Testing a newly designed two-stage coke oven

MEETING A BURNING NEED FOR CLEANER STEELMAKING

Researchers at the University of Science and Technology Beijing are supporting SUSTAINABLE STEELMAKING with clean and efficient technologies that minimize pollution and energy consumption.

Steelmaking is an energy intensive industry, whose heavy reliance on fossil fuels creates significant pollution. Using renewable, clean energy sources for steel production is one approach to reduce the impact. Employing sophisticated techniques for key processes to make the conversion of fossil energy more efficient also offers a solution. Researchers at the University of Science and Technology Beijing (USTB) are going to great lengths to revolutionize the steelmaking process, making it cleaner and more efficient.

Strong efficiencies

China is one of the world's largest steel producers, and there, the iron and steel industry consumes around 20% of the total industrial energy consumption. "Average unit energy consumption by major Chinese steel companies is still higher than that of the global average," said Xinxin Zhang, a professor from USTB's School of Energy and Environmental Engineering. "This highlights a great need to reduce energy use and emissions."

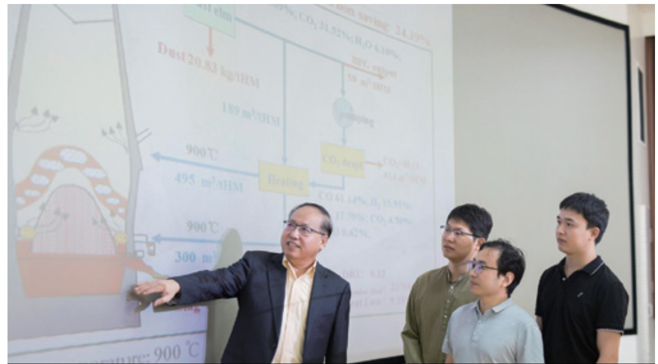
Producing pig iron in a blast furnace is a key process in steelmaking, and according to Zhang, it contributes to more than 70% of both energy consumption and pollution emission in steel production. His team is committed to advancing oxygen blast furnace ironmaking technology to improve production efficiency and lower carbon emissions.

Their blast furnace process is characterized by blowing high-purity room-temperature oxygen and recycling top gas in blast furnace via tuyeres.

The use of near 100% pure oxygen helps enhance the combustion reaction of pulverized coal, which is conducive to reducing coke consumption. The released top gas, after the removal of CO_2, can be recycled and blown into the furnace for re-use, thus, reducing the use of coke and coal, and contributing to carbon capture, utilization, and storage (CCUS).

This technological progress is the result of investigations on the complex systems and chemical reactions in the blast furnace ironmaking process. By analysing the mechanisms, building computational simulations, and experiments, Zhang's team has explored how external conditions, like full-oxygen blast, top gas recycling, and high rates of pulverized coal injection, affect the combustion and reduction processes inside the furnace, as well as the evolution rules of burden's shape and properties. Their theoretical studies have led to an integrated theory for thermochemical reactions in a multi-component, multi-phase system at high temperature,

This phase-four coking facility developed by USTB is a demonstration project for Anshan Group.



Professor Xinxin Zhang (left), the former USTB president, has nurtured many distinguished iron and steel engineers.

and the energy-mass transfer process.

Having mastered the design of high-efficiency oxygen coal burners, and determined the key parameters for the full-oxygen blast furnace ironmaking, Zhang's team developed technical solutions for other key processes. The result is a prototype top gas recycling oxygen blast furnace for industrial use. The new technology is expected to decrease the fuel rate by 85kg/t, while reducing CO_2 emission by more than 26% compared with the current average, said Zhang.

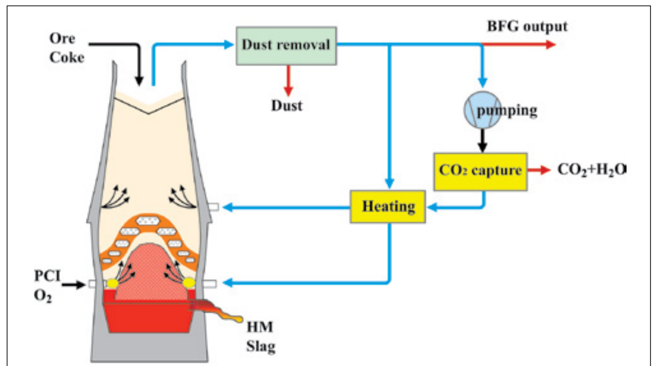
Zhang says another problem for China's iron and steel industry lies in the low recovery and utilization of residual energy, as well as a lack of planning for energy allocation and integrated technology. He says the key to solving these bottlenecks is an integrated material and energy flow system to optimize the production process.

Zhang's team has developed an integrated management platform for steel manufacturing incorporating methods to evaluate resources, energy consumption, and environmental impact. "This allows for multi-layer system integration and optimized process control," Zhang said. Under this scenario, energy consumption per tonne of steel is reduced by up to 5.5%, and CO_2 emissions by up to 6.66%. In line with China's commitment to reduce the steel industry's carbon emissions by half by 2050, Zhang is keen to address industrial challenges by accelerating structural adjustments, scrap recycling, and energy-saving technologies to reduce pollution.

Cleaner coke

Coking coal is the main energy source for the integrated process of steel production. Due to outdated technologies and equipment, coke-making in China is plagued with long-standing problems like high energy consumption and severe pollution, according to Zhang.

To achieve clean and efficient coke-making, Zhang's USTB team proposed a control theory combining flue gas recirculation and staged combustion. The former involves cooling the exhaust gas and redirecting it back into the charge air, which helps reduce combustion temperature and nitrogen oxide production. The latter reduces nitrogen oxide emissions from continuous combustion burners. The technology is used in coke ovens, cutting emissions from the source, and as it allows for uniform heating of the coal, also reducing energy consumption in coking. Working with industry to pilot the technology, Zhang's team has addressed the national strategic needs of energy-saving, cleaner coking, and was awarded the first prize of the 2018 State Scientific and Technological Progress Award for their technology and equipment.



The oxygen blast furnace process promises enhanced efficiency and lower carbon emission.

Used in large-scale coke ovens, the technology has significantly reduced nitrogen oxide concentration in waste gas to 30% lower than the emission limit allowed in China. It is estimated that use of the technology will help cut nitrogen oxide emissions by 34,000 tonnes per year, and heat consumption by 4%.

Zhang's team further proposed an innovative blueprint for a two-step coke oven, which replaces the regenerator in the traditional coke oven with heat exchange and drying chambers, leading to an integrated structure for coal preheating and dry distillation. While the rate of preheating and carbonization are synergistically adjusted, the coke oven enables cascade utilization of flue gas waste heat, and thus, optimized use of energy.

This process saves the use of quality coals, decreases the discharge of ammonia water by 85%, phenol-cyanogen wastewater by two thirds, and lowering nitrogen oxide emissions. Zhang also predicts a significant improvement of coking efficiency. "In theory, coking time can be cut by a quarter, while output can be increased by one third, and total energy consumption reduced by 18%," said Zhang. ■

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