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The new batch annealing plant at Bilstein comprises twelve bases; any hood fits on any free base

The world's first batch annealing plant with fully automatic crane operation ensures optimal use of energy

The world's most modern, highest capacity and at the same time most energy efficient batch annealing plant saves 1.5 GWh of energy every year.

Bilstein GmbH & Co. KG (hereinafter referred to as Bilstein), the parent company of the Bilstein Group, has evolved into a worldwide leading supplier of cold rolled flat steel products. The production is based on most advanced, computerized manufacturing facilities. Diligently coordinated process steps ensure the production of cold strip products of top quality. Bilstein can guarantee that all steps of the manufacturing chain – from the receipt of the material down to quality control – are perfectly harmonized. A zero defect strategy calls for perfect and reliable process and quality control in areas where the degree of automation is very high. This target is achieved by ensuring uninterrupted monitoring and documentation of all defined process parameters.

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As part of a project aimed at increasing the capacity of its cold rolling mill in Hagen-Hohenlimburg, Bilstein has installed a new batch annealing plant. During the design phase of the plant, the key focal areas were the achievement of excellent annealing results, efficient energy use and low operating costs. Heated-up coils still contain approximately 70 percent of the energy input required for the heating to annealing temperatures. This potential was to be exploited. No energy was to be input for cooling the coils after the annealing treatment in order to avoid that unused heating energy is released to the atmosphere. The idea was to exploit the energy contained in the coils in the best possible way.

Furthermore, the entire annealing process was to be made highly reproducible by introducing automated processes a far as possible. These requirements eventually resulted in an automatic crane concept enabling the coils, hoods and intermediate convectors to be transported with a constant high level of precision. This presented the manufacturers of both the annealing plant and the crane equipment with a great challenge because never before had such a solution – automatic crane operations in a batch annealing plant – been implemented anywhere in the world.

Another objective was to design an annealing plant capable of meeting the future requirements for many years to come. As early as at this initial stage, the plant was designed for the future option to heat treat wide-strip coils with a specific ring weight of 23 kg/mm, outside coil diameters of up to 2,030 mm, strip widths of up to 1,350 mm and a maximum coil weight of 30 t. The maximum annealing temperature of 850°C would also make it suitable for new material grades.

Fully automatic handling of coils, hoods and convectors (all pictures courtesy of LOI Thermprocess GmbH)

A fundamentally new approach

Bilstein involved LOI in the planning at a very early stage. LOI had already implemented several other successful projects at Bilstein. Therefore, the employees were familiar with the conditions at the rolling mill. For the issue of heat recovery, several alternatives were discussed. Measures like an enhanced insulation of the heating hoods or the recovery of waste heat from the flue gas would have provided only insignificant savings. Additionally, Bilstein deliberately decided against a solution based on the pairwise operation of two adjacent bases as this would have significantly restricted operating flexibility. The target was to implement a flexible mode allowing any heating or cooling hood to be used at any time and on any base.

The intensive discussions with LOI eventually brought about the idea that it would not be appropriate to consider the energy balance of the annealing shop separately, but to take the entire works into account. The fundamentally new aspect of this approach was that the excess energy would be decoupled as part of a comprehensive energy management system and made available to other energy using units within the works either as electricity or heat.

It was decided to use the Organic Rankine Cycle (ORC) process to convert the heat into electric power. When this decision was made, the process had already proven its efficiency in first prototype applications, however, not in batch annealing plants. This presented those involved in this project with a new challenge. For the project at Bilstein, annealing furnaces featuring the LOI-developed bypass cooling equipment were chosen. In these furnaces, the heat is extracted from the coils and transferred to a thermal oil by means of hydrogen. The oil, which attains temperatures of up to 270°C, is an ideal medium for evaporating ethanol in an ORC plant.

Additionally, warm water is decoupled at different stages of the process and appropriately used for different purposes within the works. Thus, Bilstein pioneered the use of excess heat at different – partly fairly low – energy levels. Comprehensive calculations showed that this concept would be sustainable and, once implemented, would not result in any loss of capacity.

Kranbau Köthen GmbH conceived the solutions for the fully automatic handling of coils, hoods and convectors, which due to the use of hydrogen had to comply with the high safety standards required for the transport of loads with a higher risk potential. LOI

The multi-media coupling automatically establishes all connections for the gas supply (NG, H_2, O_2) and the electrical signals

and Kranbau Köthen GmbH received the order in 2011.

Currently, the new plant anneals hot and cold-rolled medium-wide strip coils weighing up to 15.4 t. The outside coil diameters range between 1,000 and 2,000 mm. The coils are 150 to 650 mm thick. The natural-gas-heated LOI batch annealing facility comprises twelve bases with six heating and six jet cooling hoods.

Electricity and heat for the works

The annealing plant can handle stack heights of up to 5,600 mm. Twelve special burners are used at each heating hood. The annealing bases operate with a 100-percent hydrogen atmosphere as inert gas. They are equipped with a bypass cooling system. The average hourly annealing rate of the bases at a delta T of 30 K amounts to 2.82 t.

In order to reduce the fuel consumption in the heating hoods, LOI preheats the combustion air to about 600 to 650°C by means of recuperators. In conventional plants, the combustion air temperature is usually between 300 and 400°C. The recuperator surface is about three times larger than the previously usual size.

Another key feature of the new annealing plant is the automatically controlled hydrogen purging programme, which optimizes the hydrogen flow in order to always obtain a uniformly clean strip even if there are varying stack heights.

The energy recovery during cooling takes place in two steps. First, hydrogen between 700 and 350°C hot is extracted from the hood. In a special bypass cooler (gas/thermal oil), the hydrogen heats the thermal oil to a maximum temperature of 270°C. The heated thermal oil is guided through a ring line. In the downstream ORC process, the ethanol evaporates. A reciprocating piston expander generates electricity. Bilstein uses these piston-type machines – modified truck engines with a connected generator – instead of gas turbines because they operate highly efficiently over a broad operating range. Another reason is that the cooling water leaves the machine at a temperature of approximately 70°C. Therefore it can also be fed into the heating circuit.

If during the cooling process the gas temperature falls below 350°C, water is decoupled into a second bypass cooler (gas/water) and fed into a secondary circuit at a temperature of about 80°C. This secondary circuit is connected to a system of ring pipes which supplies the high-bay racks and the air curtains at the doors to the bays as well as the tanks holding the emulsion, which must be kept at a constant temperature of about 50°C.

This QR code links to a YouTube video (38 seconds) showing the crane in operation at Bilstein

Automatic crane operation

The annealing plant is the first in the world to operate with automated crane movements. Only one person is needed to monitor the crane operations from the control room. There is no personnel within the operating range of the crane. The two-beam overhead travelling crane built by Kranbau Köthen GmbH transports the coils, convectors as well as the heating and cooling hoods. Equipped with two lifting hoists with payloads of 50 and 28 t respectively, the crane spans 32.8 m. This payload allows it to lift coils of up to 1,350 mm width in the future.

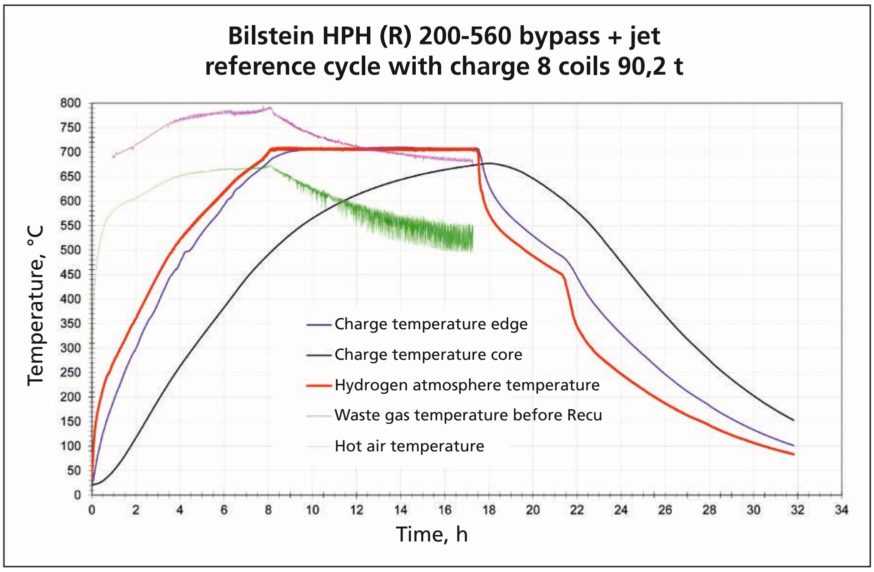
Redundant, two-channel absolute position encoders determine the positions of the crane, the trolley and the lifting gear. Displacement transducers measuring the crane travel are arranged on both sides in order to immediately recognize and correct any misalignment of the crane. The high precision of the transducers allows them to determine the position of the gripper with a tolerance below +/- 15 mm, taking into account all influences from the crane travelling movement, the trolley and the lifting hoist.

The swing damper is a camera-guided system. The camera focuses on a hairline cross on the gripper. The crane control system takes into account the different centres of gravity of the loads. Coils are very heavy and their centre of gravity is halfway down. Heating hoods, however, are much lighter with their centre of gravity much lower.

LOI took account of the automated crane operation by modifying the design of the bases to the effect that they are hydrogen leak-proof under all circumstances.

The automatic gripping tongs feature different tools allowing them to lift equally and securely the coils, the convectors and the different types of hoods. As the system works without any intervention by man, the tongs feature sophisticated sensing equipment, such as distance and tilt sensing devices as well as laser light sensors for controlling the gripping operation. An RFID antenna receives signals containing the hood numbers sent out by RFID chips installed in the hoods.

In consideration of the fully automatic crane movements above pressurized hydrogen pipes, the crane features a full range of advanced safety equipment. The drive systems for the travelling and lifting movements feature two drives each. This ensures safe continuation of operation at half speed – and thus permanent availability of the system – should one of the drives fail. Each lifting gear contains two rope systems. Should one rope break, the second one will be available to carry the full load. The winding drums feature brakes for an emergency stop in case the driving gear breaks. These brakes act directly on the shoulder ring. They will be instantly actuated in the events of excessive speed, impermissible speed differences or deviations from nominal values.



Temperature curves of a typical annealing cycle

The plant complies with all requirements stipulated in the applicable regulations, for example in DIN EN 13135. The entire annealing shop area is surrounded by a protective fence containing nine protective doors.

One person in the control room operates and monitors the complete plant. The control room is situated eight metres above the floor, providing an optimal view over the entire annealing shop. The actual loading stage of the annealing bases is visualized on monitors.

The plant control system is linked with production data acquisition systems of Bilstein and LOI. It coordinates the transport and storage of the coils, hoods and convectors. The integrated warehouse management system assigns storage places to the coils. It generates and sends the corresponding travel orders to the crane control system. In doing so, the warehouse management system takes into account storage rules, such as the maximum stacking height, and performs plausibility checks.

The coils are delivered from the rolling mill. When the coils have been unloaded, an operator scans the coil bar code by means of a manual device. The crane automatically takes the coil to its storage place. Then the empty annealing bases are loaded. Coils and convectors are stacked in an alternating sequence. At the end, the hoods are placed over the stacks. LOI has employed a multi-media coupling, which automatically establishes all connections for the gas supply (natural gas, hydrogen and nitrogen) and the electrical signals.

Positive résumé

The résumé after two-and-a-half years of operation is positive in every respect. The initially set targets have been met. Plant operation is trouble-free. All automated crane operations have proved highly reliable. No coils have been damaged as a result of the automatic operation. There are only very few exceptional cases in which the crane is operated manually.

In order to obtain reliable information about energy use and associated costs, Bilstein uses the software package MESSDAS to monitor the energy management. For detailed analyses, the software acquires values such as consumption data for hydrogen, nitrogen and natural gas as well as the heat rates.

Fuel consumption of the annealing shop is about 11 percent lower than in the case of a conventional design. While the energy requirement of con-

The LOI-developed bypass cooling system featuring dual coolers has been installed in the basement

ventional plants is usually about 180 kWh/t, the new plant's energy use has been reduced to about 160 kWh/t.

The plant achieves the energy efficiency promised by LOI without compromising on capacity. Three percent of the recycled energy is converted into electricity, 55 percent into thermal energy for other heat consuming units at various places in the works. The recycling rate amounts to about 58 percent, corresponding to a 39 percent increase in energy efficiency. Per charge, the ORC plant generates approximately 300 kWh electricity. In total, 5,300 kWh of thermal energy are obtained from the decoupling of heat. Since the new plant was built, Bilstein has saved approximately 350,000 euros on electricity and natural gas costs per year.

The evaluation of the heat meters has shown that, alone in 2014, Bilstein was able to recover 1.5 million kWh of energy as a result of heat decoupling. The additional electricity consumed by the heat recovery equipment amounts to just 21,000 kWh.

A "hot" inert gas outlet in the annealing base has been specially designed for this application. This solution extends the intervals required for cleaning the flanges at the bases. During the more than two years of operation, it has not yet been necessary to clean the flanges or replace any seals.

From the outset, Bilstein has planned the new annealing shop and the entire infrastructure with a future expansion by additional bases in mind. Starting in July 2015, four more bases will be added to the current 12-base plant. Additionally, it is planned to transport the coils in conjunction with the intermediate convector plates in order to halve the number of crane movements.

Conclusion

The new batch annealing plant at the Bilstein cold rolling mill is the world's first featuring automatic crane operation. Its innovative heat recovery concept and energy management also make it the most energy efficient plant of its kind in the world. During cooling, it recovers energy from the hot coils and generates electricity and heating energy for other units in the works. ■