DEVICES FOR ACCELERATED COOLING OF ROLLED METAL PRODUCTS

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Increasing the quality and output of efficient types of rolled metal products would be nearly impossible without the use of efficient cooling devices. The All-Union Scientific Research Institute of Metallurgical Heat Engineering (VNIIMT) has developed various devices and methods for the acclerated cooling of rolled products in different types of treatment.

Quenching Plates After Normalizing. The normalizing of 10-50-mm-thick plates of steels 10KhSND, 15KhSND, 14G2AF, and 16G2AF in the line of the 3600 mill at the "Azovstal'" combine, done by the traditional method (heating above A_{C_3} followed by cooling in air), does not improve the mechanical properties compared to hot-rolled plates and, in some cases, fails to satisfy the requirements of GOST 19282—73 and GOST 6713-75. Accelerated cooling with water after normalizing at 650-720°C and subsequent cooling in air increases mechanical properties by 25%. However, the lack of efficient cooling devices after the normalizing furnaces has held up the broad adoption of this practice on the 3600 mill.

Since the cooling devices designed in Czechoslovakia and in use at the combine have proven unworkable due to buckling of plates and low cooling rates, VNIIMT developed equipment and regimes for quenching plates after normalizing. Here, designers considered the specific features of the water supply system: the low head developed by the pumps (0.18 MPa); the use of polluted seawater for cooling. The manifolds that were designed by the institute do not become obstructed and ensure uniform cooling by feeding water onto the product from above and below in the form of planar symmetrical flows. The direction of these streams is transverse to the direction of plate motion. The capacity of the accelerated cooling unit is 100 tons/h, water flow rate is 0.35-0.45 m^3/sec, water pressure is 0.18 MPa, and the cost is 30,000-50,000 rubles.

The institute and the combine made and installed three cooling devices. Each consists of three sections, one for intensive cooling and two for cooling at lower rates. The required cooling time for plates of different thicknesses is assured by changing the cooling rate from 0.1 to 1.0 m/sec. Satisfactory flatness of the plates after cooling is achieved with a ratio of 1:2 for the water supplied by the sections above and below the plate.

Controlled accelerated cooling of plates after normalization at 650-720°C makes it possible to increase useable output to 95% for steels 10KhSND, 15KhSND, 09G2S, 12G2AF, and 14G2AF. Studies conducted the Institute of Ferrous Metallurgy (IChM) and the "Azovstal'" combine showed that if the heating were discontinued at a lower temperature (550-600°C), it would be possible to obtain mechanical properties that were comparable to those required by GOST for quenched and tempered rolled products.

The design of the device and the cooling rate are such as to permit the equipment to be used in the full-quench regime. Planarity was satisfactory when test plates were cooled to 80-120°C. The annual savings that would be realized just by eliminating repeat heat treatment amount to 250,000-300,000 rubles. The cost of the equipment is recovered in less than a year.

Cooling of I-Beams. In the course of introduction of its universal beam mill, the Nizhniy Tagil Metallurgical Combine discovered that an increase (to 950-1030°C) in the finishing temperature for large I-beams and the presence of a substantial temperature gradient between elements of the beams adversely affected the structure and mechanical properties of the metal. To improve the service properties of these products, it was decided to subject the more massive elements of the beam to forced cooling.

Researchers at VNIIMT collaborated with the Ural Scientific Research Institute of Ferrous Metallurgy (UralNIIChM) and the combine to conduct trials of the most important designs of cooling devices and different cooling regimes. The manifolds provide for a spray density of 15-20 m^3/h per meter of length of the most massive beam

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elements at a water pressure of 0.1-0.15 MPa. This makes it possible to attain heat fluxes of 3.5-5.5 MW/m^2 in the intensive cooling zone. Symmetrical cooling is assured by movement of the manifolds in the vertical and horizontal planes.

The use of cooling sections in conjunction with other organizational and technical measures has made it possible to halve the amount of metal rejected for poor mechanical properties. The annual savings realized here have amounted to 200,000 rubles.

Cooling of Thin Steel Strip. The Lys'va Metallurgical Plant has installed equipment for chromium-plating and lacquering steel strip 712-1020 mm wide and 0.2-0.32 mm thick. After lacquering, the strip is moved upward at a rate of 0.5-2 m/sec and heated in an induction drying chamber to 280-290°C. The strip must undergo accelerated cooling before it is cooled. The air-jet cooling chamber and water-cooled roller currently being employed for this purpose do not ensure cooling at the necessary rate with the requisite uniformity, thus causing warping of the strip and the formation of defects in the lacquer coating.

To ensure the required strip cooling conditions, researchers developed a water-air cooling device based on manifolds with special nozzles for feeding coolant onto the strip. Total water consumption ranges up to 2 m^3/h, while total air consumption goes up to 1200 m^3/h. To prevent water from falling in the induction heating chamber below and to eliminate the possibility of contamination of the shop atmosphere, the device is equipped with cutoff manifolds and an exhaust chamber to remove spent water-air mixture.

The water-air cooling unit provides for cooling of the entire range of strip produced from 280-300 to 30-100°C at a rate of 40-300°C/sec. Here, the heat-transfer coefficient reaches 16-24 $kW/m^2 \cdot °C$. The cooling is uniform — the temperature drop across the strip after cooling is no greater than 5-8°C. The amount of strip rejected due to coating defects has now been substantially reduced, and the plant has realized an annual savings of 200,000 rubles a year from the introduction of this equipment.

The use of accelerated-cooling devices does not require large capital expenditures. The equipment can be made by the rolling-mill and machine shops at plants in the ferrous metallurgy sector.

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OJSC Scientific-Research Institute of Metallurgical Heat Engineering (VNIIMT) established in 1930 as Ural Division of All-Union Heat Engineering Institute is widely known in Russia and the CIS. The Institute focuses on development of high-technology heat engineering units, energy efficient and ecologically friendly technologies in ferrous and non-ferrous metallurgy, machine-building and other fuel-consuming branches of industry.

Highly-qualified academic researchers, unique experimental and production facilities and own research and design centre enable efficient scientific-and-research, design-and-experimental, engineering and project works, delivery of equipment, designer's supervision and commissioning works including execution of turnkey contracts in the following areas:

Sintering:
- development of techniques and modes of metal raw material heat treatment;
- design of energy-efficient agglomeration hearths and agglomeration gas heat recovery circuits allowing to reduce energy consumption and dust and gas emissions.

Pellet production:
- optimal traveling grate pelletizing furnaces for heat treatment of iron-ore pellets from various concentrates (hematite, magnetite, etc.) with optimal automatic process control system.

Preparation of metallic and nonmetallic raw materials:
- technique of iron-ore raw material dephosphorization by roasting and leaching;
- installations for drying high-moisture dispersive materials of various designs;
- efficient techniques of magnetizing roasting and subsequent dressing;
- technique of rare-earth element extraction (for example, germanium from germanium iron ores).

Blast-furnace ironmaking:
- explosion-proof near-furnace systems of blast furnace slag granulation giving a high-quality product for cement production;
- optimal control system for hot blast stoves;
- an innovative bench for drying hot metal and steel-smelting ladles;
- copper coolers and tuyeres of blast furnaces.

DRI (direct reduction of iron)
- improvement of the reduction technique in shaft furnaces for radical improvement of technical and economic indicators of their operation (productivity is increased twice);
- technique of raw material reduction in rotary furnaces using coal as the reductant.

Lime production: development of the technique and increase of lime production process efficiency:
- in shaft furnaces;
- in double-shaft furnaces;
- in rotary furnaces;
- in “stacked-tower preheater - rotary furnace” installations;
- in “shaft calciner - rotary furnace” installations (VNIIMT innovative technology).

Granulation of metal melts:
- development of technologies and designs of explosion-proof plants for near-furnace granulation of metallurgical slag, molten metal, etc., including heat recovery;

Reheating furnaces:

- development of new and update of the existing designs of furnaces for stock heating;
- high-performance systems of reheating furnace firing with recovery and regeneration firing systems based on the innovative burner units designed by VNIIMT;
- switching the furnace firing systems to cheaper fuel types;
- development and implementation of optimal furnace operating parameters.

Heat-treatment furnaces development of techniques and equipment for heat treatment of roll stock and metal products including those with protective atmospheres:

- thermochemical treatment conditions ensuring retention or directional change in chemical composition of metal surface;
- gas dampers for heat-treatment furnaces;
- spray quenching units and other elements of convective cooling systems;

Furnaces with protective atmosphere and gas treatment units:

- development of the furnace structure, design, manufacture, delivery and commissioning works;
- development of a technology for treatment of articles and devices for protective gas generation;
- calculation, development and manufacture of endogas and exogas atmosphere generators for metal product thermochemical treatment units;
- gas analysis systems for monitoring and control of physico-chemical properties of protective process atmospheres.

Reheating, heat-treatment and drying furnaces with convection heat transfer:

- development, design and manufacture using industrial heat-resistant (up to 900 ^{o}C) furnace fans designed by VNIIMT.

Rolled products:

- techniques and units for controlled high-speed air-to-water cooling (quenching) of rolled ferrous and non-ferrous metal products including thick plate on mill 5000;
- replacement of oil quenching technology with VNIIMT's eco-friendly air-to-water technique;
- innovative technique of oily mill scale processing;
- line of wire rod accelerated air cooling with process improvement.

Manufacturing manufacture and delivery of:

- high-performance burner units;
- heat-resistant (furnace) fans (up to 900 ^{o}C);
- copper coolers for blast furnaces and nonferrous furnaces based on VNIIMT technology;
- Pitot tubes for measuring flow rates and pressures.

OJSC VNIIMT developments are widely used in metallurgical enterprises of Russia, Ukraine, Kazakhstan, China, India and others.

For detailed information on institute developments, please visit OJSC VNIIMT site at www.vniimt.ru

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