HARDENING AND TEMPERING STEEL STRIP

Hardened and tempered steel strip is used in a broad spectrum of applications, ranging from everyday items to high-performance tools and safety components. The product requirements are complex, encompassing special microstructure, highest possible homogeneity, precise tensile strength tolerances, extreme flatness and geometry characteristics as well as special surface properties.

TECHNOLOGY

Continuous in-line hardening and tempering of unalloyed and low-alloy carbon steel as well as martensitic Cr steel strip using hydrogen quench systems or molten metal quench technology is a process that has won worldwide acceptance.

In a continuous steel strip hardening and tempering line, unalloyed and low alloy carbon steel strips can be transformed with the following technologies:

- Martensite (martempering) with hardening, leveling and tempering to produce material for hand saws, band saws, head saws, circular saws, springs, flapper valves, tools, etc.

- Bainite (austempering) with isothermal transformation in the austempering duct and following furnace units, to produce material with good bending and punching qualities for products such as blanking knives, cutting and minting lines, precision components for the automotive industry, etc.

- Pearlite (patenting) with isothermal transformation in the patenting section, to produce material for safety belt springs for the automotive industry, cable drum springs, high-strength spiral springs, etc.

Stainless steel strip (chromium martensite) is martempered to produce material for leaf springs for compressors and cooling units, tools, cutlery, etc.
OTHER APPLICATIONS INCLUDE:

- Annealing cycles for multi-phase steels with quenching gradients of >200 K/s:mm and subsequent transformation to produce DP, CP, TRIP and Q+P steels for automotive applications.

- Normalizing anneals with limited cooling gradients < 25 K/s to produce “earring-free” material (such as battery sleeve strip).

- Recrystallization anneals of material such as LC steels with quenching and subsequent overaging.

Well-designed and flexible facility concepts allow several technologies to be combined in a single facility. This ensures highly-economical facility utilization.

FACILITY DESIGN WITH HICON/H$_2$Q$^\text{®}$ HYDROGEN QUENCHING TECHNOLOGY

Unalloyed and low alloy carbon steel strips require very high quenching speeds, which used to only be possible in a molten metal quench.

The experience gained from the many molten metal quenches we have supplied which incorporate innovative 2-stage hardening, has been seamlessly transferred to gas quench technology during several years’ development work. The new process has been successfully launched as HICON/H$_2$Q$^\text{®}$ Technology (= High Convection / H$_2$ Hydrogen Quench).

Schematic diagram of a martensite bright H&T line with HICON/H$_2$Q$^\text{®}$ quenching technology.

1. tension stand
2. inlet seal with integrated safety system
3. austenitizing furnace
4. HICON/H$_2$Q$^\text{®}$ hydrogen quenching unit
5. outlet seal with integrated safety system
6. martensite cooler
7. leveling furnace
8. HICON$^\text{®}$ tempering furnace
9. HICON$^\text{®}$ process atmosphere jet cooler
This technology has already given many facility operators numerous new opportunities, allowing them to process their existing product range with improved surface quality, expand their range with additional sophisticated materials, and to supply new industries.

The lead/bismuth quenchant alloy is completely eliminated.

This makes it possible to offer a completely new premium product - “lead-free hardened and tempered steel strip” - for the food industry, automotive industry, etc.

Environmental guidelines and customers with special requirements of even lower lead residue levels are no longer an issue.

Hardening and tempering with hydrogen carries lower operating costs than the molten metal method, since far fewer wear parts are necessary.

The hydrogen is blown symmetrically onto the strip from above and below by a gas-tight high-capacity circulation blower. Special adjustable nozzles with infinitely variable covers ensure an extremely high and uniform cooling rate allowing the temperature of the strip to be rapidly reduced and controlled at the desired level.

The gas is cooled in a heat exchanger and recirculated, requiring very little fresh gas.

The inlet and outlet seals are designed as safety seals and integrated into the higher level safety system.

Process steps such as grinding or polishing, which are currently necessary to remove lead residue, become unneeded and the nice cold-rolled surface finish is preserved. If a ground or polished surface finish is desired, it can be produced with significantly less effort.

Strip can move through the quench either horizontally or vertically, without needing to be deflected. The chance of a strip break approaches zero and facility uptime increases.

The time it takes a HICON/H$_2$O$^\circ$ quench to change process parameters is many times faster than a sluggish molten-metal quench. This minimizes the scrap length following the weld seam, which in turn increases yield.

Special processes in the quenching system and supplementary equipment also permit isothermal transformations such as austempering and patenting.

Another technological advantage over the molten-metal quench is the significantly shorter distance from the exit of the hardening furnace through the jet system (first cooling stage), and on to the martensite transformation section (second cooling stage).

This second cooling stage can be carried out with the revolutionary FLEXFLAT$^\circ$ system. This special leveling system uses a cooling plate with an infinitely variable shape to directly influence strip geometry during martensite transformation. Perfect flatness can be easily reproduced.

The quick reaction time of the HICON/H$_2$O$^\circ$ quench and the use of the shapeable cooling plate technology (FLEXFLAT$^\circ$ system) make a combination with a flatness measuring system possible. This enables quick modifications to the flatness parameters and soon, automatic optimization of strip flatness.

The combination of the two technologies sets new standards in terms of achievable surface quality, flatness and productivity.
Hardening and tempering steel strip

View of a HICON/H₂Q® quench in a horizontal bright H&T line for martempering unalloyed and low alloy carbon steel strip as well as martensitic chromium steels.

View of a martensite cooling section including a FLEXFLAT™ leveling system for martempering unalloyed and low alloy carbon steel strip.

Horizontal bright hardening and tempering line with HICON/H₂Q® quench for martempering unalloyed and low alloy carbon steel strip as well as martensitic chromium steels.
Comparison of productivity and operating costs of HICON/H₂Q® technology vs. molten metal quench technology at a mid-sized facility (type BVHg 65/25/1100 M).

<table>
<thead>
<tr>
<th>Type of quenching technology</th>
<th>Molten Metal Quenching (MMQ)</th>
<th>HICON/H₂Q® Hydrogen Quenching</th>
<th>ADVANTAGES / DISADVANTAGES HICON/H₂Q® vs MMQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comparision of productivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average operating hours per year [h/a]</td>
<td>7,000</td>
<td>7,500</td>
<td>500</td>
</tr>
<tr>
<td>Average throughput capacity [kg/h]</td>
<td>800</td>
<td>800</td>
<td></td>
</tr>
<tr>
<td>Average yield factor [%]</td>
<td>90.4</td>
<td>96.1</td>
<td>based on average coil OD of 1500 mm (59&quot;)</td>
</tr>
<tr>
<td>Average net output per year [t/a]</td>
<td>5,060</td>
<td>5,769</td>
<td>709</td>
</tr>
<tr>
<td>Comparision of operating costs (1st year)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of consumables per year [EUR/a] per ton [EUR/t]</td>
<td>268,278 53.0</td>
<td>121,733 21.1</td>
<td>-146,546 €</td>
</tr>
<tr>
<td>Cost of media (NG, H₂, N₂, HN-mix, electric) per year [EUR/a] per ton [EUR/t]</td>
<td>258,557.7 51.1</td>
<td>339,476.3 58.9</td>
<td>80,919 €</td>
</tr>
</tbody>
</table>

-65,627 €
MODERNIZATION OF EXISTING FACILITIES

The HICON/H₂Q® hydrogen quench can also be integrated into existing facilities to replace a molten metal quench. This technology can also be integrated into non-EBNER facilities, with careful consideration of each individual case.

Upgrading to hydrogen quenching technology involves the following modifications:

- new inlet seal with integrated safety systems
- various new parts for the austenitizing furnace
- new gas-tight HICON/H₂Q® quench unit
- new gas-tight high-performance cooling blower with heat exchanger
- new outlet seal with integrated safety systems
- new valve stand for hydrogen/nitrogen/cooling water/emergency water supply distribution
- new pressure control system for hydrogen/nitrogen
- associated electrical control center with safety functions

While modernization this part of the facility, other optimizations could also be considered. Some options include:

- new roller support system for the austenitizing furnace to improve strip surface results.
- new modular martempering section with a cooling plate with an infinitely variable shape (FLEXFLAT® system) for improved flatness.
- new directly electrically heated leveling furnace to improve temperature uniformity and flatness, as well as saving space, since the hot air heating duct from the austenitizing furnace to the leveling furnace is eliminated.
- new roller support system for the tempering furnace to improve strip surface results and flatness.
- new flatness measuring system implemented together with the flexible cooling plate (FLEXFLAT® system) for improved throughput and in-line quality assurance.

Upgrade of the oil quench of an existing facility to HICON/H₂Q® quenching technology for martempering unalloyed and low alloyed carbon steel strip.

SUMMARY

An extensive package of facility concepts and modernization options are available in order to help our customers produce top quality hardened and tempered strip steel.

Modular facility design allows several technologies to be combined in a single facility, covering a broad spectrum of products.