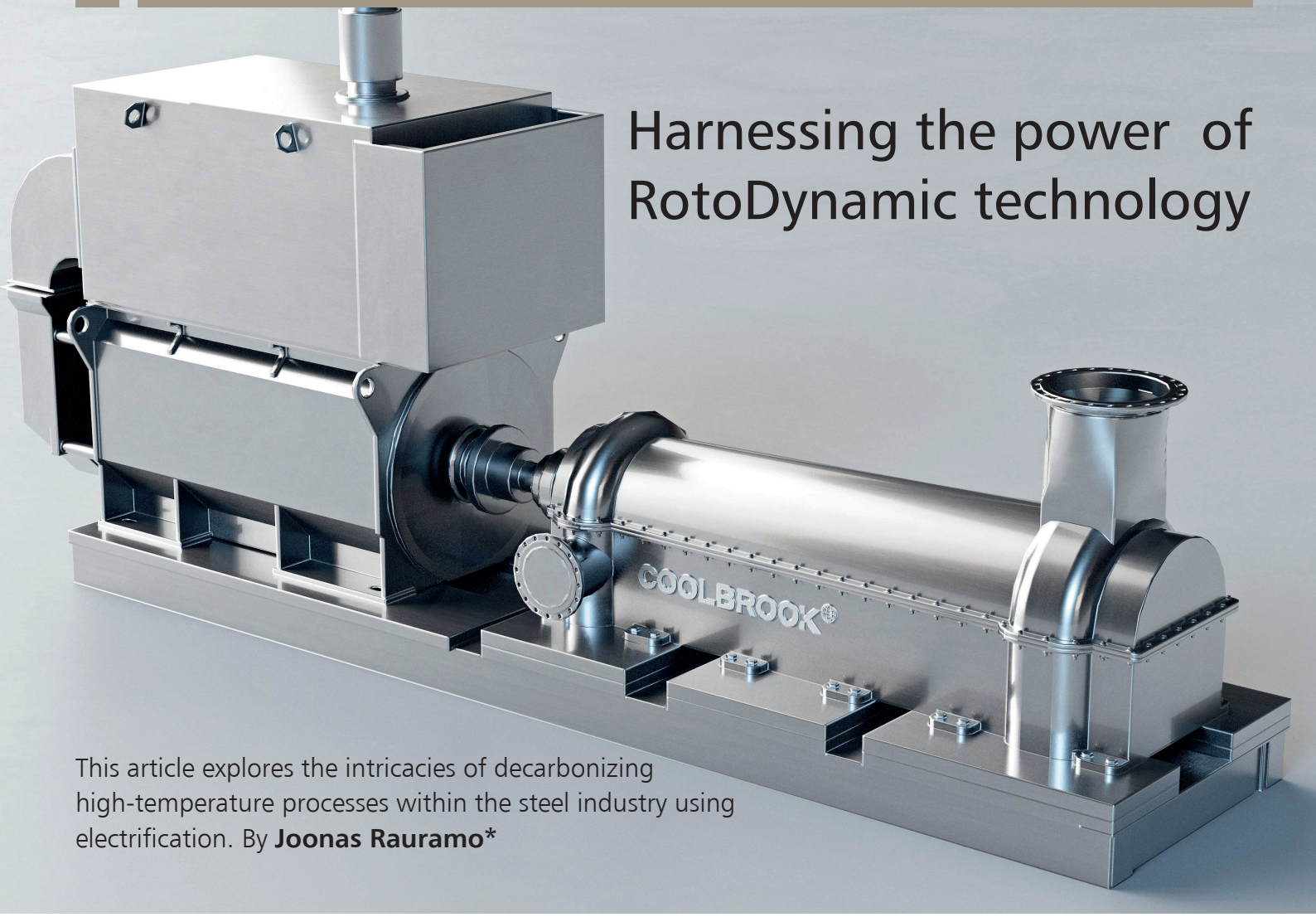
Harnessing the power of RotoDynamic technology



This article explores the intricacies of decarbonizing high-temperature processes within the steel industry using electrification. By **Joonas Rauramo***

STEEL is a fundamental building block within virtually every sector in the global economy, valued for its high durability, ease of mass manufacturing, and 100% recyclability. However, as it stands, the steel industry is the largest emitting manufacturing sector, accounting for 7% of all man-made emissions worldwide, and requires urgent transformation if it is going to meet the goal of net zero emissions by 2050. This becomes even more of a priority as global demand for steel continues to rise, from 1.8 billion tons in 2020 to an estimated 2.0 billion tons by 2030.

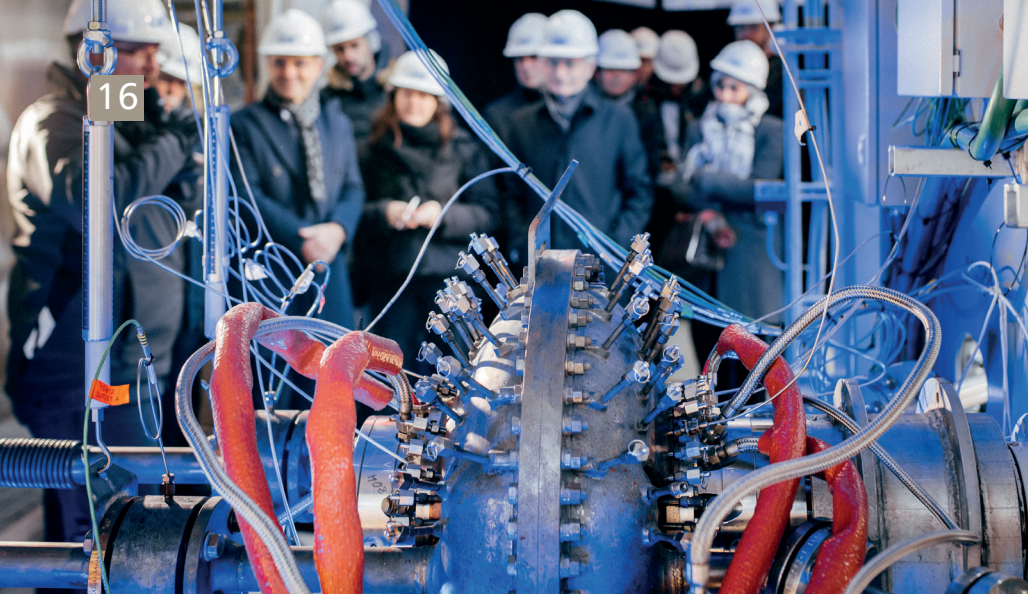
Steel is primarily made up of iron, which is bonded with a low percentage of carbon to give it its unique properties. In the first stage of primary steel production, mined iron ore is taken and reduced to metal using carbon and simultaneously smelted into pig iron in a blast furnace – a process that requires a considerable amount of energy – and then, in the second stage, the molten pig iron is converted into steel in a converter or blast oxygen furnace (BOF) and alloyed to the desired composition. This process is known as the BF-BOF process. Secondary steelmaking involves taking recycled iron and smelting it in an electric arc furnace (EAF) to remove impurities and add carbon and other alloying elements. Both processes require temperatures of over 1,600°C to bring iron to its melting point and purify and alloy the steel.

In addition to smelting, steel also goes through additional processes including casting, hot rolling, often also cold rolling, annealing and tempering to optimise its qualities – requiring temperatures of up to 1,200°C. Around 85% of total energy consumption in steel manufacturing primarily arises from the burning of fossil fuels. In primary steelmaking, the production of hot metal iron in a blast furnace requires coke made from coal as a raw material. The production of coke itself requires additional energy and, therefore, releases further CO_2 emissions.

Now, cutting-edge electrification technologies are ushering in a new era for the steel industry, paving the way for steel manufacturers to make significant progress towards net zero emissions. Coolbrook's RotoDynamic Heater™ (RDH™), a patented heating technology powered completely by renewable electricity, is on track to generate temperatures up to 1,700°C. On the point about a system being 'powered completely by renewable electricity', Joonas Rauramo responded to the fact that not everywhere in the world has access to renewable energy by saying: *"While it's true that not all parts of the world currently have widespread access to renewable energy, there are a few important factors to consider.*

Firstly, renewable electricity can be accessed directly in many regions or through Power Purchase Agreements (PPAs), where companies can source green energy even if it's not locally available. This is a key strategy for global decarbonization, as the demand for green electricity drives further investment in renewable infrastructure.

*CEO at Coolbrook



"Moreover, transitioning to renewable energy often happens in phases. Even in regions where green electricity isn't yet fully established, investing in technologies like RDH helps accelerate the shift by increasing demand. Many of our customers are also investing directly in renewable projects to secure their supply.

"It's also important to note that CO_2-free power sources, such as nuclear energy, play a significant role in some regions. For example, in Europe in 2023, the electricity mix included 22.8% from nuclear and 44.7% from renewables, meaning that over 67% of the electricity was completely CO_2-free. This highlights the ongoing shift towards cleaner energy and shows that a substantial portion of electricity in some areas is already sourced from carbon-free technologies.

"So, even if renewable energy isn't yet universally accessible, adopting technologies powered by it is a crucial step in the global transition to sustainable energy."

This novel technology can replace fossil fuel combustion as the heat source throughout the steel manufacturing process, eliminating 600Mt of global CO_2 emissions annually in the steel industry alone. The RotoDynamic Heater™ is a product of two decades of research and development by Coolbrook, and partnering with notable academic institutions such as the universities of Oxford and Cambridge in the United Kingdom.

A better way to reach steelmaking temperatures

In mere milliseconds, the RotoDynamic Heater™ can generate the temperatures required for steel production, boasting an impressive 95% conversion rate of electrical energy to thermal energy, without relying on the combustion of fossil fuels. This feat is accomplished through a cyclical sequence of steps.

Initially, powerful electric motors, optimised for industrial use, set rotor blades in motion, propelling gas molecules – such as air, nitrogen, steam, CO_2, or hydrogen – at supersonic speeds. Subsequently, these swiftly moving gas molecules undergo rapid deceleration upon encountering a diffuser, transitioning to subsonic velocities. This abrupt change in speed triggers turbulence and shockwaves, effectively converting the kinetic energy of the gas into thermal energy, thereby generating heat. This process iterates through multiple stages, each seamlessly transitioning to the next within milliseconds, progressively elevating temperatures up to a remarkable 1,700°C.

By directly heating the gas efficiently within itself, this method eliminates the necessity for bulky resistive heating components. Consequently, the RotoDynamic Heater™ boasts a compact footprint of just a few metres for capacities of dozens of megaWatts while achieving the desired temperatures with unparalleled efficiency and speed.

Seamless integration, widespread decarbonization

Another key advantage of the RotoDynamic Heater™ lies in its seamless integration potential into existing steel manufacturing plants without imposing complexities on current infrastructure. Due to very high energy intensity and compact equipment size the RotoDynamic Heater can be installed directly at the location where heat is needed thus enabling efficient energy integration also in brownfield sites. This straightforward application facilitates swift adoption of the technology by steel manufacturers, sidestepping additional complications, laborious tasks, or infrastructure investments. Utilisation of the RotoDynamic Heater also enables capture of waste heat streams which can significantly improve the overall energy efficiency of the process.

Other decarbonizing technologies for steelmaking are aiming to facilitate the reduction of iron ore into metallic iron using hydrogen gas, instead of the conventional natural gas. However, the reaction between hydrogen and iron oxide still requires temperatures up to 1,000°C, and the process itself has to be constantly heated as it consumes thermal energy. The RotoDynamic Heater can be integrated into hydrogen-based iron oxide reduction plants to provide the high temperatures and constant heating needed for the reaction and process without fossil fuels or emissions.

Moreover, RDH technology can be used to improve efficiency and reduce emissions in recycling of steel. For instance pre-heating of scrap metal can be used to remove impurities and reduce the energy input required in electric arc furnaces improving plant throughput in addition to a lower carbon footprint per ton of steel.

As a result, the RotoDynamic Heater can decrease fossil fuel usage per tonne of steel, decarbonizing processes ranging from the preheating of air to blast furnaces, provisioning of heat for hydrogen-based reduction processes, casting, hot rolling, annealing, coking, tempering lime production for use in removing impurities from steel, reheating furnaces, and other supporting processes. In electric arc furnaces, the RotoDynamic Heater can be used in scrap preheating to shorten the smelting sequence.

By reducing fossil fuel usage per tonne of steel throughout the manufacturing process, the RotoDynamic Heater significantly brings down the cost to decarbonize each tonne of steel produced, allowing manufacturers to improve the overall return on investment of their decarbonization efforts and more efficiently advance towards a prosperous net zero future.

The technical feasibility of the RotoDynamic Heater has been proven at Coolbrook's large-scale pilot facility, inaugurated in December 2022 at the Brightlands Chemelot Campus in Geleen, the Netherlands. There, its capability to attain the required temperatures for heavy-duty industrial operations was successfully showcased. The initial phase of pilot testing concluded in September 2023, surpassing the 1,000°C threshold and validating the RotoDynamic Heater's suitability for industrial-scale high-temperature process heating; underscoring its potential to annually reduce global industrial CO_2 emissions by 30%. Furthermore, this breakthrough not only unlocks a significant portion of the €1 trillion global industrial heating market for RotoDynamic Technology™ but also paves the way for its deployment in large-scale projects at customer sites.

The steel industry holds great decarbonization potential

In the pursuit of net zero emissions within the steel industry, the integration of complementary decarbonization technologies is paramount. For instance, the lime used in steelmaking is obtained through the decomposition reaction of calcium carbonate, which releases CO_2 as a natural byproduct.

While clean heating technologies such as the RotoDynamic Heater can provide the heat required for this reaction, the CO_2 byproduct must also be removed to achieve total decarbonization, which can be achieved using carbon capture and storage processes. Combustion-free heating technologies such as the RotoDynamic Heater can enable a more efficient, streamlined carbon capture process by producing a much higher concentration of CO_2 gas from the decomposition reaction, eliminating the nitrogen and argon from the exhaust gases.

A clean, new industrial era for all

At the forefront of catalysing full decarbonization in the steel industry, the RotoDynamic Heater boasts a compact footprint, delivering the extreme temperatures required for steel manufacturing, with an excellent 95% energy efficiency, without reliance on fossil fuels. Manufacturers that invest in existing and developing decarbonization technologies now can have a competitive advantage moving forward by operating at the cutting edge of steel manufacturing and contributing to the widespread implementation of steel decarbonization worldwide — leading a clean, new industrial era for all.