the conversion of process parameters into plant parameters is still a matter of "trial and error".

As a digital solution Tenova LOI Thermprocess has developed a Mathematical Quenching Model (MQM). The quenching parameters are calculated in a targeted way to ensure that the specifications required are immediately met. Plant parameters are developed 100 % on the computer system. For the conversion of the process parameters calculated by mathematical and physical processes into plant parameters, the model accesses a comprehensive database for the plant technology used. There are no manual interventions at any point

in the process. The plant can be operated on a fully automatic basis with the aid of the MQM intelligent quenching model.

3rd GENERATION MQM

- Calculation and simulation of recipes, microstructure and mechanical properties
- Simulation and optimization of the quenching process
- Dynamic parameter adaption making mechanical properties more homogeneous (such as hardness distribution, elongation) on the basis of calculated structure fractions (martensite, bainite and/or ferrite/pearlite)

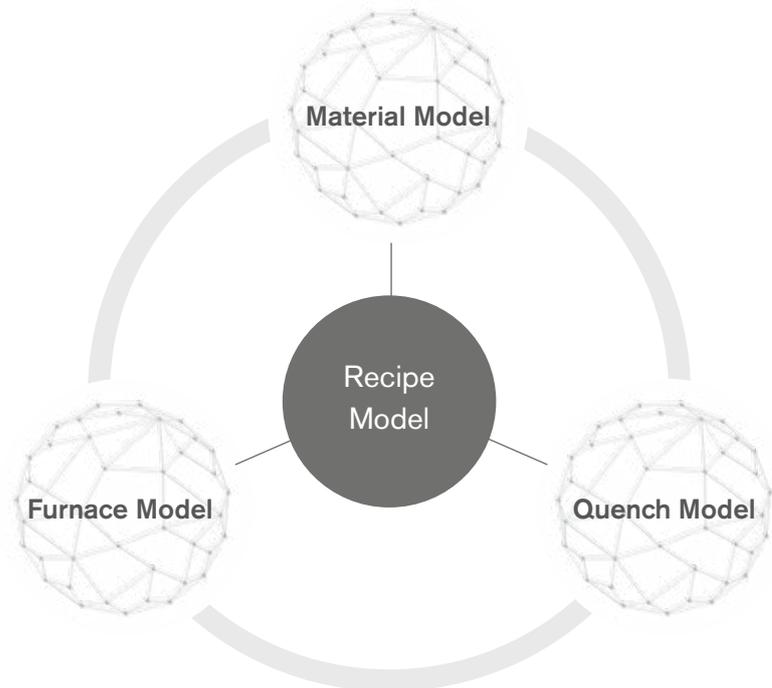
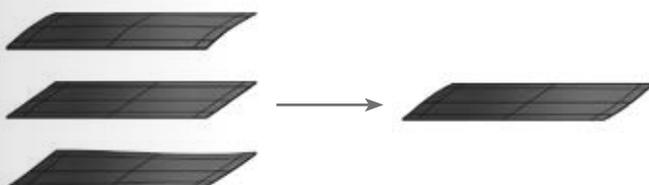
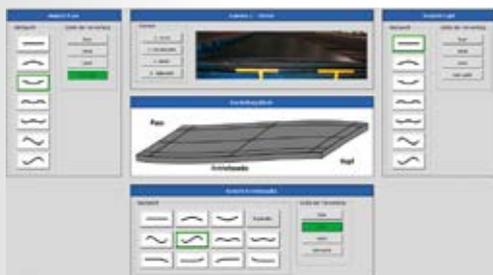
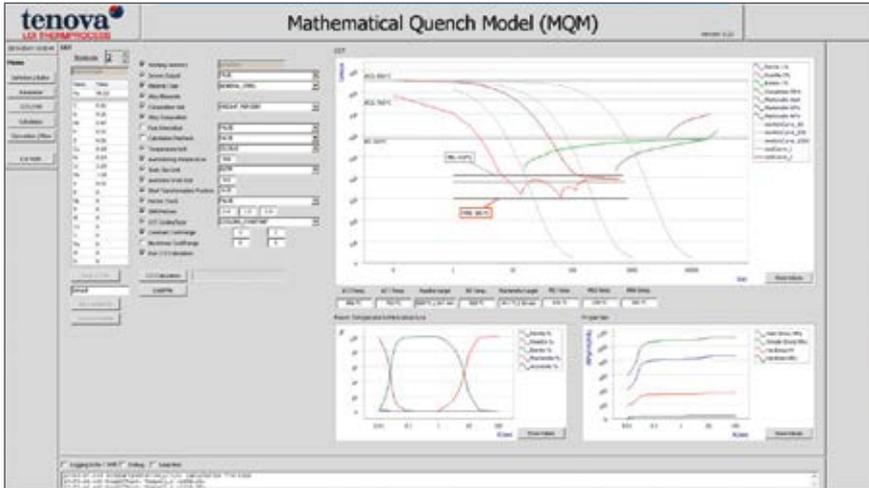


PLATE FLATNESS MODEL (PFM)



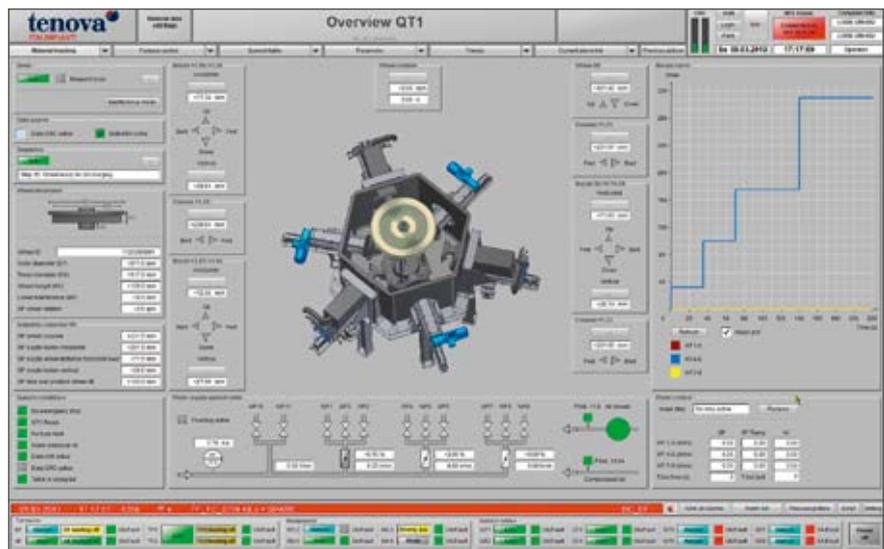
PFM to determine recipes by optical evaluation of the plate flatness

- Optical evaluation of the plate from different views
- Rating of deviation from flatness via intuitional dialog
- Embedding of camera systems
- Counteraction on the basis of the type and size of distortion
- PFM creates new recipe using
 - base setting
 - empirical value provided by self-learning algorithm (in progress).



Our MQM (Mathematical Quench Model) receives inputs including the properties to be met by the finished product and the quenching parameters calculated from the product geometry and the material composition. MQM initially calculates the cooling curve. Using the heat transfer properties of the nozzles at different pressures and flow rates the model then calculates the ideal settings for the individual nozzles with a view to achieving the calculated temperature plot.

- ▶ Mathematical Quenching Model (MQM) showing TTT Diagram and resulting mechanical properties.
- ▶ Human Machine Interface (HMI) showing recipes created by MQM.



QUENCH RECIPE COMPUTER (QRC)

QRC - Recipe database for automatic hardening

- Direct link to process control
- Recipe administration
- Heat treatment history
- Curves
- Flatness model
- Server/client
- Different data bases
 - Oracle[®]
 - Microsoft[®] SQL Server
 - Maria DB

MATHEMATICAL FURNACE MODEL (MFM)

MFM - Online model with process link for furnace control

- Determination of the heating process and the control of the heating system
- Determination of the optimum temperatures in the furnace sections depending on speed settings
- Open-loop temperature control to allow the ideal temperature to be reached faster and with greater fuel efficiency

Convenient Audit Management

AMS 2750 E/CQI-9 GOES MOBILE

Heat treatment plants for automobile or aircraft components must be continuously audited according to the applicable standards. These standards are mostly related to instrumentation that demonstrates system accuracy and temperature uniformity. In order to ensure continuous AMS 2750 E/CQI-9 auditing holistically and without major bureaucracy, Tenova LOI Thermprocess has developed an all-in-one software solution. This allows the audit procedure to be completed directly and paperlessly at the plant using a mobile panel or tablet. Thanks to the instrumentation provided by Tenova LOI Thermprocess, the audit can be carried out and reported by only one auditor without additional personnel during production.

OUR HIGHLIGHTS... YOUR ADVANTAGES:

- Auditing of SAT check possible on regular working days during production
- Paperless AMS 2750 E/CQI-9 documentation



- Convenient mobile touch panel or tablet for on site entry of measurement and verification data
- Convenient PC-based audit management and reporting
- Easy scheduling of audit procedures
- Plant-specific parameters
- Convenient management of thermocouple data (e.g. type, supplier, interpolation values...)
- Convenient management of measuring instrument data (e.g. type, supplier, calibration values...)
- SAT report (System Accuracy Test)
- TUS analysis (Temperature Uniformity Survey) and report
- Direct application of logger result data to TUS procedure

Tenova LOI Thermprocess supplies intensive consulting and operation support for the implementation and execution of customer audit procedures.

▼ On-site data input with Mobile Touch Pad.



SERVICE AND SPARE PARTS



Services backed by the expertise developed by Tenova LOI Thermprocess are available to our customers at all times and places. The world-wide presence of Tenova offers our customers direct access to our maintenance and modernization specialists.



SERVICES

We provide our customers with tailor-made maintenance programs, regular technological updates, operation assessment and personnel training.

SPARE PARTS

The right spare parts can be supplied within the shortest time (e.g. 24 h). On request, a web-based catalog for new and old equipment can be created, which facilitates the identification of spare parts and simplifies procurement considerably.

MAINTENANCE AND REPAIR

Our experts are available for maintenance work on process control systems including mathematical models and on systems including mechanical and electrical elements, refractory linings, burners, heating/cooling systems, controllers and automation devices.

MODEM AND TELEPHONE SERVICE

Control systems and connected plants can also be inspected online by remote diagnosis.

RETROFIT AND MODERNIZATION

Our specialized service solutions allow customers to operate at the highest possible productivity and efficiency levels at the same time as focusing on safety and sustainable development.

CONSULTANCY

Our process engineers and our commissioning and control systems specialists are available to provide advice to customers either on-site or via remote diagnosis.



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