DOI: 10.34185/1991-7848.itmm.2025.01.023

IMPROVEMENT OF COOLING REGIMES FOR THE FORMATION OF MECHANICAL PROPERTIES OF HOT-ROLLED SHEETS

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Abstract. *The global demand for hot-rolled sheets made of steel and non-ferrous alloys continues to grow steadily due to their versatility and wide range of applications. Hot-rolled products serve as a basis for further processing into cold-rolled materials used in the automotive industry and other sectors. At the same time, a significant portion of hot-rolled sheets is used directly in construction industry and mechanical engineering, as well as being in demand in the energy and shipbuilding industries. High requirements for strength, plasticity, durability and corrosion resistance of hot-rolled sheets dictate the need for precise control over temperature regimes throughout the entire technological process. Optimization of the pre-rolling heating and controlled cooling regimes of hot-rolled products allows the modification of the metal's microstructure and mechanical properties. The use of mathematical modeling will allow for the study of thermal regimes and the development of recommendations for their improvement.*

Keywords: *hot-rolled sheet, mechanical properties, heating regimes, cooling regimes, mathematical modeling*

The analysis of modern technological schemes for the production of hot-rolled steel products, such as the Danieli QSP-DUE caster-rolling complex [1], under various rolling conditions, particularly using endless rolling mode, reflects current trends in thermomechanical processing.

A typical production scheme of the hot-rolled sheets (Figure 1) involves slab formation via continuous casting, followed by soft reduction and feeding into a tunnel furnace where temperature homogenization of the slabs occurs. Next, the material is rolled through roughing and finishing stands, with subsequent controlled multi-zone laminar cooling. A unique feature of endless rolling is the additional high-speed reheating of the sheets using induction heaters, installed between the roughing and finishing groups of stands. This allows for uniform temperature distribution across the sheet thickness, which is critical for ensuring the required mechanical properties of steel.

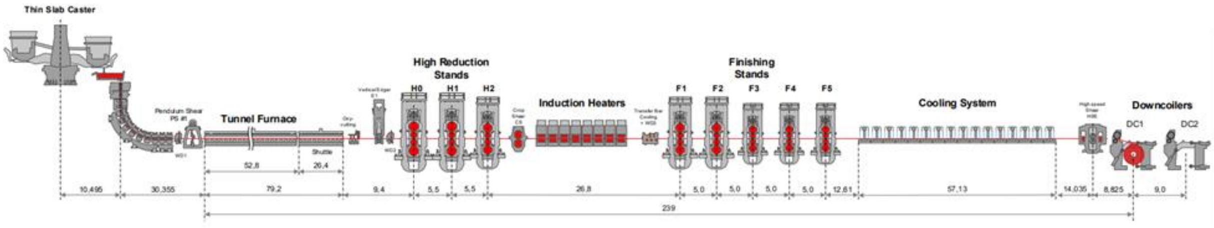

Figure 1 – Technological layout of the Danieli QSP-DUE caster-rolling complex [2]

A precise analysis and control of heating, rolling, and cooling temperature regimes is essential for forming the final characteristics of hot-rolled sheets. One of the most important stages is controlled cooling after rolling, as it directly affects phase transformations, grain size, residual stresses, texture, and the final mechanical properties of the material. Available research confirms that cooling rate significantly influences the mechanical properties of hot-rolled sheets.

Excessive cooling rates may lead to the formation of martensitic or bainitic structures, which increase hardness but reduce plasticity. Conversely, slower cooling promotes the formation of ferrite-pearlite structures, improving machinability but potentially reducing strength [3, 4]:

- slow cooling (0,5 – 1 K/s) contributes to the formation of polygonal ferrite and pearlite, improving plasticity but reducing strength;
- accelerated cooling (5 – 30 K/s) results in bainitic structures with fine-grained elements, providing balanced mechanical properties;
- extremely fast cooling (up to 90 K/s) facilitates martensitic formation, increasing hardness but reducing plasticity and impact strength.

Conclusions. The use of traditional cooling schemes does not always ensure full control over the required properties of the metal, which requires the development of new approaches and the improvement of existing cooling strategies. Considering the complex relationship between temperature regimes and the final properties of hot-rolled sheets, numerical modeling is essential for analyzing cooling processes.

The development of a mathematical model will allow for the determination of optimal temperature intervals and cooling regimes, as well as the analysis of phase transformations required to achieve the desired mechanical characteristics of hot-rolled products.

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ВДОСКОНАЛЕННЯ РЕЖИМІВ ОХОЛОДЖЕННЯ ДЛЯ ФОРМУВАННЯ МЕХАНІЧНИХ ВЛАСТИВОСТЕЙ ГАРЯЧЕКАТАНИХ ЛИСТІВ

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Анотація. *Споживання гарячекатаного листового прокату зі сталей та кольорових сплавів у світі стабільно зростає через його універсальність та широке застосування. Гарячекатаний листовий прокат є основою для подальшої переробки в холоднокатаний прокат для автомобілебудування та ін. Значна частина гарячекатаного листового прокату безпосередньо використовується у будівельний галузі та машинобудуванні, прокат затребуваний в енергетиці та суднобудуванні. Високі вимоги до міцності, пластичності, зносостійкості та корозійної стійкості гарячекатаного листового прокату вимагають ретельного контролю температурних режимів під час усього технологічного процесу. Оптимізація температурних режимів передпрокатного нагріву і контрольованого охолодження гарячекатаних листів дозволяє керовано змінювати мікроструктуру та механічні властивості металу. Використання математичного моделювання дозволить дослідити температурні режими та розробити рекомендації щодо їх вдосконалення.*

Ключові слова: *гарячекатаний листовий прокат, механічні властивості, режими нагріву, режими охолодження, математичне моделювання*

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