Technologically advanced wire rod plant for special steel

Success in the wire rod market can only be achieved by combining high plant productivity, efficiency and flexibility, with superior quality finished products. These requirements, in addition to Danieli's latest research efforts and industrial activities, point the way to a circular economy model of environmental sustainability and true green steel production. Tangible results have been achieved at the ABS QWR 4.0 project, which first rolled billet on November 27, 2020, and is now considered a word-leading, benchmark producer for wire rod suppliers.

With a 190m Euro investment, the plant in Cargnacco, Udine, Italy, produces 500,000tpa of special steel and automotive application wire rod, with diameters from 5.0 to 25mm and at finishing speeds of 430km/h. The final product is equally shared between the Italian and European markets. A rolling mill speed record of 132.4m/s for 5.5mm diameter wire rod, was set on September 17, 2021, and was achieved due to equipment reliability and process resilience. High plant productivity and flexibility are guaranteed up to 130tph capacity, for 170 to 230mm round blooms and 150 180mm square billets.

The feedstock is supplied by ABS in Italy, or Sisak in Croatia.

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ABS QUALITY WIRE ROD (QWR) PLANT LAYOUT

The layout of the whole plant was developed following the principle by which the entire rolling mill production area is intended – more as a mechanical workshop, like those used for numerical control machines, rather than a conventional rolling mill. The building structure is a clear expression of this concept, having a low roof height with a short-span shed. Individual machines are used only when needed, optimizing space, process flexibility and equipment readiness (*Figure 1*). The workshop area is located behind shutter doors and all installed equipment can be automatically moved there to be prepared, or changed due to wear. It takes only eight minutes, and generally not more than 15, to change the entire mill. A further three minutes are required between the end of one billet end and the start of a new section.

This integrated approach embraces the design of long-life, easily refurbished equipment. Resources and energy consumption are optimized in favor of renewable sources. The 10,000t of Ecogravel® (recycled EAF slag) used for paving, is a virtuous example of environmental care but also a profitable investment.

KEY TECHNOLOGICAL EQUIPMENT

Top-class levels of productivity, reliability and performance efficiency are achieved by the smooth flow of materials across the equipment. The Danieli Centro Combustion walking beam furnace is effectively scale-free, with only

Fig 1 **Plant layout**

0.32% scale formation (*Figure 2*). It has an energy saving design that minimizes oxidation, through a combination of a highly accurate combustion control in sub-stoichiometric conditions and a tightly sealed furnace chamber. This patent-pending furnace chamber has been separated into several 'micro-chambers' using walls, noses and diaphragms to control individual volumes with a different air-gas ratio. By controlling such parameters it is possible to actively intervene on oxidation kinetics to inhibit scale formation.

Enhanced combustion control was developed using higher pressure drop flow transmitters for gas, and flow

Fig 2 **Furnace**

straighteners for air. The reducing atmosphere generated in the hottest zones is compensated by post-combustion air injected into the furnace using nozzles arranged on the roof and side walls. A laser spectrometer continuously detects the oxygen percentage in the recuperative zone before waste gases leave the furnace. This parameter is part of a safety control loop that acts on post-combustion air, to achieve the desired oxygen level at the exhaust.

All stands are fully electrified to comply with the 'green mill' concept. Replacing hydraulic controls with electrical ones ensures multiple advantages, from eliminating oil and oil leaks to cutting off the central hydraulic unit's electrical consumption, as well as savings in civil works and erection time.

3MW induction heating technology from Danieli Automation is installed between the free roughing stands and the continuous mill. It represents the most environmentally friendly solution for reheating steel and reducing scale formation. Its environmental advantages include reduced consumption when efficiently transferring energy to the material and no gas emissions. The required electrical energy can be sourced from renewable green energy generation.

The high-speed shear avoids manual operation of head and tail trimming and so removes the need for a dedicated workforce. It can trim rolled material with high accuracy and repeatability at speeds beyond 430Km/h, synchronizing the laying head to ensure proper coil laying on the cooling conveyor. One additional benefit from this equipment is that it increases the safety of operators in the area.

The Easy Drawing Continuous (EDC) system can be applied as an alternative to traditional cooling fans to achieve in-line patenting of high carbon grades using boiling water. For maximum flexibility, the system has been designed to shift sideways from online to offline, to treat suitable steel grades and dimensions through a process water tank. Compared with other methods, the EDC process provides a sorbitic microstructure, in terms of uniformity. It controls grain growth and scale formation, enhancing cold drawability.

The most recent iteration of automatic, motorized smart guides is installed on both the stands and the wire rod blocks. It receives real-time feedback from each billet, adjusting the guide force acting on the bars, monitoring the bearing status and the position of the rollers. Several pyrometers and thermal imaging cameras are placed along the entire line. These tools continuously monitor and record material temperature, making fine adjustments automatically to the reheating furnace, on-line induction heating and in-line water box treatment status.

Hi-Section eddy-current mass flow meters and Hi-Profile laser-based measurement instrumentation solutions continuously control material dimensions. They offer

Fig 3 **Warehouse**

live feedback to automatically regulate the workflow, ensuring bar optimization in terms of size tolerance, cobble reduction and rolling guide wear. Special cameras installed between the stands check material tension for a looper-less mill layout.

PRODUCT TRACEABILITY AND QUALITY CONTROL

Danieli believes maintenance is paramount to ensure high plant availability and reliability. That is why all key equipment includes an ID tag with a barcode to identify device information, such as storage operations and remaining tons, or hours before refurbishmentis are required. Many devices, such as cartridges, cylinders and guides, are equipped with radio frequency ID tags.

A workshop management system supervises equipment preparation and organization, checking and providing continuous groove and guide status updates. An advanced, integrated laboratory located next to the coil finishing facilities is used for instant feedback on the final mechanical and metallurgical properties of the rolled product. It allows final product certification before shipping, with real-time product traceability, closing the circle on a fundamental requirement for a modern plant by tracking the product from melting to customer delivery.

Coils are stored in a fully automated warehouse designed to safeguard the surface quality of the products, while ensuring a high degree of process flexibility with short lead times on orders (*Figure 3*). The warehouse can hold more than 11,000t of wire rod coils. After being automatically tagged and stored, the material can be organized in relation to incoming orders and production requirements.

A new generation pulpit with 3Q technologies is fundamental to supporting advanced technologies such as artificial intelligence (AI), augmented and mixed reality, empowering operators' perception and helping them to both identify and predict anomalous process behaviors. An additional advantage of this pulpit is that all mill functions and process parameters are supervised by just two operators: one for the mill process itself and the other for on-line heat treatments. These operators monitor the main plant KPIs and process parameters.

THE DANIELI ORIGINAL PROCESS SOLUTION

Mill efficiency is directly related to the ability to manage the process. That is why the rolling line is controlled via an innovative monitoring system with more than 2,000 data acquisition sensors and over 15,000 continuously recorded parameters. Sensors provide continuous real-time process and plant data, whether directly measuring physical values, or applying process models. Digitalization helps operators avoid mistakes, increasing workplace safety and, as an added benefit, improving product quality.

In-line heat treatments are a critical part of the process, where properly controlled thermo-mechanical rolling ensures that the metallurgical and mechanical properties of the wire rod meet expectations for strength, toughness and ductility. The use of several controlled cooling stages along the mill and roller conveyor makes grain refinement a most-effective way to deal with these quality demands without increasing alloying elements. The thermo-

Fig 4 **Different process routes can be selected for different diameters**

mechanical rolling process is characterized by deformation in the non-recrystallization region of austenite, usually in the range from 750 to 850°C, where it may be targeted at a specific area of reduction necessary to obtain the desired grain refinement and microstructure modification.

For medium-carbon, micro-alloyed steels for cold forming, the Prior-Austenite Grain Size (PAGS) achieved by means of thermomechanically controlled processes, avoids hardness hot spots that would have required annealing treatments before cold forming. Improvements in cold drawability can be achieved by controlling the scale layer, which is thinner and uniformly distributed. The mechanical strength of high-carbon steel is related to interlamellar pearlite spacing and can be enhanced through control of continuous cooling on the roller conveyor. Consequently, variation in mechanical properties along the coil and ring can be reduced. Benefits can also be achieved for bearing grades, where deformation at a non-recrystallization region of austenite may permit enhanced carbide distribution.

QUALITY PERFORMANCE FROM THE START

The Quality Wire Rod (QWR) approach allows the operator to supervise and control all changes and mill preparation activities, with limited or no manual intervention. Robotics are used extensively, alongside on-line instruments and sensors, for quality and product checks. There is a closed-loop control and multi-route layout for different steel grades and product dimensions. The setup for heat treatment is an example of this, where the process control system automatically loads the proper setup table from the database and sends it to the equipment controller, without manual intervention.

The equipment has been changed from a traditional maintenance management and condition-monitoring system, to real-time support and diagnostics. The process has been developed so that models and monitoring are widely deployed to manage all parameters along the mill and optimizing the final product quality and mill performance. Predictability is now possible, to anticipate a phenomenon before it manifests. The implementation of the 'Danieli Intelligent Plant' philosophy is a revolution for plant management and post-processing analysis.

MAXIMUM PRODUCTION FLEXIBILITY

To maximize product size changing, Danieli custom-designed three routes for specific dimensions and the more than 1,000 steel grades in the ABS portfolio. Three distinct rolling lines have been installed to optimize the process, machine utilization and availability (*Figure 4*). A straight roll pass-line has been adopted for 5.0 to 11.5mm final diameters, with a second route allowing a bypass of the eight-pass, semi multi-drive fast finishing block, for rod diameters of 12.0 to 23.0mm. The third line is used for final sizes ranging from 23.5 to 25mm and permits bypassing the six-pass, multi-drive pre-finishing block, guiding the feeder material into the sizing twin module block, operated by a multi-drive system.

Respecting the motto "any size, any grade, at any time", this concept optimizes process flexibility in terms of steel grades to be produced, rolling strategies to be applied,

Fig 5 **The plant can be controlled from a single pulpit**

and quick size changes, including for small-scale orders. To further confirm the flexibility of the plant, it is also possible to adopt different routes on the roller conveyor to cool down the material, such as air cooling, slow cooling under hoods, fast cooling with fans, or by the EDC method. It is also possible to collect the material in two different locations, using the hot or cold pit.

APPLICATION OF QWR SPECIAL STEEL PRODUCTS

Achieving a flexible configuration, with rapid setup and changes, eliminating trial billets and ensuring the first coil produced is quality compliant for both metallurgy and dimensions, cannot be done by overwhelming the operators, nor by stressing the equipment. In recent years, the production of quality wire rod grades has boosted research into new and more efficient technologies. This is the result of the increasing demand for high value-added wire rod, to be used in applications such as cold heading wire for bolts, high-strength cables, galvanized wire for suspension bridges and roadways, railroad switches, spring wire, reinforcement strands, rods for reinforcing pre-stressed concrete structures, bearing steel, piano wire and welding wire. The large number of steel producers and continuously progressing technology makes the long product market increasingly competitive and selective. The QWR approach is to adopt automation with a human-centric approach, actively contributing to the understanding of the operators managing the plant, while the surrounding technologies guide them to easier target identification, realizing immediate product quality.

DANIELI INTELLIGENT PLANT: AN INNOVATIVE APPROACH TO PLANT AND PROCESS SUPERVISION

By exploiting IIoT (Industrial Internet of Things) platforms and advanced technologies, an entire plant can be controlled from a single pulpit which no longer needs to be in the production area (*Figure 5*), just as at ABS's quality wire rod mill plant. The system proactively interacts with the operator, focusing their attention on what is needed at that precise moment. This is for both the control on the human-machine interfacepage, or Operator Assisant, that has replaced obsolete push bottons, and for the LED wall displays with images of the plant.

Events, or points of interest, are identified and stored in the system, allowing all anomalies to be tracked. Specific situations can be logged by triggering manually through voice control. Points of Interest are then used for ex-post analysis, identifying possible malfunctions and quality issues, allowing for the discovery of trends and improvements. The resulting numeric, visual, audio and other data, build a data pool to support AI models, which automatically improve the performance of the plant.

'ZERO MAN ON THE FLOOR' CONCEPT

This is the only wire rod mill in the world where mill management is remotely controlled, based on the 'zero man on the floor' approach during production and size changes. All mill activities are performed automatically thanks to robust process controls, ensuring there are no operators on the field. Benefits include improved safety and working conditions, with only 14 operators required for each shift.

This plant makes 35 automatic changes on rolling stands, blocks, water boxes, high-speed shears, Hi-Profile devices, loop-laying head and Hi-Profile guide channels. Everything that is required to change a section is fully automated. Advanced automation plays a fundamental role throughout the plant, especially with the 'first coil in quality' concept, i.e., with no losses. This is possible due to on-line sensors and measuring instruments, working in closed-loop control and managing metallurgical, dimensional, and quality aspects.

LATEST DANIELI SPECIAL STEEL WIRE ROD INSTALLATIONS

ABS QWR 4.0 is the latest exclusive wire rod mill reference for Danieli and features the most advanced technical solutions. It defines the rolling mill of the future in terms of technological innovation, digitalization, safety, and having a green steel approach. **MS**

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