INNOVATIVE PROWESS

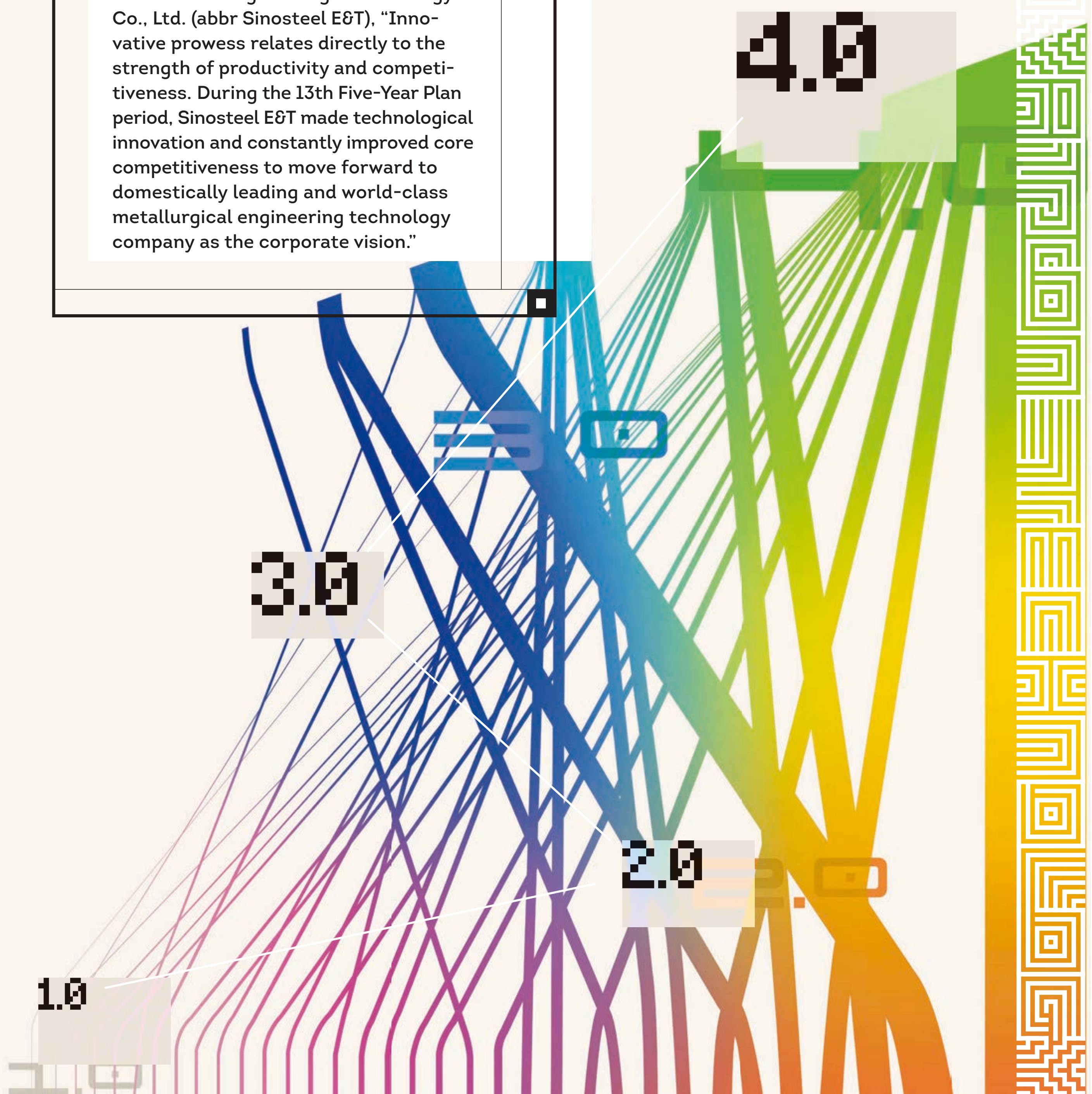
Technological Innovation 4.0

Go Into Low-Carbon Technologies

Leading the Technology of Highly Effective Bar & Wire rod Rolling

Digital Revolution

According to Lu Pengcheng, Chairman of Sinosteel Engineering & Technology Co., Ltd. (abbr Sinosteel E&T), "Innovative prowess relates directly to the strength of productivity and competitiveness. During the 13th Five-Year Plan period, Sinosteel E&T made technological innovation and constantly improved core competitiveness to move forward to domestically leading and world-class metallurgical engineering technology company as the corporate vision."



TO BUILD SINOSTEEL E&T's INNOVATION 4.0

In a rapidly changing world, the global industrial chain & trade map has always been reshaped. Innovation has become an important driving force for social development and economic growth and also for Sinosteel E&T.

Unlike most of its peers originating from engineering institutes, Sinosteel E&T, which grew out of the Equipment Company under the Ministry of Metallurgical Industry, has a weak technical foundation. After successfully transforming from a planned economy company to a market-oriented enterprise, Sinosteel E&T has prioritized innovation, especially sci-tech innovation since 2002.

In the following decades, Sinosteel E&T has experienced technological innovation stage 1.0 characterized by the integration of individual equipment and technologies stage 2.0 characterized by involvement and capacity of international and domestic EPC project contracting and management, as well as stage 3.0 characterized by technology and core equipment with independent intellectual property rights. At the beginning of the 14th Five-Year Plan, Sinosteel E&T entered the stage 4.0.

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As the world's second-largest economy, China has made the announcement to peak carbon emissions and achieve carbon neutrality, which demonstrates its strategic determination in pursuing green and low-carbon development and its responsibility as a superpower to actively tackle climate change. The goals point the steel industry in the direction of green development. With keen insight and a forward-looking plan, Sinosteel E&T focuses on green and low-carbon transformation and innovation by optimizing conventional processes in terms of energy conservation and carbon reduction and industrializing revolutionary low-carbon technologies.

Seminar on Technological Innovation

On January 27-28, 2022, Sinosteel E&T held a technological innovation seminar on the theme of *Innovative Development for a Shared Future*

"INNOVATIVE DEVELOPMENT FOR A SHARED FUTURE"

Hua Guanglin

General Manager
Sinosteel MECC

Jiang Yongmin

Deputy General Manager
Sinosteel MECC
hosted the seminar

Hua Guanglin delivered the opening speech. He said that the world today is undergoing thorough changes unseen in a century. The influence of science and technology has never been as profound as it is today. Sinosteel E&T, guided by China Baowu Group's new positioning as a high-tech enterprise provides comprehensive solutions of steel and advanced materials as well as industrial ecosystem services, has entered the stage of technological innovation 4.0 to focus on the green and low-carbon transformation of steel industry and industrialization of revolutionary low-carbon and independently developed technologies.

At the meeting, topics regarding energy efficiency improvement, industrialization of revolutionary low-carbon technology, digital innovation, synergy control of pollution and carbon, smart security, cooperation with universities and research institutes, talent cultivation, intellectual property application and protection and technical standards establishment were discussed.

Hua Guanglin underlined that technological innovation played crucial role in the steel industry and it is important to constantly improve the mechanism, capability and talents of technological innovation to achieve its industrialization rapidly and effectively and create value for customers with more high-quality products.

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The prosperity of a nation and the strength of a country derives from scientific and technological achievements

Lu Pengcheng
Chairman of Sinosteel E&T

> To achieve its industrialization rapidly and effectively and create value for customers with more high-quality products.

Lu Pengcheng, Chairman of Sinosteel E&T, quoted what Chinese President Xi Jinping pointed out on many occasions, "The prosperity of a nation and the strength of a country derives from scientific and technological achievements. Scientific and technological development must target the global science frontiers, serve the main economic battlefields, and strive to fulfill the significant needs of the country. We shall accelerate scientific and technological innovation in all fields and take preemptive opportunities in the global scientific and technological arena." Sinosteel E&T ought to take scientific and technological innovation as the the company's primary development strategy, seize opportunities, deepen reforms, and continuously improve the company's innovative prowess. With fruitful innovation achievements, we can create value for the high-quality and sustainable development of the steel industry and China Baowu ecosystem.

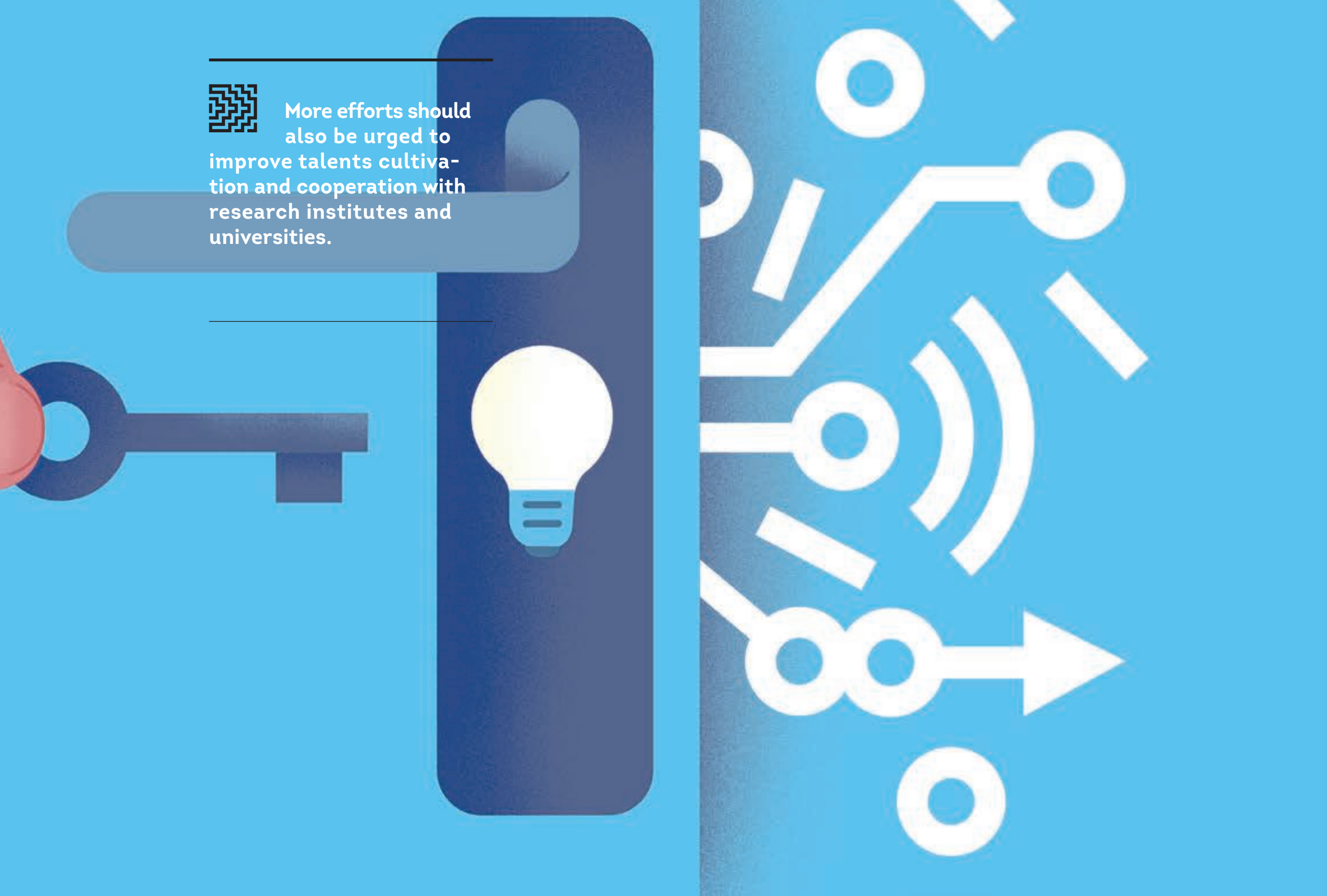
Lu Pengcheng proposed to :

Advance the development of technological innovation to a deeper and broader level by:

- Accelerating the industrialization of hydrogen metallurgy
- Hydrogen-enriched carbon recycling blast furnace
- Direct rolling of bar and rod wire
- Thin strip continuous casting and rolling.

Through integrated innovation, Sinosteel E&T ought to expedite :

- The development of network steel plant system technology with digital intelligence and extreme efficiency, as well as big data center and digital factory projects.
- More efforts should also be urged to improve talents cultivation and cooperation with research institutes and universities.



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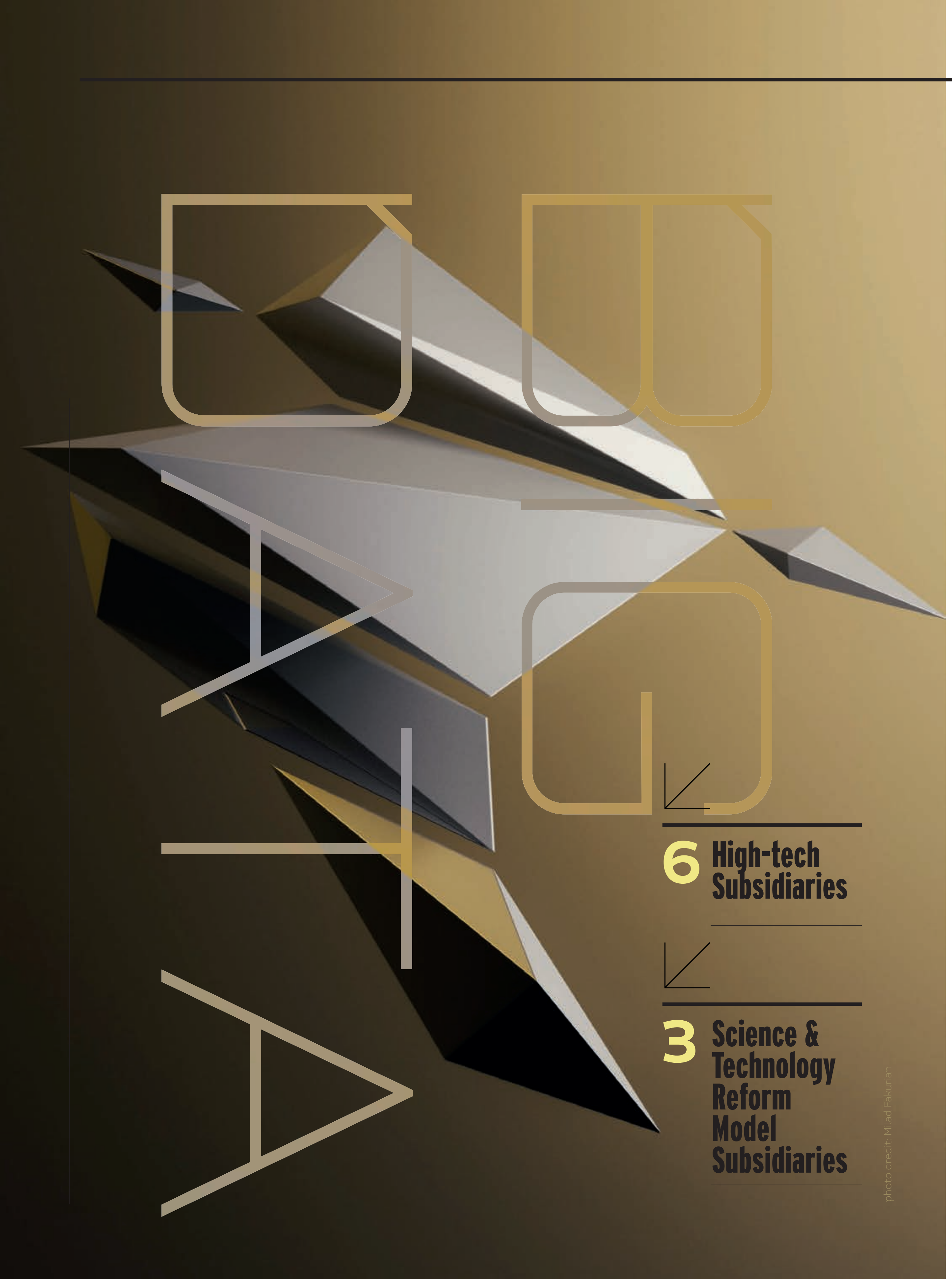
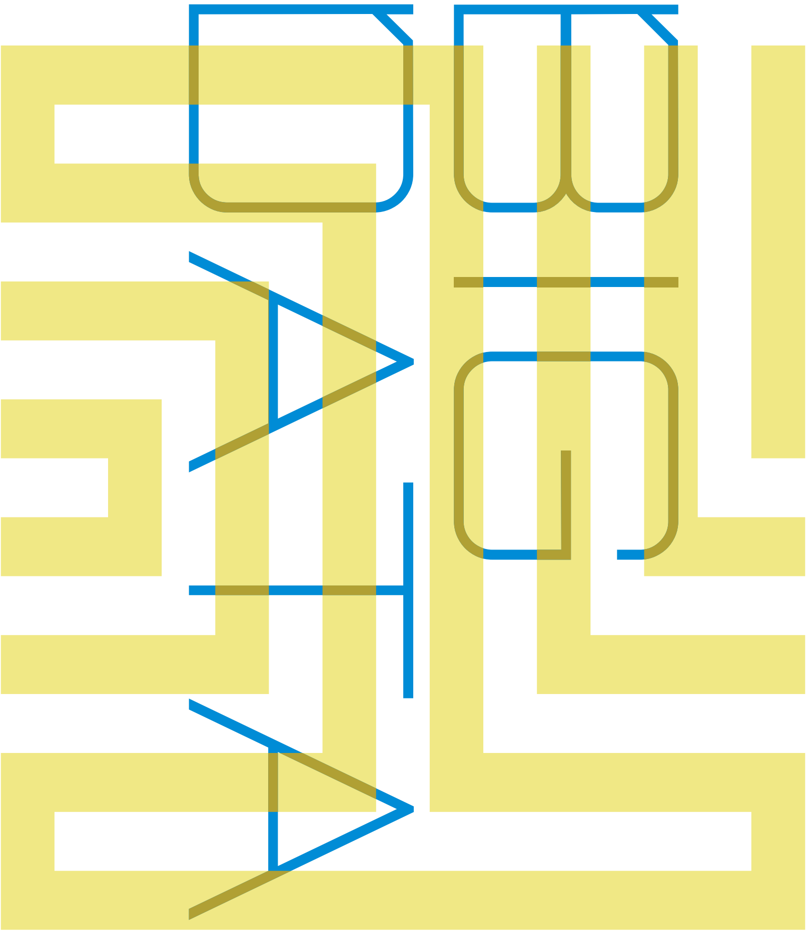


6 High-tech Subsidiaries

3 Science & Technology Reform Model Subsidiaries

photo credit: Milad Fakurian

IMPORTANT DATA



National Industrial Flue Gas Dust Removal Engineering Technology Research Center under the Ministry of Science and Technology

Supporting company for National Environmental Protection & Industrial Flue Gas Control Engineering Technology Center under the Ministry of Ecology and Environment

Co-built National Engineering Laboratory for Flue Gas Multiple Pollutants Control Technology and Equipment under the National Development and Reform Commission with Tsinghua University

China's only Academician Workstation focusing on ultra-low emission technology in the steel industry

State-level Laboratory for Analysis and Identification of Occupational Hazards in Metal & Nonmetal Mines

National Center for Quality Supervision and Testing of Labor Protection Articles (Wuhan)

The only professional supervision team in the marine field of the National Key Research and Development Program

Participated in 8 National R&D projects and 1 National Development and Reform Commission project

Drafted / Co-drafted more than 100 national standards

Formulated and revised 46 national and industrial standards in the field of environmental protection

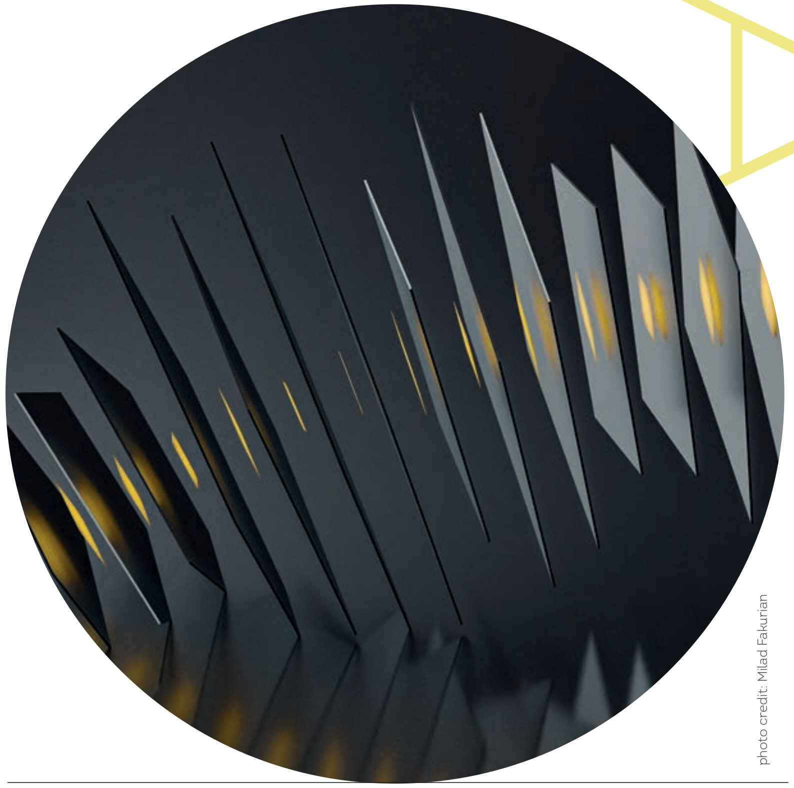


photo credit: Milad Fakurian

Important Data

8x NR&D

1x NDRC

100+

60+

Safety technical standards
Safety regulations

46x

Complete qualifications

Covering industries and fields of metallurgy, construction, communication towers, non-metallic minerals and raw material processing, and environmental engineering

- Grade A of Engineering Design in metallurgical industry, construction industry (construction engineering), electronic communication, radio and television industry (communication tower), environmental engineering (solid waste treatment and disposal engineering), municipal industry (drainage engineering and environmental sanitation engineering), and environmental engineering (water pollution prevention and control engineering and air pollution prevention and control engineering)
- Grade B of Engineering Design in environmental engineering (physical pollution prevention and control engineering and solid waste treatment and disposal engineering), municipal industry (water supply engineering), and fire protection facilities engineering
- Grade A of ecological construction and environmental engineering and municipal public works consulting. Grade B of metallurgical (including steel and non-ferrous metallurgy) engineering consulting
- Grade I for discipline contracting of environmental protection engineering; Grade II for discipline contracting of fire protection facilities engineering
- Having qualifications for discipline contracting of special works (structural reinforcement)
- Grade A of Hubei Province environmental pollution control (water pollution control and environmental restoration engineering)
- Class I operation services of dust removal, desulfurization and denitrification facilities (dust removal facilities, desulfurization facilities, and denitrification facilities); Class II operation services of pollution control facilities (industrial wastewater)
- Work safety inspection and testing agency qualification certificate
- Construction engineering quality inspection agency (main structure and steel structure inspection)
- Having safety evaluation agency qualification
- Standardized work safety (Class II, including metal and non-metal mines, hazardous chemicals and industry and trade industries)
- Category I technical service institution of occupational health
- China Inspection Body and Laboratory Mandatory Approval (CMA) issued by the Certification and Accreditation Administration of China
- Member of Low-carbon Standard Expert Committee under "Steel Industry Low-carbon Work Promotion Committee" Expert Committee established by China Iron and Steel Association
- Director Member of the Chinese Society for Metals
- Director Member of China Metallurgical Construction Association
- Director Member of China Chamber of Commerce for Import and Export of Machinery & Electronic Products
- Director Member of China International Contractors Association
- Director Member of China Engineering and Consulting Association

Member of Low-carbon Standard Expert Committee established by China Iron & Steel Association

- Director Member of China Association of International Engineering Consultants
- Secretary-General Member of Bag Filter Committee of China Association of Environmental Protection Industry
- Secretary-General Member of ESP Committee of China Association of Environmental Protection Industry
- Director Member of Chinese Society for Environmental Sciences
- Director Member of China Petroleum and Petrochemical Engineering Institute
- Deputy Director Member of Air Cleaning Equipment Sub-committee of Technical Committee for Environmental Protection and Standardization of Machinery Industry
- An affiliated unit of China Occupational Safety and Health Association
- China Energy Conservation Association
- Metallurgical Nonferrous Safety Standardization Sub-committee of National Technical Committee for Work Safety Standardization
- Industrial Dust Protection Committee of China Occupational Safety and Health Association

Major Awards

Sinosteel Tiancheng Wins the First and the Second Prizes of 2020 National S&T Progress Awards

The State Council announced its annual awards to scientists and organizations that have made great contributions to science and technology progress, economic and social development and national defense modernization on November 3 in Beijing. The achievements of "the Technology and Application of Collaborative Control for Industrial Flue Gas Multi-pollutant" and "the Technology and Application of Ultra-low Control on Multi-process & Multi-pollutant of Iron & Steel Industry" co-completed by Sinosteel Tiancheng Environmental Protection & Technology Co., Ltd. (Sinosteel Tiancheng) were awarded respectively the first and second prize of the State Scientific and Technological Progress Award.

State Scientific and Technological Progress Award

- First prize of the 2020 State Scientific and Technological Progress Award - Technology and Application of Industrial Flue Gas Multi-pollutant Control by Sinosteel Tiancheng
- Second prize of the 2020 State Scientific and Technological Progress Award - Technology and Application of Ultra-low Control on Multi-process Multi-pollutant of Iron & Steel Industry by Sinosteel Tiancheng

Engineering News-Record (ENR)

- Since 2008, Sinosteel MECC has been listed on ENR Top 250 International and Top 250 Global for several consecutive years, and hit a new high in 2019 on 107th.

National Quality Engineering Award

- The Gas Cleaning Works for the Relocation Project of Hebei Risun Coking (EPC) won the 2020-2021 National Quality Engineering Award.
- The 2.5mtpa SISCO straight grate pelletizing project in the Middle East (EPC) won the 2020-2021 National Quality Engineering Award.
- The 2.5mtpa ZISCO pelletizing project in the Middle East (EPC) won the 2018-2019 National Quality Engineering Award
- The 3mtpa Cudeco copper ore beneficiation plant project in Australia (EPC) won the 2018-2019 National Quality Engineering Award.
- The ICDAS BIGA 2x600 MW power plant unit 2 project in Turkey (EPC) won the 2016-2017 National Quality Engineering Award.
- The 1.2mtpa MSPL pelletizing project in India (EP) won the 2014-2015 National Quality Engineering Award
- The Isdemir No.4 blast furnace project in Turkey (EPC) won the 2012-2013 National Quality Engineering Award.
- The Tosyali Osmaniye 950mm hot rolled strip EP project in Turkey (EP) won the 2011-2012 National Quality Engineering Silver Award.

Ministry of Ecology and Environment

- 2021 National Advanced Pollution Prevention and Control Technology Catalogue (air pollution prevention and control field) - Catalytic cracking regeneration flue gas bag filtering + wet desulfurization cleaning technology by Sinosteel Tiancheng;
- First Prize of 2019 Environmental Protection Science and Technology Awards - Ultra-low emission control technology of multiple pollutants from multiple processes and its application by Sinosteel Tiancheng;
- 2018 National Advanced Pollution Prevention and Control Technology Catalogue (air pollution prevention and control field) - Pre-charged bag filter technology and catalytic cracking regeneration flue gas dedusting and desulfurization technology by Sinosteel Tiancheng;
- Second Prize of 2017 Environmental Protection Science and Technology Awards - Technology and equipment for ultra-low emissions of fine particles from kilns and furnaces in the steel industry by Sinosteel Tiancheng.

Ministry of Industry and Information Technology

- Catalogue of Major Environmental Protection Technology and Equipment Encouraged by the State (2020 Ed.) - Pre-charged bag filter, coke oven flue gas multiple pollutants dry co-processing equipment, and catalytic cracking regeneration flue gas treatment equipment by Sinosteel Tiancheng

Ministry of Education

- Special Prize of 2019 Outstanding Achievements Award in Scientific Research of Colleges and Universities - Key technologies for an in-depth treatment of multiple pollutants in flue gas and its application in non-electrical industries by Sinosteel Tiancheng;

National Development and Reform Commission

- Green Technology Promotion Catalogue (2020) - Pre-charged bag filters for capturing fine particles in flue gas from kilns and furnaces to achieve an ultra-low emission developed by Sinosteel Tiancheng;

Fastmarkets Global Performance Excellence Award

- The controlled rolling and controlled cooling process and supporting equipment of the self-developed long product rolling technology were shortlisted for the 2020 Fastmarkets Global Performance Excellence Award, the only shortlisted one from a Chinese engineering company;

China Engineering and Consulting Association

- Sinosteel MECC has been selected into the 2019 and 2020 List of Overseas Engineering Benchmarking Enterprises in the National Survey and Design Industry consecutively;

China Association for Science & Technology

- Top 10 Scientific and Technological Advances in China's Ecological Environment in 2019 — "Key Breakthroughs in Core Technology of Ultra-low Emission in China's Steel Industry" and "Collaborative Deep Treatment Technology for Multiple Pollutants in Industrial Flue Gas" by Sinosteel Tiancheng

China Association for Work Safety

- The Second Prize of Scientific and Technological Progress Award in 2021 — research on the standardized management system for work safety of enterprises and the formulation and application of national standards conducted by Sinosteel SEPRI

All-China Federation of Trade Unions

- 2021 National Worker Pioneer — "863" technical achievement promotion team of Metallurgical and Building Materials Division of Sinosteel Tiancheng

World Metals

- Top 10 Technology Highlights of the Global Steel Industry in 2021 — Hydrogen-enriched carbon recycling blast furnace project constructed by Sinosteel MECC on EPC basis for Bayi Iron & Steel Co., Ltd. and intelligent sintering control system developed independently by Sinosteel MECC
- Top 10 Technology Highlights of the Global Steel Industry in 2020 — the Twin high-speed bar mill project for Hunan Valin Group LY Steel Co., Ltd. constructed by Sinosteel MECC on EP Basis, which is also the first domestically manufactured twin high-speed bar mill line

China Metallurgical News

- "Green and Low-Carbon Technologies" on Green List of Steel and Industrial Chain in 2021 — the travelling grate pelletizing technology, DRI technology, and long product rolling technology of Sinosteel MECC, and the technology of pre-charged bag filter for capturing fine particles in flue gas from kilns and furnaces to achieve an ultra-low emission of Sinosteel Tiancheng.
- Green Benchmarking Enterprises of Steel Industry Chain in 2021 — Sinosteel MECC and Sinosteel Tiancheng

Leading Technologies Empowering High-quality Development

Category	Technology	Description
Green metallurgy	Comprehensive utilization of flue gas from sintering machine and annular cooler	By adopting proprietary technologies including sintering flue gas circulation, micro-power circulation of annular cooler flue gas, cascade utilization of annular cooler flue gas, and efficient comprehensive utilization of flue gas waste heat, low-energy-consumption sintering has been achieved. The continuous innovation of new sintering machine, annular cooler and expert system have improved the stability and intelligence of sinter production.
	Intelligent sintering control system	Mathematical modeling, knowledge base, big data analysis and artificial neural network are used to realize the complete sintering intelligent control by subsystems of sintering process control, closed-loop quality control and production information management.
	Travelling grate pelletizing (2-7million tons per year)	The self-developed travelling grate pelletizing is among the key technologies to realize the energy efficiency improvement and low-carbon production of conventional blast furnace ironmaking. The process energy consumption is less than 18Kgce/t at full magnetite production. As the cleanest burden and a substitute to sinter in blast furnace iron making, the travelling grate pellets have substantial advantage in decreasing pollutants and carbon emission which will drop by 10% in case fraction of pellet for blast furnace is increased from 10% to 50%.
	7.5 m top-charging coke ovens of low energy consumption and low emissions (Type ZG7.5x3-I)	Integrating the clean, efficient and advanced process technology and automatic and intelligent control technology of large coke ovens, the system allows the key economic and technical indicators to reach advanced level among similar types. The development of infrared imaging and automatic temperature measurement of lontitudinal temperature by robot as well as intelligent heating control system led to intelligent, optimized and stable heating operation of coke ovens.
	Heat recovery coke oven	Solves the problems of high pollution and emission of conventional coke ovens in terms of coking process, assures complete combustion of all volatile substances produced by coking, and make full use of the high-temperature flue gas generated for power generation or heating. Technological optimization and upgrade of flue gas combustion system and suction adjustment system are made to improve the upward temperature uniformity and thermal efficiency of coke ovens.

Category	Technology	Description
	Hydrogen-enriched carbon recycling blast furnace	Low-carbon blast furnace featuring full-oxygen smelting, hot gas injection at furnace stack and tuyeres can not only reduce CO_2 emissions by 30%, but also greatly improve the efficiency of furnace, exploring a new low-carbon smelting route for conventional BFs.
	Ferroalloy	Technologies of ferrochrome and silicon-manganese alloy hot charging, SAF flue gas waste heat utilization, and SAF automatic charging system.
	EAF steelmaking	EAF continuous charging technology: full scrap top charging, DRI hot charging and cold charging, horizontal charging scrap preheating and hot metal mixing; induction furnace melting DRI; HDRI hot charging and hot transfer technology.
	DRI	DRI is considered as the main technological approach for the steel industry to achieve carbon emissions peak and carbon neutrality. "DRI + EAF" steelmaking can reduce CO_2 emissions by 50-60% compared to conventional "BF + BOF". Two of the world's largest DRI projects -- 2.5mtpa DRI project for TOSYALI Algeria and 2.5mtpa DRI project for Algerian Qatari Steel (AQS), have been constructed by Sinosteel MECC and put into production.
	High efficiency long product rolling	Independently developed technologies and equipments such as bar and wire rod TMCP technology, rolling mills and flexible water cooling device, high-speed bar delivery system, as well as modular rolling mill and water cooling device, can reduce alloy adding and cost. With use of this domestically leading technology, Sinosteel MECC constructed China's first twin high-speed bar line, with a maximum rolling speed of 45 m/s and to be increased to 50 m/s.
	Hydrogen metallurgy	Contracted the hydrogen-based shaft furnace of Baosteel Zhanjiang on EP basis. As the first million-ton hydrogen-based shaft furnace in China, and also the first DRI production line integrating hydrogen and coke oven gas for industrial production, the project, after being put into operation, can reduce CO_2 emissions by more than 500,000 tons compared to the conventional BF ironmaking process of same liquid iron output.
Synergetic Pollution and Carbon Emission Reduction	PM2.5 pre-charged fine particle control technology and equipment	As an achievement of a scientific research project under the National High-tech R&D Program (863 Program) during the 12th Five-Year Plan, this technology is an effective means to control fine particles. The pre-charged electrostatic fabric filter has been applied in the "First (Set) of Major Technical Equipment" project in China, with its core indicators rated as the internationally leading level.

Category	Technology	Description
	Bag filtering technology and equipment for flue gas from charge end of large sintering machine	Independently developed the vertical top air intake bag filter, special anti-corrosion filter material, and core technologies of anti-condensation and anti-corrosion to ensure the safe operation of bag filter system suitable for the flue gas from charge end of sintering machine, which achieves the ultra-low emission of flue gas, with particles concentration emission less than 10mg/m^3, equipment resistance of 800~1,000Pa, and operating energy consumption reduced by more than 40% compared to conventional bag filters.
	Control and collaborative treatment technology for fugitive emissions of waste gas from coke storage tank of delayed coking units	With this technology, the coke storage tank, top coke-grabbing crane, decoking water sedimentation tank, and tar separator are sealed to control the waste gas generated from coke storage tank. The company has independently developed technology and equipment such as sealing, collection and treatment of waste gas from decoking of delayed coking units, as well as intelligent coke-grabbing crane. The concentration of H_2S is less than or equal to 25mg/m^3 and particles emission is less than or equal to 10mg/m^3 post-treatment, far lower than the national and local standards.
	Bag filtering + wet desulfurization cleaning technology for catalytic cracking regeneration flue gas	This proprietary technology renovated the conventional wet scrubbing and dedusting, and changes the particles treatment "from wet to dry". After dedusting by "high-efficiency bag filter", wet desulfurization, gradient "absorption + scrubbing" and modular absorption and demisting process independently developed, ultra-low emission of flue gas can be achieved.
	Dedusting, desulfurization, and denitration technology for reheating furnaces and hot blast stoves	The combined process of "medium-high temperature SCR denitration + SDS dry type desulfurization process with baking soda + bag filter" independently developed can clean the NO_x, SO_2 and particles in the flue gas emitted by reheating furnaces, to achieve ultra-low emissions. The company developed the indirect heating system to heat up and denitrificate the flue gas on the coal smoke side of reheating furnaces, the combined heating of coal smoke and air smoke, and the integrated process of SDS desulfurization and dedusting, which can realize safe, energy-saving and efficient cleaning of flue gas from reheating furnace.
	Comprehensive steel slag recycling technology	It is a project under the National Science and Technology Support Program during the 12th Five-Year Plan. A three-stage mathematical model of gradient slag utilization model and comprehensive utilization evaluation of "metallurgical process reuse → valuable element extraction → end utilization" was established and successfully applied in Hunan Valin Xiangtan Iron & Steel Co., Ltd. This technology can improve the slag utilization and sensible heat recycling in steel enterprises, and achieve economic and environmental benefits.
	High-concentration refractory organic wastewater treatment technology	The deep treatment and recycling technology for leachate in waste incineration plants and the treatment technology for concentrated organic wastewater produced from RO process with the synergy of Fe_3O_4 and pulse electrolysis have been developed, reaching an international advanced level. A large number of treatment processes and technical equipment for landfill leachate and coking wastewater from coking plant have been developed, and more than 30 engineering projects of leachate treatment for municipal waste sanitary landfills and waste incineration plants have been completed.
Smart safety and occupational health	Smart safety management and control platform and safety consulting integrated technology	Intelligent safety perception network, safety risk management and control map, safety emergency big data center, safety risk prevention and control and emergency command center are completed, realizing a smart safety management mode featuring thorough perception of safety status, comprehensive integration of safety data and regulatory business, and highly intelligent safety management.

Category	Technology	Description
	Early warning system for smart safety and smart construction site	Modules include management of related parties, intelligent management and control for operator safety, intelligent equipment safety, safety performance assessment automation, safety visualization center, and expert consultation. Smart safety management is achieved via VR experience, intelligent management and control, functional supervision, quantitative assessment, and visualization.
	PPE and smart cloud management R&D system for occupational health	With smart and safe technical means, self-management, application for use and user training of PPE, PPE supply chain distribution, employees' using habits and effects, smart management of multi-user terminals including enterprise managers, supply chain merchants and operators based on the big data analysis, smart PPE management will be realized to ensure the reliability of PP, and reduce unnecessary costs for enterprises.
	Interactive safety education and training system platform and experience center based on "Internet Plus"	By adopting the cloud computing technology, online training implementation management platform is established. With Internet as the carrier, and computers, mobile communication device, as well as VR interactive device as customer terminals, the company can provide customers with one-stop service for the implementation and management of work safety training.
	Big data platform for safety accidents in the metallurgical industry	Software system is developed with accident case collection, import and upload, pre-processing, automatic retrieval (crawler function) and data cleaning, accident database establishment, online address resolution service based on mainstream network e-maps (two-dimensional – the whole process of metallurgical production technology; three-dimensional – ironmaking, steelmaking and hot rolling (phase I), and thermodynamic chart and related charts of production safety accidents.
	Process monitoring and tip-over protection control system for high temperature molten metal lifting operation	With distributed system, the field instruments exchange data through remote I/O; the real-time and highly reliable online monitoring and control of motor operating parameters of crane and trolley, as well as tilting angle and frequency of steel cables when lifting hot molten metal are achieved to prevent lifting container from tipping over.
	Intelligent ventilation regulation and control system for metal and non-metal mines	As one of the key projects of the mining industry of the 14th Five-Year Plan, it reflects IT-based and intelligent construction, and mainly includes 3D ventilation simulation system of mines, real-time monitoring and pre-warning system of operation parameters of mine ventilation system, intelligent decision-making system remote intelligent adjustment of underground ventilation structures, intelligent response to mine disasters, and mine power line data transmission system.
	Explosion-proof technology for combustible dust in industrial and trade enterprises	It is a pioneer technology in the development of dust explosion risk assessment software for feed processing and mechanical processing, which can effectively cut the cost of dust explosion risk assessment for enterprises.
Low carbon planning and carbon emissions consulting		Provides governments and enterprises with professional carbon asset management and consulting services throughout the entire life cycle to achieve the goal fo carbon emission peak and carbon neutrality.

Updates

Two self-developed technologies of Sinosteel MECC identified to reach international advanced level

On December 17, 2021, the Complete Equipment and Key Technology for High-efficiency and High-precision Controlled Rolling Twin High-speed Bar Rolling and the R&D and Application of 7.5-meter Low-energy and Low-emission Top-charging Coke Oven independently developed by Sinosteel MECC were identified by the scientific and technological achievement evaluation in the meeting hosted by China Iron and Steel Association.

The Evaluation Committee composed of 11 senior industrial experts led by the CAS Academician Mao Xinping unanimously agreed that the Complete Equipment and Key Technology for High-efficiency and High-precision Controlled Rolling Twin High-speed Bar Rolling independently developed by Sinosteel MECC significantly improved production efficiency, product precision and quality, reduced the alloy costs and energy consumption, and reached international advanced level and the Φ265 top-cross heavy-duty modular mill tops the world level. Mao Xinping expressed his expectation: "I wish Sinosteel MECC a greater success in the follow-up commercial application."

The Evaluation Committee composed of the Chinese Society for Metals, China Coking Industry Association, University of Science and Technology Beijing, and coking plants unanimously agreed that the ZG7.5X3-1 Coke Oven independently developed by Sinosteel MECC was applied succesfully at Fangchenggang Steel Base of Liuzhou Iron & Steel Co., Ltd. and realized stable operation with low energy consumption and low emission, putting an end to the absence of the extra-large coke oven models. The achievement created significant economic and social benefits, with a broad prospect for promotion and reached the international advanced level. Expert from the Chinese Society for Metals said: "I hope Sinosteel MECC outputs great achievement not only in engineering, but also in technology, to contribute to the transformation of the coking industry."

More efforts made to tackle climate change: national R&D project of Sinosteel SEPRI officially launched

In December 2021, the key R&D project of the Ministry of Science and Technology, led by Huazhong University of Science and Technology and participated by Sinosteel SEPRI -- Research and Application of NQI Collaborative Innovation to Lead Typical Industries to Realize Carbon Peak was officially approved.

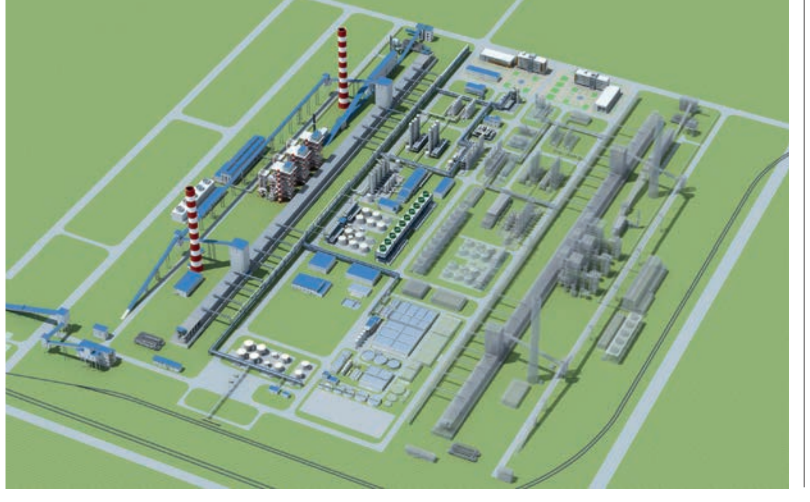
This key project (Carbon Peak, Research and Application) is the only one focusing on carbon peak among the 36 projects. The 5-year Project contains 5 sub-topics, of which 2 are undertaken by Sinosteel SEPRI – Topic 1: Research on Technology Roadmap for Prioritized Carbon Peak in Typical Industries Including Thermal Power, Steel, and Building Materials, and Topic 4 – Research on Key Technological Standard System and NQI Collaborative Control for Carbon Peak in Typical Industries. Sinosteel SEPRI has been involved since application of the Project, and prepared the project plans and budgets for the steel-industry-related contents in the two sub-topics.

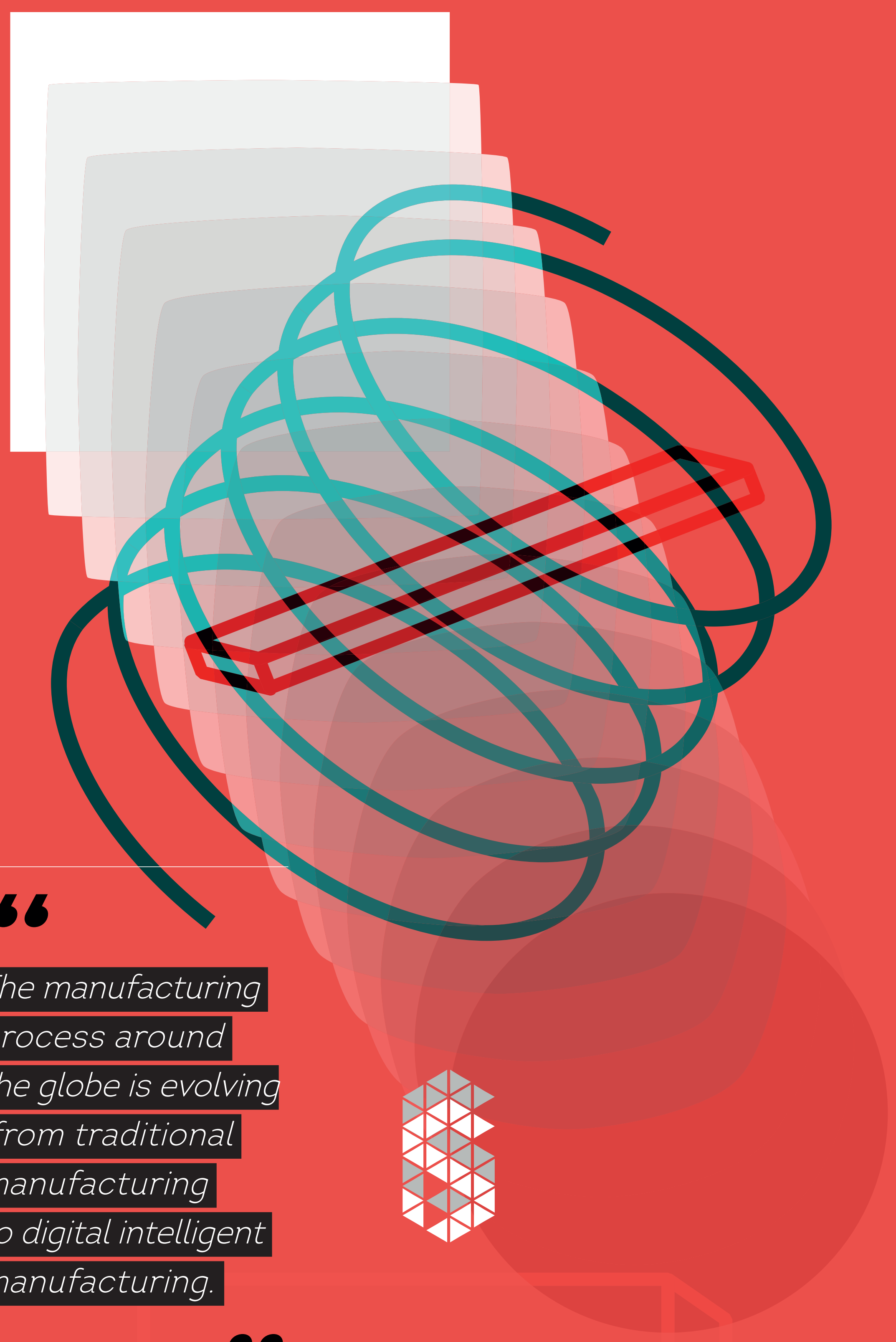
Sinosteel SEPRI will give full play to its outstanding capabilities in carbon asset management and consulting, prepare the Steel Industry Carbon Emissions Inventory of China and 2 steel industry standards considering the actual demand of the steel industry and the typical enterprises in their carbon peak work fully complying with the statistical and accounting system being upgraded and improved by China, and assist in pilot work of implementing the carbon peak technology roadmap for the steel industry, in a bid to achieve the following goals:

- **To complete at least 1 special report on the typical industries' carbon emissions inventory and analysis;**
- **To conduct more than 6 enterprises implementing the carbon peak roadmap as pilots;**
- **To draft 2 steel industry standards, and carry out the defense for approval.**

The above goals, if fulfilled, will effectively guide and advance the green and low-carbon development of steel enterprises, facilitate the enterprises to establish and improve the management system to monitor and control their carbon emissions data, help them set low-carbon development goals and technology roadmaps in a more rational way, and provide them with references for more efficient execution and timely adjustment of the implementation approaches to carbon neutrality.

At the end of 2021, a demonstration meeting on the plan was held, where the expert panel agreed that the Project Implementation Plan was well in line with the requirements in the guideline, with rational topics, clear logic, proper technology routes, and feasible research methods and execution schemes, offering guidance and suggestions to the following Project implementation.





> The manufacturing process around the globe is evolving from traditional manufacturing to digital intelligent manufacturing.

Digitalization Unlocks Full Potential in Steel Industry

Sinosteel E&T: Build a Solid Digital Foundation for Steel Industry

Background of Digital Transformation

The steel sector upgrades rapidly, and the development possibility of digitalization, networking and intelligence is undoubtedly the new catalyst for high-quality development. Embracing digital disruption is essential for advancing the combined growth of the steel industry and digital economy.

Sinosteel E&T is riding on the momentum for growth and actively exploring ways to speed up the development of digitally intelligent infrastructure. It also fully utilizes the enabling and transformative effects of digital technology on the growth of the steel industry, as to significantly improve the quality and effectiveness of enterprise products and services. Sinosteel E&T focuses on key tasks like "new technology development of low-carbon metallurgy, carbon reduction of conventional steel production process, engineering technology development of combined steel and chemical production, and the promotion of digital transformation" in order to solidify the foundation for the development of an outstanding enterprise and for the development of intelligent manufacturing.

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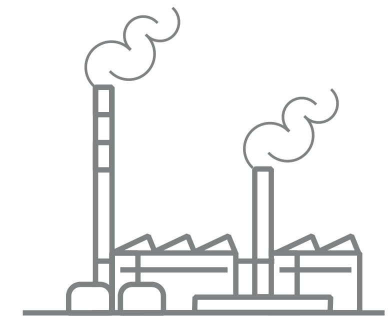
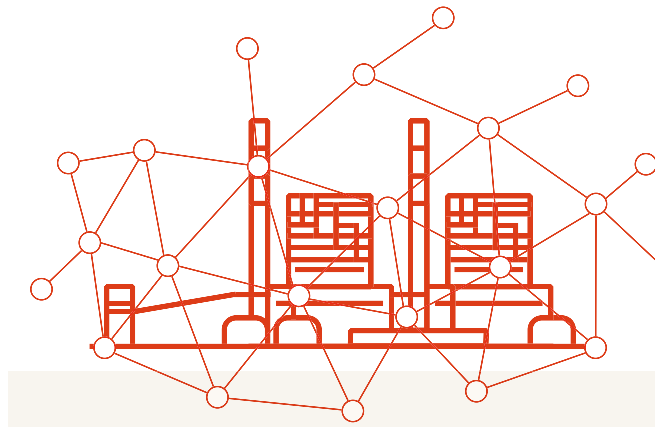
The Impact of Digitalization in the Development of the Steel Industry

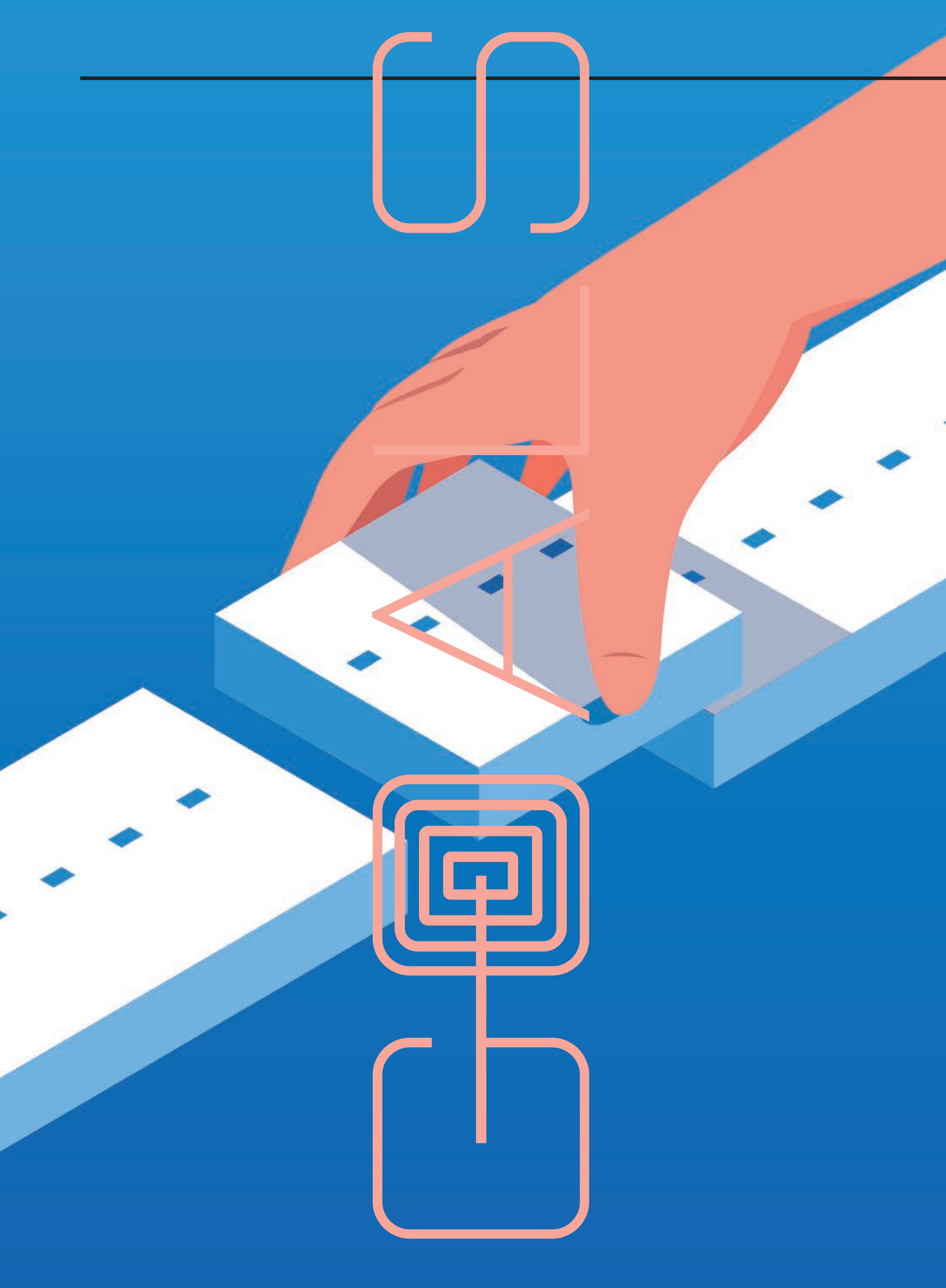
As the pillar industry of China's national economy, the steel industry, which is crucial to people's livelihoods, plays an irreplaceable role in China's industrial modernization.

Since the steel industry struggles with issues like low resource utilization efficiency, high energy and material consumption, high production costs, and severe environmental pollution because it is characterized by the complex production process, strong coupling between processes, and challenges with overall optimization. The broader adoption of information technology within the industry has been aggressively advanced in recent years and there have been early successes in quality improvement, efficiency enhancement, cost reduction, and green and safe development.

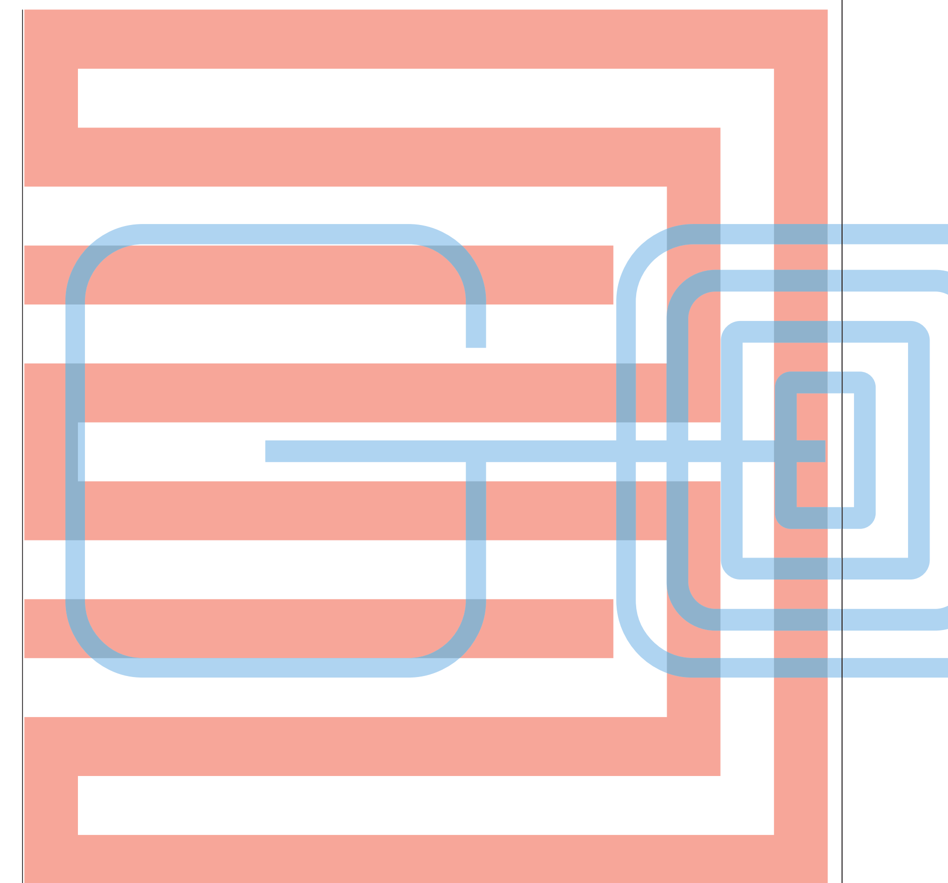




CONVENTIONAL Plant		DIGITAL Plant
High labor dependency causes issues including challenging quality inspection efficiency control and shaky precision.	**Quality**	**Comprehensive quality control capability, including collaboration across the entire industry chain & online analysis and optimization.**
Production on a large-scale, with sales based on yield. Serious resource waste led by overcapacity.	**Product**	**Mass manufacturing of bespoke product. Resource usage efficiency will increase with flexible production that is oriented on user needs.**
Given that diversified channel construction capabilities, products might not be marketable due to lack of insight.	**Market**	**Accurate marketing to boost product sales, sensitive market response, and real-time perception of clients' demands.**
High costs for R&D due to protracted product development cycle, a full-scale test's failure or a mid-term plan's modification, etc.	**R&D**	**The paradigm of "big design, small experiment" has been adpoted in favor of the model of "trial & error R&D", greatly increasing the effectiveness of R&D.**
The cost of labor rises yearly, and the cost of raw materials fluctuates dynamically with considerable unpredictability.	**Cost**	**Automation, intelligence, online operation and maintenance, and other factors help to improve cost management while lowering personnel participation & other costs.**



Target of Sinosteel E&T's Digital Transformation



3.1 Vision

To realize the green construction of the engineering projects and the green manufacturing of steel companies, Sinosteel will develop an independent and controllable digital construction platform, assisting the company in offering top-notch industrial engineering technology services.

3.2 Major Goals

Taking the EPC contracting of the engineering projects as an example, project management needs to be thoroughly examined in advance. In the process, it is necessary to balance decision made regarding cost, progress, and quality as well as to foresee and analyze the project's current position with the use of dynamic vision and qualitative data. The success of the engineering project determines the future of the businesses involved in the manufacturing and operation of steel enterprises. Sinosteel E&T's goal of digital transformation has been established in light of the aforementioned urgent necessities.

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Driven by digital technology, the company seeks to realize the digitalization of the entire engineering process, including all components and all participants, in order to enhance project execution quality and benefit clients as well as the steel industry.

3.3 Strategy Implementation

We will promote a new mindset of "increment, integration & innovation" for the digital transformation;

We will continue in the new direction of green construction and green manufacturing with digital factories, focusing on the needs for the transformation and development of the steel sector that is green and low-carbon;

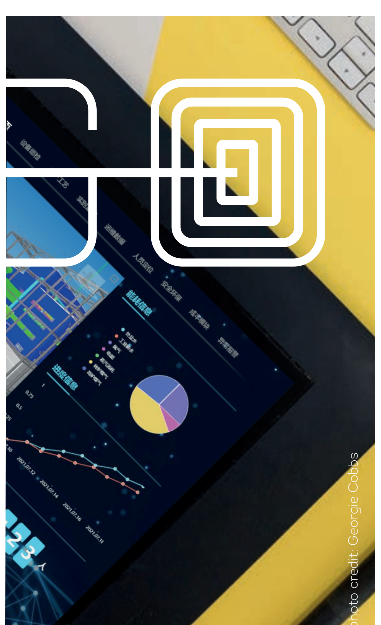


photo credit: Georgie Cobbs

We will develop a brand-new digital twin platform that connects all parties involved in project construction, opens up virtual reality and runs through the life cycle of construction projects;

We shall establish a new ecology of digital creation with the ongoing cooperation and iteration of stakeholders.

3.4 Modes

Digitalization of the management system: Data-driven and big data analysis are used to make it easier to manage project progress, costs, quality, safety and other businesses with greater precision.

Digitization of the operational process: The digitization of design, procurement, and construction is utilized to improve efficiency and quality to ensure effective project implementation.

Digitalization of R&D innovation: Production factors and operation processes are monitored and managed comprehensively and intelligently using on-site real-time data, and historical data, offering a wealth of big data and verification techniques for R&D innovation.

Value-added services are being digitalized, which uses technology to increase the range of available services and business models.

3.5 Measures

① Modifications to business models

Customized services are introduced to the delivery mode in addition to factory entities to increase added value. The transaction model has been modified to include the uses and functions of products and services. To get closer to customers with more interactions, the life cycle service is adopted.

② Consolidation in the use of digital design and delivery to empower business

To encourage digitization at the outset of factory design, a master engineering data system is set up;

In order to cut costs, boost efficiency and customer satisfaction, the refinement of each link of the EPC project is improved from the perspectives of visual forward co-design, collision inspection, quota optimization design, and progressive digital delivery;

To help set up a digital design and delivery system in green and low-carbon metallurgical projects, an engineering big data center is built, thus addressing the low-carbon technological transformation market in the steel industry.

③ Speed up commercialization of the digital twin platform

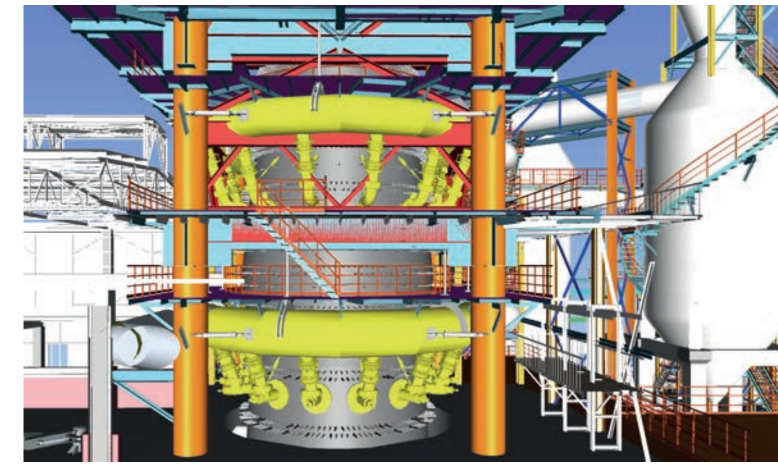
In order to provide digital upgrading services for existing factories and to construct digital twin factories harboring the data for life cycle, full operation, and overall business management.

④ More focus on the talent team

We will employ additional specialists to build a team of digital talents consistent with our "intellectualization" plan, accelerating the digital transformation and upgrading through hiring and internal training;

We will hold trainings on BIM 3D design abilities, digital delivery software and digital delivery standards to provide a thorough grasp of the evolution of digital delivery standards at home and abroad, as well as the functions and application scenarios of digital delivery systems;

Targets of digital transformation



We will initially set up the environment with software and hardware facilities supporting digital construction before constructing a digital delivery service team and supporting software and hardware facilities, leading to the echelon of digital delivery team management and talent for the team.

⑤ Continuous improvement of network security protection capabilities to maintain the information network environment

We will set up a rapid emergency response mechanism and a sub-headquarters for network security;

We will comprehensively sort out information-based assets, put risk identification into practice, enhance emergency plans, and expedite danger point correction;

We will strengthen the capacity to address serious hazards, improve the emergency protection mechanism, and the assurance of fundamental information infrastructure;

We will raise employees' awareness of the importance of protecting network information by imparting knowledge and providing training on network security.

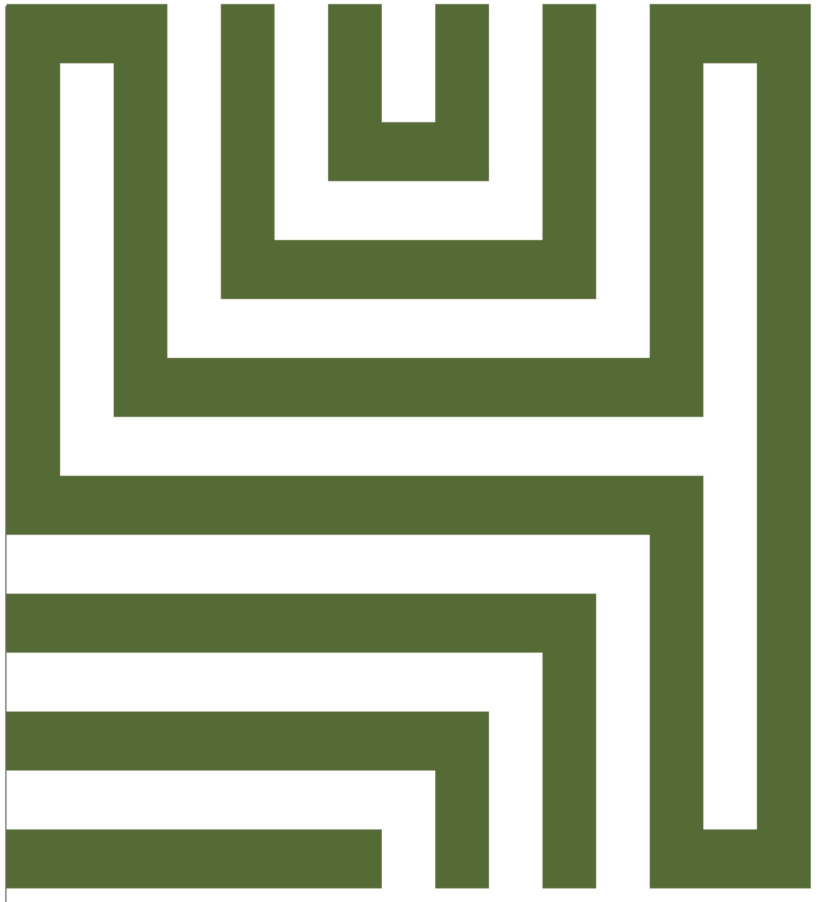
> *Embracing digital disruption is essential for advancing the combined growth of the steel industry and digital economy.*

photo credit: Redd

4.1 Digital Design

Since 2013, Sinosteel E&T has realized visual design, collision inspection and pipeline forward drawing in the projects of Ukraine AMKR travelling grate pelletizing, Bolivia Mutun integrated steel complex, Turkey blower station, Tosyali Algeria steelmaking and rolling, Tosyali Algeria travelling grate pelletizing, Tosyali Algeria DRI, two of which also adopted quota design, optimization design and 3D model delivery. At present, we are able to implement digital design, multifaceted participation in different work settings, and complete pipeline, electrical system, and civil engineering coverage in software architecture.

Our Digital-related Work and Achievements



4.2 Digital Delivery

Coupled with the brought-in developed digital delivery products and independent R&D, we have set up the network server to digital delivery and developed the own-brand digital delivery platform.

We have drawn up rules for digital delivery that cover digital systems and procedures at the project level. Additionally, programs for digital distribution are beginning to take shape as proprietary technologies and management processes get established.

To improve the Sinosteel coding system, we have set up the foundation of the digital standard system guided by in-depth study on the pertinent standards at home and abroad. To this end, we have established the coding regulations, data dictionaries, collecting requirements, and handover guidelines.

We have developed a real-world 3D platform on which the model of existing digital sites and old factories can be generated with the use of oblique photography and laser scanning technology.

Digital delivery is in practice in projects of the traveling grate pelletizing of Baowu Ma'anshan Steel and Ukraine AMKR respectively, as well as of the hydrogen-enriched carbon recycling blast furnace of Baowu Bayi Steel, helping foster the digital delivery capability.

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4.3 Intelligentization

Guided by the carbon peaking and carbon neutrality goals, we have optimized the green and low carbon pelletizing technology for travelling grate pelletizing equipment. We have created a CFD simulation-based industrial Internet architecture that is reliant on numerical calculation for traveling grate pelletizing technology. A secondary expert control model with an operational "control cabin" has also been built based on the big data operation center to support the digital twin function and enable intelligent decision-making and operation.

We have been investigating how traditional sintering and blast furnace operations may be transformed digitally. We have built digital product models based on sintering and ironmaking processes in addition to a digital factory that strives to customize solutions in line with product design specifications. The "intelligent control system for sintering" independently designed and developed by Sinosteel MECC made the automation and intelligence of the sintering production process a reality, helping or replacing the operators to control the sintering production. It combines artificial intelligence with the fundamental theory and production practice of sintering process.

photo credit: Sajad Nori

High-end wire rod and bar rolling has a strong digital & intelligent design integration. This enables the digital design of process, pipeline, steel structure and building, and the rolling workshop of high-speed wire and bar. With the centralized control system for the intelligent production, we have built the mode of one line in one room, or one line in two rooms. This enables all rolling lines to operate automatically or with minimal staff.

In continuing low-carbon metallurgical engineering projects, we have fully embraced digitization to efficiently promote the quantitative analysis of project progress management using information technology, providing scientific and accurate data support for project implementation decisions.

4.4 Highlights and Capabilities

4.4.1 Sinosteel E&T's Digital Twin Platform

With decades of construction experience in engineering projects and practical experience in digital design and handover, Sinosteel E&T has developed its own digital twin platform, which is composed of a digital design platform, a digital handover platform, and a real 3D platform. It performs the following functions:

Interconnectivity. In order to realize the connection between business flow, information flow, and capital flow, its digital design platform, which serves as an industrial internet platform, integrates the digital genes of key engineering data, factory objects' tags, and material codes into a digital factory. The digital handover platform and the actual 3D platform allow remote collaboration of the entire process, all components, and all project participants as well as real-time online monitoring of all the elements involved, including "manpower, machinery, materials, methods, and environment". In this way, systems like digital customization can be used to realize a comprehensive interconnection between demanders and suppliers, eventually forming a digital ecology of data-driven projects, flexible complementarity between enterprises & industries, and efficient configuration, thus fostering a steel ecosystem of B/S architecture.

Synergy. It can completely satisfy the needs of customers and businesses by offering virtual construction services and virtual-real twin operation and maintenance services to meet the needs of multi-party collaboration at various stages. On the same platform, in the design stage, multiple designers collaborate throughout the design phase, which is followed by the handover of a digital factory. Equipment and material procurement lists are prepared automatically. In the construction phase, the factory building and on-site installation are driven by on-site demands to achieve an effective allocation of construction resources. In the operation and maintenance phase, a visualization platform is utilized to provide customers with personalized and precise data services necessary for operation, maintenance and decision-making.

Digital intelligence. Engineering projects' intelligent brain and scheduling hub will undoubtedly be the digital twin platform. Multiple application systems can sense and identify the entire process and all elements of the objects generated by a project through the deployment of IoT devices and on-site activities, thus achieving smart construction through a "data + algorithm" approach.

Security. In order to guarantee the security of the data for each engineering project, it is implemented on the company's private cloud server.

4.4.2 Capabilities of a Digital Factory

Platform empowerment to achieve virtual and real handover. For any engineering project, a digital twin factory may be built using Sinosteel E&T's Digital Twin Platform to realize fully digital design, process simulation & progressive handover. Then, a physical factory can be built and handed over based on the digital twin factory. All stakeholders can engage in the whole process on the platform, enhancing both the "soft power" of refined management of the whole industry process and the "hard power" of fully digital construction and services. Utilizing real-time optimization and iteration of handing over digital virtual and physical objects, it systematically realizes the optimal resource allocation along the entire industry chain, maximizes production efficiency, and meets customer needs.

Multi-party participation and efficient collaboration. The company can fully maximize resource allocation efficiency of enterprises thanks to the digital transformation & platform empowerment. It can also make science and data-based decision, resulting in intensive project management and simultaneous digital application in numerous large projects. On the digital handover platform, the designer, customer, construction party, and supervisor are united for project docking & reconciliation. This allows conflicts to be resolved in advance, reducing rework and greatly increasing work efficiency.

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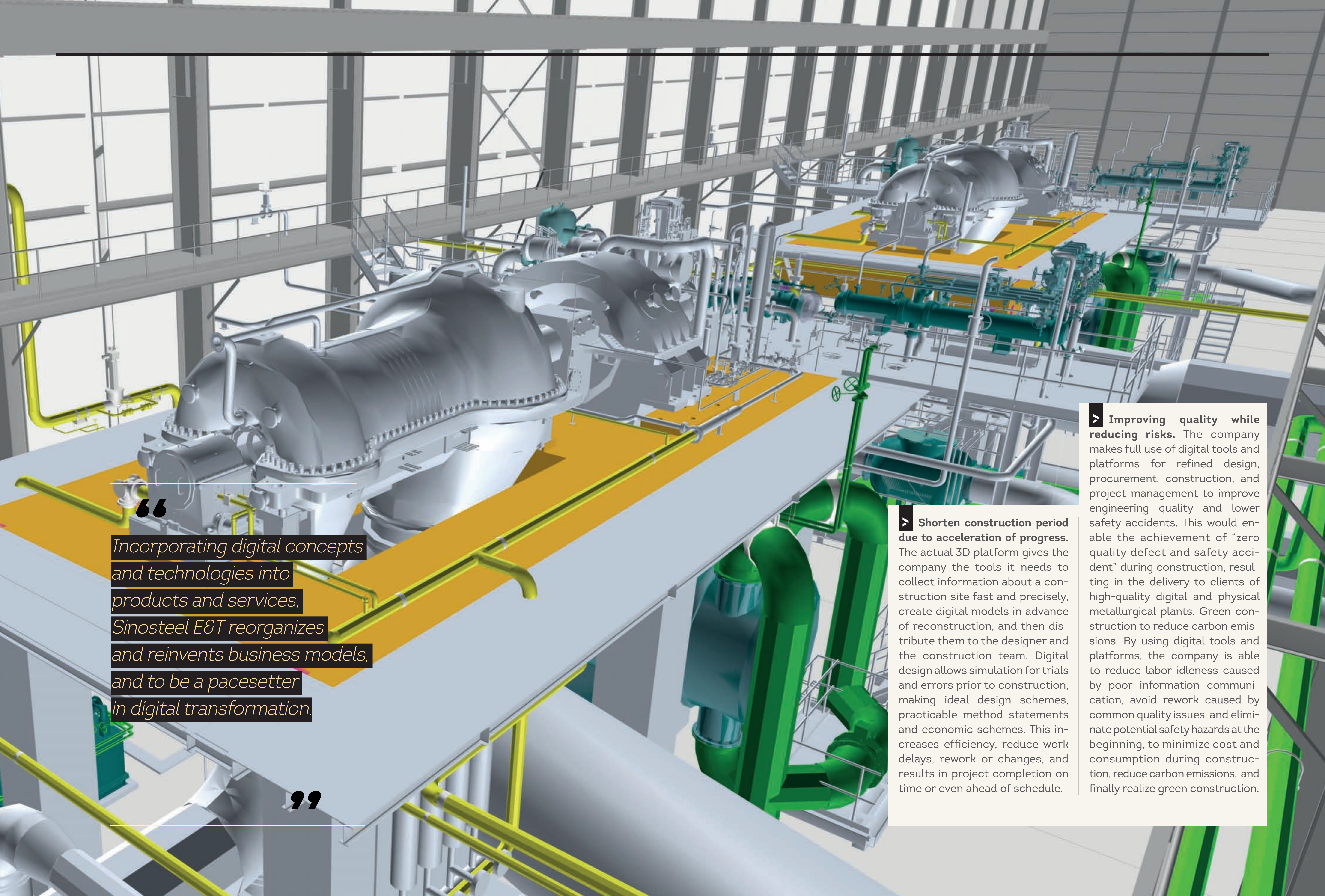
Interconnectivity

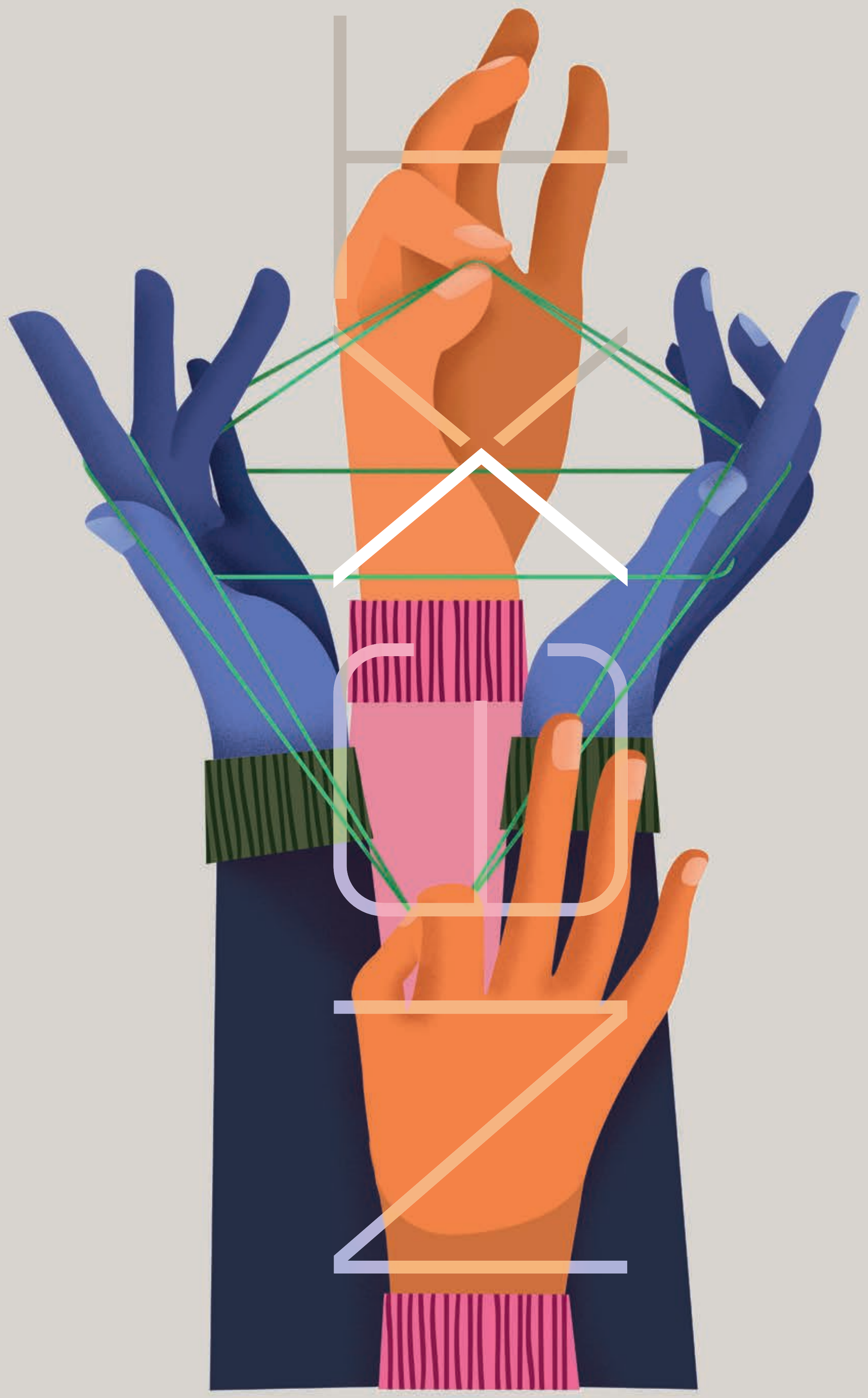
All project participants as well as real-time online monitoring of all the elements involved, including "manpower, machinery, materials, methods, and environment".



> *Incorporating digital concepts and technologies into products and services, Sinosteel E&T reorganizes and reinvents business models, and to be a pacesetter in digital transformation.*

Shorten construction period due to acceleration of progress. The actual 3D platform gives the company the tools it needs to collect information about a construction site fast and precisely, create digital models in advance of reconstruction, and then distribute them to the designer and the construction team. Digital design allows simulation for trials and errors prior to construction, making ideal design schemes, practicable method statements and economic schemes. This increases efficiency, reduce work delays, rework or changes, and results in project completion on time or even ahead of schedule.

Improving quality while reducing risks. The company makes full use of digital tools and platforms for refined design, procurement, construction, and project management to improve engineering quality and lower safety accidents. This would enable the achievement of "zero quality defect and safety accident" during construction, resulting in the delivery to clients of high-quality digital and physical metallurgical plants. Green construction to reduce carbon emissions. By using digital tools and platforms, the company is able to reduce labor idleness caused by poor information communication, avoid rework caused by common quality issues, and eliminate potential safety hazards at the beginning, to minimize cost and consumption during construction, reduce carbon emissions, and finally realize green construction.



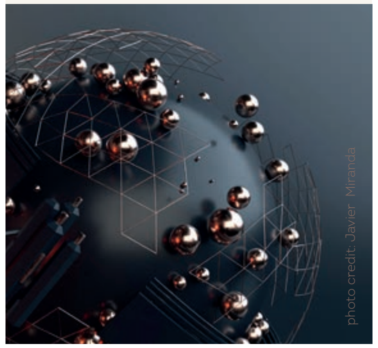
Goals for the Next Stage

Sinosteel E&T has entered the stage of technological innovation 4.0.

Focusing on the green and low-carbon transformation of the steel industry, participating in disruptive low-carbon technical engineering verification.

Promoting engineering application of proprietary intellectual property rights.

This is done under the guidance of "high-tech enterprises providing comprehensive solutions for steel and advanced materials and industrial ecosystem services" proposed by China Baowu.



Sinosteel E&T has made progress toward digital transformation through numerous experiments and partial transformation and is now set to usher in the stage of model innovation. In order to reorganize and reinvent business models and to be a pacesetter in digital transformation, the company uses digital concepts and technologies to be incorporated into products and services. It has built visible, tangible and marketable digital factories represented by traveling grate pelletizing equipment, hydrogen-based shaft furnaces for DRI production, and hydrogen-rich carbon cycling blast furnaces, which consolidate the foundation of the digital platform, and contribute to the construction of China Baowu's smart factories in China.

Practice on Hydrogen-Rich Carbon Recycling Blast Furnace 01

Yin Huan, Deputy Chief Engineer of Iron Making Department, Sinosteel MECC

CO_2

30%

Capability to cut carbon-emission around 2025

30%

Reduce carbon emissions from the peak

1 Introduction

\At the 75th Session of the United Nations General Assembly in September 2020, President Xi Jinping announced: China will strive to achieve carbon dioxide emissions peak before 2030 and carbon neutrality before 2060. At the 2020 Central Economic Working Conference, the work on carbon emissions peak and carbon neutrality was clearly defined as one of the eight key tasks in 2021. On March 15, 2021, Xi stressed at the 9th Meeting of the Central Finance and Economics Committee that achieving carbon emissions peak and carbon neutrality is an extensive and profound systemic reform for the economy and society, and it should be incorporated into the overall planning of ecological civilization development.

In 2020, China produced 1065 million tons of crude steel, among which the blast furnace ironmaking consumed a large amount of coal-based fossil energy and is the largest source of carbon emissions in steel production (accounting for 73% of the total carbon emissions in the steel industry), accounting for 11.7% of China's total carbon emissions.

To achieve carbon dioxide emissions peak before 2030 and carbon neutrality before 2060, all industries are actively making their own strategies, and the steel industry, as the third largest industrial CO_2 emitter in China, following power generation and transportation industries, is urgently demanding low-carbon development and attracts more attention from the society. The carbon peak target for China's steel industry is initially set as follows: to achieve carbon emissions peak before 2025, and reduce carbon emissions by 30 percent from the peak by 2030, or 420 million tons a year. In November 2021, China Baowu Group releases Action Plan to Achieve Carbon Neutrality: to achieve carbon dioxide emissions peak before 2023, reduce carbon dioxide emissions by 30 percent before 2035, and achieve carbon neutrality before 2050. Metallurgical technologies to achieve carbon neutrality include extreme energy efficiency, hydrogen-rich carbon recycling blast furnace, hydrogen-based shaft furnace, near net shape manufacturing, metallurgical resource recycling, as well as carbon recycling.

The mismatch between the level of green development and the needs of the ecological environment has become the main contradiction confronted by the steel industry, with a focus on reducing the intensity of carbon emissions. Controlling carbon emissions during steel production is becoming the biggest challenge to the development of the global steel industry. For China's steel industry, which produces more than 50% of the world's steel (Fig. 1) and over 60% of the world's iron, how to choose a reasonable path for low-carbon steel and iron production suitable for China's conditions is a major issue concerning the future international competitiveness of China's steel products as well as the sustainable and healthy development of the industry. In China, most of the crude steel is still produced from the long-process production, the technologies are well developed, and energy saving and emission reduction are almost at the bottleneck, so making breakthroughs in the existing production mode is the only way to continue seeking substantial energy saving and emission reduction.

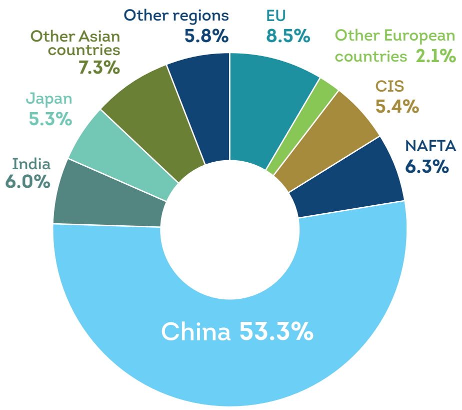
The technology of hydrogen-rich carbon recycling blast furnace is a forward-looking new low-carbon ironmaking process, and thus has not seen large-scale industrial tests in the world. China Baowu has listed it as a key low-carbon technology to reduce carbon emissions by 30% by 2025, thus laying a foundation for achieving carbon neutrality by 2050. As a user of this technology in engineering, Sinosteel Equipment and Engineering Co., Ltd. (Sinosteel MECC) boasts the first-mover advantage. Through the all-round layout covering process research, design, R&D of core equipment, summary of production and operation experiences, safety-related technical standards, etc., Sinosteel MECC will gradually form a process package with complete core technologies.

2050

Lay foundation for achieving carbon neutrality

> "Continue seeking substantial energy saving and emission reduction"

Fig. 1 Crude Steel Output by Countries



2 Technical Background

Since blast furnaces are still the mainstream equipment for ironmaking in China in the future, their low-carbon operation is the primary path to realize the low-carbon development of China's steel industry. However, though the conventional blast furnace process is a quite mature technology with very high thermal efficiency (around 93.5%), the carbon utilization efficiency is only 65~70%, and the advanced indicators of their energy consumption are considered to be close to the thermo-dynamic limit. The essence of low-carbon ironmaking with blast furnaces is to design a new carbon reduction path for blast furnaces by breaking through the heat balance limit of conventional blast furnaces, that is, decreasing process energy consumption, reducing chemical energy of gas, and seeking alternatives to carbon. A hydrogen-rich carbon recycling blast furnace is a combination of an oxygen blast furnace and the hydrogen-rich reduction process, which takes the technical advantages of both processes to make full use of the chemical energy of gas and replace carbon with hydrogen in reduction through full oxygen smelting, furnace top gas recycling as well as the injection of hydrogen-enriched gas, thus achieving the target of carbon emissions reduction.

2.1 Development History of Oxygen Blast Furnaces

The concept and the earliest process flow of oxygen blast furnaces were put forward by Wenzel, Gudenau, et al. in Germany in 1970, and pilot tests were carried out then. However, the tests ended in failure. The main problem is "cold upper part and hot lower part". On the one hand, the gas volume in the hearth is greatly reduced, and the heating of the furnace burden is insufficient, which seriously hinders the reduction in the furnace shaft, resulting in greatly reduced indirect reduction degree. On the other hand, the theoretical combustion temperature increases, leading to the reduction and evaporation of a large amount of Si and other elements, which eventually causes a sharp rise of the fuel ratio and poor furnace conditions. To tackle those two key problems, scholars at home and abroad had successively proposed various process flows for oxygen blast furnaces, such as Germany's FinkProcess proposed in 1978, Canada's Lu process proposed in 1984, Japan's NKK process and Russia's Tula process proposed in 1987, China's Qin Minsheng FOBF process proposed in 1987, and EU's ULCOS process proposed in 2004.

0.1°
Direct reduction degree

983℃
Gas temperarture

480 Nm^3
Recycling gas volume in the furnace shaft

379 Nm^3
Recycling gas volume in the furnace hearth

385.6 kg/tHM
Minimum fuel ratio

The major differences among these processes include:

1. Whether the CO_2 in the gas is removed or not;
2. Whether the gas is preheated before injecting into blast furnaces;
3. The gas injecting positions;
4. Whether full-oxygen blast is used;
5. Whether the hydrogen-rich medium is injected through tuyeres.

In the early 1990s, Russia's Tula Company and Japan's NKK Company respectively carried out the industrial tests of oxygen blast furnaces. The theoretical analysis and experimental research showed that full-oxygen blast and large-amount pulverized coal injection were technologically feasible. However, due to the immaturity of oxygen generation and CO_2 removal technologies at that time, the production cost was high, and thus their industrial production was not realized. In recent years, with the impact of greenhouse gases on the environment and the global urge for CO_2 reduction, a new round of research on oxygen blast furnace-based ironmaking technology has been started at home and abroad in an attempt to significantly reduce CO_2 emissions of ironmaking production. The EU and Japan have respectively launched the ULCOS and the COURSE50 programmes, both of which take the oxygen blast furnace-based ironmaking process as the medium and long-term ironmaking development direction of steel enterprises. China's steel research institute has conducted pilot tests of ironmaking with full-fuel blast since 2009, which advanced the researches on oxygen blast furnaces in China.

Under the current general trend of low-carbon development and emissions reduction, the purpose of oxygen blast furnaces has switched from replacing coke with coal for improving productivity to low-carbon smelting. Its basic features include: replacing air with pure oxygen for blasting, top gas recycling, and large-amount pulverized coal injection, of which the core is gas recycling. In the process design of a top gas recycling oxygen blast furnace (TGR-BF), to obtain a low fuel ratio, it needs to remove CO_2 from the top gas before heating and recycling, and the temperature is required to be higher than 900℃. Moreover, two rows of tuyeres are designed at the furnace hearth and the shaft, which is conducive to carbon reduction.

The heating of recycling gas can make up for the reduction in heat input (about 1.8GJ) caused by full-oxygen blasting in ambient temperature, which mainly plays two roles in an oxygen blast furnace: First, the recycling gas serves as a heat carrier to bring the excess heat from the lower part to the upper part, so as to alleviate the "cold upper part and hot lower part" condition of the oxygen blast furnace. Secondly, the recycling gas is used as a reducing agent at the upper part to participate in the indirect reduction of ore. As a part of the heat carriers, the recycling gas is heated in the tuyere raceway of BF and then rises with the gas flow. During the rising process, it does not participate in the reduction of iron oxides, but only transfers the excess heat from the lower part to the upper part of the BF, thus increasing the effective heat of the gas in the upper heat exchange zone. As the amount of recycling gas increases, the fuel ratio decreases, and less oxygen is required to smelt per ton of iron.

The calculations show that the direct reduction degree is 0.1, the gas temperature is 983℃, the recycling gas volume in the furnace shaft is 480Nm^3, the recycling gas volume in the furnace hearth is 379Nm^3, and the minimum fuel ratio is 385.6kg/t of hot metal.

2.2 Hydrogen-enriched Reduction

Hydrogen metallurgy seems to be the ultimate solution for low-carbon steel production. The final product of hydrogen as a kind of reducing agent is water, which can achieve zero carbon dioxide emissions. Therefore, the research on hydrogen metallurgy technology using hydrogen instead of carbon as the reducing agent is expected to bring hope for the sustainable development of the steel industry, and the large-scale hydrogen generation technology is expected to be realized in this century. The application of hydrogen energy to metallurgy is one of the effective ways for the green transformation of the metallurgical industry.

Hydrogen metallurgy seems to be the ultimate solution for low-carbon steel production.

Compared with CO as a reducing agent of iron ore, hydrogen has the following characteristics:

1. From a thermodynamic point of view, CO is more reductive than hydrogen at the upper part of a BF, and its reaction is exothermic; while hydrogen reduction has an advantage only in the high-temperature zone, and its reaction is endothermic.
2. As the most active reducing agent, hydrogen boasts higher reduction efficiency and reduction rate than carbon. Therefore, the hydrogen-enriched gas has better diffusivity and permeability, better heat exchange with furnace

Application of hydrogen energy to metallurgy is one of the effective ways for the green transformation of the metallurgical industry.

burden, better reduction kinetic conditions and a faster reduction process, leading to higher productivity.

3 The thermal conductivity of H_2 is much larger than that of CO, and thus the hydrogen-enriched reduction features faster heat transfer and thus accelerated convective heat exchange between gas and solid.

However, the effect of hydrogen in promoting ore reduction is restricted by the following water-gas reaction:

$$H_2O+CO=H_2+CO_2 \quad 41.3kJ/mol$$

The H_2O generated by H_2 reduction reacts with CO in the BF to generate CO_2 and H_2. This equilibrium reaction limits the utilization of H_2 while increasing the utilization of CO. This effect becomes more obvious especially as the hydrogen content of the gas at the lower hearth increases. Therefore, the technical obstacle to the effective utilization rate of hydrogen in a BF (the ratio of FeO reduction) is only about 30% should be taken into account.

The most reliable method currently recognized as the source of large quantities of hydrogen in the future is brine electrolysis. And the electricity consumed by brine electrolysis can only be obtained from clean energy sources such as nuclear or solar power. Before green hydrogen can be used economically, injecting hydrogen-enriched media into BF to replace part of the coke can yield significant results in terms of reducing coke consumption and CO_2 emissions. The fuels to be injected include natural gas and coke oven gas, which have well-proven performance at home and abroad. Due to resource constraints, more BFs adopts coke oven gas injection in China, such as Benxi Steel, Chengde Steel, Anshan Steel and, Jinan Steel. It is technically feasible, and the process route is well-proven and reliable.

Coke oven gas contains a large amount of valuable component gases such as H2 and CH4, making itself a good reducing agent with high concentration of hydrogen. The methane in the coke oven gas participates in the following reaction in the tuyere raceway of a BF: $2CH_4 + O_2 \rightarrow 2CO + 4H_2$, and the hydrogen content of coke oven gas is as high as 75% when it leaves the raceway. The injection of coke oven gas can give full play to the hydrogen-based reducing agent, increase the value of coke oven gas, and improve energy utilization. The difficulty in the utilization of coke oven gas is that it contains a small amount of impurities such as BTX (a mixture of benzene, toluene and xylene), tar and naphthalene, which may cause carbon precipitation when the reducing gas passes through heaters, resulting in pipeline clogging.

2.3 Technical Features of Hydrogen-rich Carbon Recycling Blast Furn ace

The new low-carbon ironmaking technology of gas recycling + full oxygen + hydrogen enrichment has the following features:

1 Under the full-oxygen smelting conditions, carbon recycling is technically possible to achieve emission reduction due to the absence of N_2 in the gas.

2 The indirect reduction degree of ore is greatly improved. The indirect reduction range of conventional blast furnaces is limited, and the conditions for theoretically minimum carbon consumption are as follows: the direct reduction degree is 0.45, the fuel ratio is 452kg/t, and the gas utilization rate is 57%. The top gas recycling and hydrogen-enriched reduction can reduce the direct reduction rate close to 0, and the utilization rate of carbon can theoretically reach 100%.

3 With a full-oxygen blast, the concentration of reducing gas is close to 100%, and the final reduction degree of ore can reach more than 90%, which will generate a soft melting zone featuring low position and small thickness, and may even lead to the complete disappearance of the soft melting zone. Therefore, the constraints of conventional blast furnaces can be eliminated, and consequently a higher productivity can be obtained.

3 Production Practices

Relatively few industrial tests of hydrogen-enriched gas recycling have been conducted worldwide. Relevant tests were made with the Sweden-based LKAB's 8.9m³ BF and the Japan-based Nippon Steel & Sumikin's 12m³ BF in 2013 and 2015 respectively to verify the concept of hydrogen-enriched gas recycling, and the results showed that the carbon saving effect can be achieved to some extent. Baosteel of China Baowu Group has listed the hydrogen-rich carbon recycling blast furnace as one of Baowu's low-carbon ironmaking process routes and built the world's largest 430m³ BF industrial test base in Bayi Steel. At present, the first and second stages of industrial tests have been completed, and the third stage of industrial tests is expected to be carried out in 2022, with the ultimate target of reducing carbon by 30% realized. Sinosteel MECC applies this technology to engineering.

3.1 Early-stage Verification Tests (Stage I and II)

1 Test Device

The previously idled 430m³ BF of Bayi Steel, has 14 tuyeres, 1 tap hole, and a hearth diameter of 5.2m. With the decarbonization device for Ouye furnace that has been put into operation, it has the functions of CO_2 removal and hydrogen-enriched cold gas injection through tuyeres, which can complete the verification tests of injecting decarbonized hydrogen-enriched gas under high oxygen enrichment conditions, thus providing the basis for the Stage-III of industrial tests with full oxygen and decarbonized hydrogen-enriched gas heating and recycling. The composition of injected gas is shown in Table 1 and Table 2.

2 Test Process and Results

In 2020, Stage-I tests were completed, achieving the targets of 35% oxygen content in the blast, and the exploration of BF operation technology under high oxygen enrichment started, with the fuel ratio of 600kg/t, the coal ratio of 170kg/t, and the blast temperature of 900℃. Oxygen was added from the built-in oxygen channels at the tuyeres.

In 2021, Stage-I tests were completed, achieving the targets of 50% ultra-high oxygen enrichment, and injection of decarbonized hydrogen-enriched gas through tuyeres. >>>

On June 11, 2021, the decarburized reducing gas (with the actual CO content of 70~75%) was injected into the Ouye furnace. On July 30, the oxygen content in the blast reached 50%. On August 7, the injection flow rate of decarbonized gas exceeded 14,000m^3/h, i.e., 250m^3/h per ton of iron, and the fuel ratio was reduced by 85kg/t or 14% compared to the benchmark value before the tests. Coke oven gas was injected since August 8, till BF shutdown on August 25. After the injected gas flow rate was increased, the oxygen enrichment rate increased, the smooth operation condition improved, and the utilization rate of BF gas once dropped to 35%, which was restored to the original level of about 40% through adjusting the furnace burden system.

50%

the oxygen enrichment reached

The tests focused on testing the feasibility of high oxygen enrichment and gas injection. With gas injection, the oxygen enrichment reached an unprecedented 50%. The Stage-II tests of decarburized gas injection and hydrogen-rich metallurgy with hydrogen-rich carbon recycling BF showed that the replacement ratio is 0.35kg/(m^3/t) when decarburized gas was injected, and 0.45kg/(m^3/t) when coke oven gas was injected.

3.2 Later-stage Industrial Tests (Stage III)

The Stage-III industrial tests aim to achieve top gas heating and recycling. Key technical issues to be resolved:

1. The theoretical combustion temperature before the full oxygen blast tuyeres is very high, and thus the long-life oxygen and coal lances featuring high temperature and wearing resistance, as well as long-life tuyeres, need to be developed. Moreover, the long-life tuyeres and their cooling parameters have to be developed as well.

2. Different injection modes for oxygen blast furnaces may lead to drastically varied gas flow distribution in the furnace, and thus affect the gas-solid reaction. Therefore, the reasonable design parameters for BF profile, recycling gas injection amount and gas flow distribution under different injection modes have to be studied.

3. Heating of recycling gas. The hot blast heating technology for BF is quite mature, but gas heating is much more difficult. On the one hand, carbon precipitation may occur during gas heating due to much higher CO content in the recycling gas compared to H_2, which may cause pipeline clogging (the gas heating technologies of Miderx and HYL are relatively mature, but they are mainly used to heat hydrogen-enriched gas, and thus there is basically no carbon precipitation); on the other hand, the gas heating is subject to potential safety hazards, and accidents such as explosions and gas leakage are prone to occur during heating.

4. Sealing of gas injection devices. Because the CO content in the injected gas can reach even 60~70%, its leakage will pose a fatal threat to personal safety.

5. Matching of heat supply when a large amount of H_2 is involved in the reduction reaction in a BF.

For that purpose, Sinosteel MECC established deepened cooperation with the University of Science and Technology Beijing and equipment suppliers, to redesign the equipment and process of the testing BF, and finally realized the following three major targets: full-oxygen smelting, hot gas injection via tuyeres, and hot gas injection into furnace shaft. At present, the construction drawing design is completed and the project is under construction.

tb. 1 Chemical Composition of High-reducing Gas for Ouye Furnaces

Composition	CO	CO_2	H_2	CH_4	N_2	H_2O
Content (%)	65.9	1.0	15.3	0.5	16.1	1.1

tb. 1 Composition of Coke Oven Gas

Composition	CO_2	CnHm	O_2	CO	CH_4	H_2	N_2
Content (%)	4	1.2	0.6	7.4	21	57	7.0

4 Conclusions

The carbon-reduction-oriented comprehensive transformation of the existing BF-based ironmaking process is urgent work to be carried out, and is also a prerequisite for enterprises to survive the future competition regarding carbon reduction. The hydrogen-rich carbon recycling blast furnace technology has broken through the technical bottleneck of efficient utilization of carbon resources in conventional blast furnaces, and thus opens up new application scenarios for hydrogen metallurgy. As an important way for the green transformation of the ironmaking industry, it is highly expected to become the mainstream process of blast furnace ironmaking in the future.

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Digital Ecosystem of Traveling Grate Pelletizing Technology Contributes Intelligent Development of the Steel Industry

02

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Abstract: In recent years, a new generation of digital technologies, such as artificial intelligence, 5G, cloud computing and big data, has developed rapidly. China's booming digital economy can be primarily attributed to a number of forward-looking policies to encourage industry transformation. Green and intelligent development dominates the domestic steel industry which turns to prioritize quality over quantity. The acceleration of digitalization, information & intelligence of steel plants sees the broader application of industrial networks and allows the efficient operation and transformation which Sinosteel MECC has undergone and has taken the first step in traveling grate pelletizing technology.

1 Forward-looking Decision

As early as 2008, Sinosteel MECC has put forward to advance the traveling grate pelletizing technology and digitalization on parallel, and developed collaboratively application development, platform building, data governance, talent empowerment and management transformation.

From 2008 to 2013, traveling grate pelletizing and the digitalization are at the early stage. Some spare parts were designed and manufactured via 3D top-down design to and are highly recognized by both domestic and foreign customers. With 3D tow-down automation design, 4D construction simulation, cloud-based collision collaboration, independent-temperature-field-based control, big data and simulation calculation in plant operation and maintenance, Sinosteel MECC has established a digital ecosystem of EPC+M+O for traveling grate pelletizing technology - online experience, operation management and production, which helps achieve greener and more sustainable development of steel producers and intelligence transformation of the steel industry.

2 Innovative engineering underpins the ecosystem

The top-down design, 3D plant layout design and parameterized interface design are the key digital technology components to ensure design quality, improve design efficiency, and guarantee final digital plant handover and smart plant operation.

The top-down design technology is applied in the equipment scheme design stage, to effectively associate the scheme design with the design of each component. In case the scheme structure is modified, the components are also modified accordingly. As an extension of the top-down design technology, the parameterized interface design technology enables the realization of design automation. A major premise for the realization of the parameterized interface design is to connect the entire design, store the associated components in the database, and carry out platform-based management. The design of a new project can be made based on the modification of the corresponding solutions stored in the database. By entering parameters through the customized interfaces, the real-time and interlocked adjustments of components can be realized to meet the design requirements of the new project. Such a design mode can shorten the time for design modeling, modification, and error correction, and thus greatly improve the reuse efficiency of serialized products. Now, we can save about 40% of the time to develop a new product compared to the previous work.

The 3D layout design generated the 3D views of the plant layout and arrangement of each shop, regardless of newly constructed project or existing workshop renovation. To facilitate the conversion between 2D and 3D views, a complete set of 3D model library is established and associated with 2D drawing library, so that the 2D design can be converted into 3D design through one-click in the design software, and vice versa. The final solution is presented to the customers in a quite intuitive way to help them understand on a deeper level and enhance communication efficiency and quality with each other.

Greatly improve efficiency and save time by

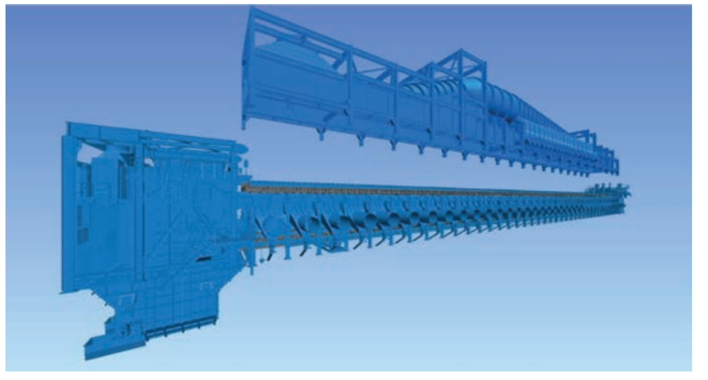
30%

3 Empowering digital delivery

The major step after 3D design is project management, which Sinosteel MECC implemented in a digitalized 4D way. The digital plant construction nodes are associated with the project construction nodes. In this way, everyone involved in the construction can view the progress status and check whether the supporting resources can effectively provide collaboration at any time. >>>

Details of inside could be viewed through digital platform

Assembly of indurating machine



Simulation of hot air flow, material flow and heat balance

In the digital plant, all equipment, buildings and pipes are given lives and their conditions can be obtained in real-time. Customers may see parameters of any equipment. Even during the production, a virtual person can "jump" into the indurating machine to directly observe situations such as hot blast flow, material flow, heat transfer, chemical reactions, temperature changes, as well as equipment structure changes, which is hard to achieve in a physical plant.

The 2x4.8mtpa traveling grate pelletizing plants is handed over to HBIS with digital plant design. At present, the project is characterized by the largest pellet output per unit area and the most complete process in the world. It is equipped with two circular stock houses, each having a storage capacity of 200,000t concentrate fines and finished pellet bins with the largest storage capacity in the world, each having storage capacity of 100,000t of pellets.

In terms of model levels, LOD100, 200, 300, and 400 could be provided. Technical capability is reserved to develop LOD500 model.

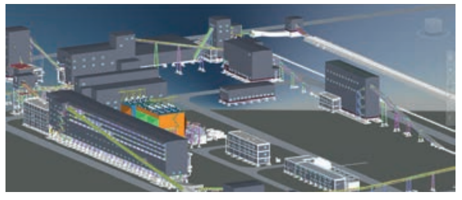
> "The top-down design, 3D plant layout design & parameterized interface design are key digital technology components."

4 Intelligent operation

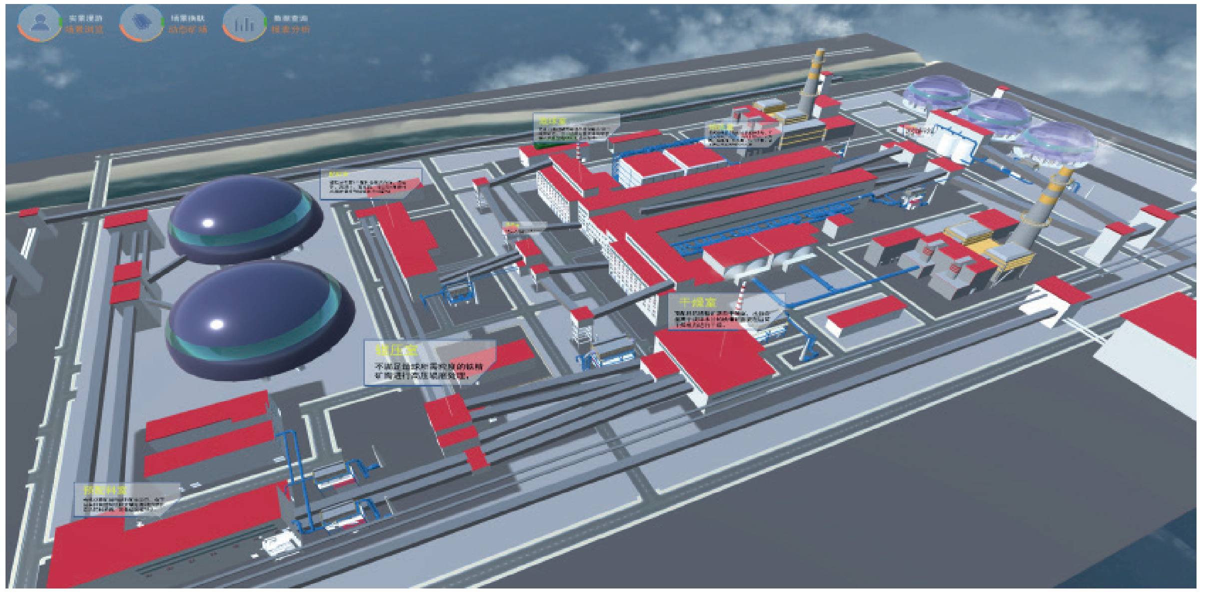
Sinosteel MECC has established an overall data platform and intelligent analysis system based on the mass data produced from design to operation through big data center of pellet plants, using artificial intelligence analysis. Intelligent operation plays a vital role in guiding production by means of providing analysis and observation, which make management more scientific, efficient and elaborated.

Big data enables cause trace of quality abnormity, real-time equipment detection, and intelligent optimization of multi-process collaboration and even of all-process production technology,

A 4mtpa digital traveling grate pellet plant delivered to customer



Digital plant of 2x4.8mtpa traveling grate pellet plant for HBIS Tanggang

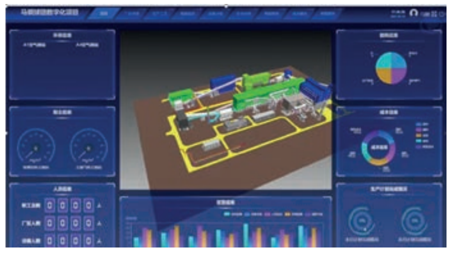


which further guarantee the precise control of product quality and whole cycle maintenance of equipment. Pelletizing is one of the most critical processes in production. To achieve fast production of green pellets in qualified size conform to requirements, images of pelletizing are captured by intelligent cameras and analyzed in big data center, based on key parameters such as moisture, rotation speed and dosage, by the set algorithms, so as to judge, control and finally achieve intelligent pelletizing.

Camera and image recognition also work for the diagnosis and intelligent maintenance of equipment conditions, in particular the effective early warning and alarm for the abnormal status of equipment, which can mitigate risks, allow time for spare parts preparation, improve inventory turnover and optimize cost.

The physical plants built with advanced technologies have brought great benefits to the customers during the whole project process. The comprehensive energy consumption, environmental control, water treatment, equipment life forecast, and the material-related process modification after processing provide a complete set of data as the basis for management, control and decision-making, from which Sinosteel MECC and customers both benefit.

Digital platform



Intelligent Sintering Control System Innovated Independently by Sinosteel MECC

03

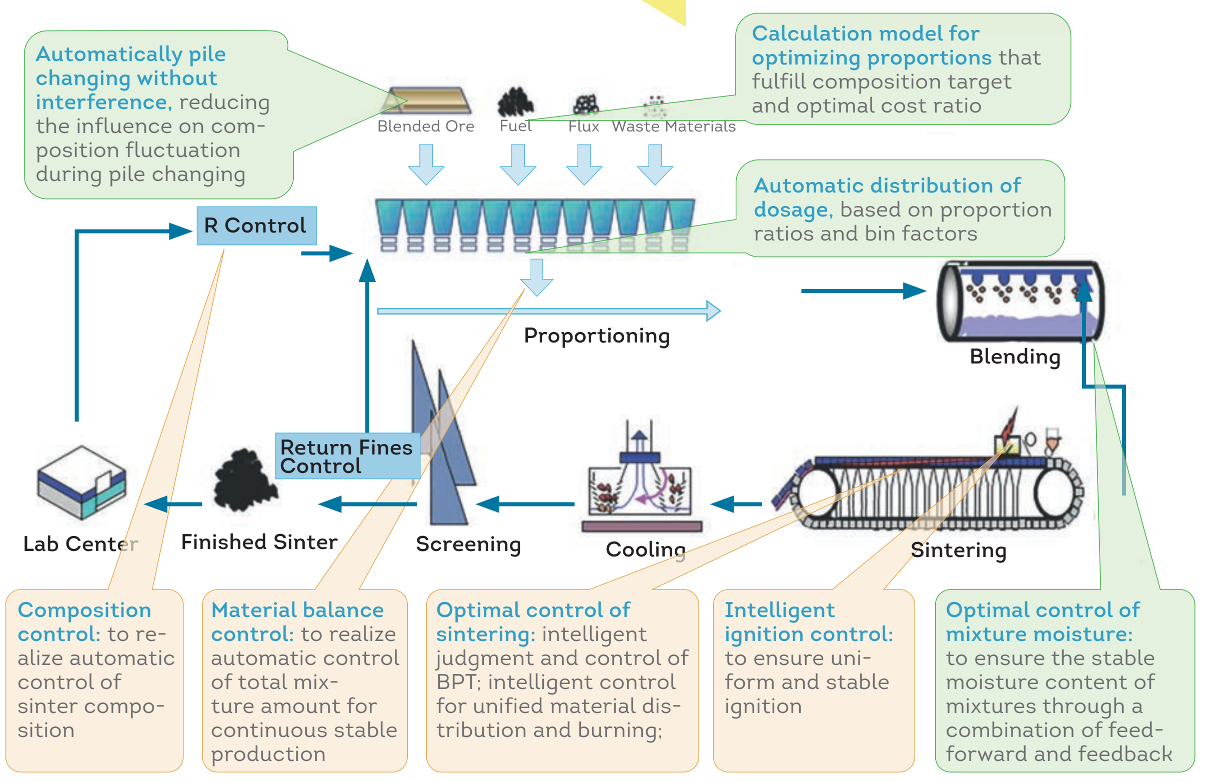
Zhou Wei, Senior Engineer of Iron Making Department, Sinosteel MECC

Abstract: This article introduces the intelligent sintering control system innovated independently Sinosteel MECC, which consists of a material proportioning calculation model, a basicity control model, a burn-through point (BTP) control model, an ignition model, etc. The successful application of the system has greatly improved automation and intelligence level in the sintering process, resulting in less manpower demand, higher yield and quality of the sinter as well as lower energy consumption of the production process.

1 Background

Sintering is a process of steel production to turn ore fines into artificial ore agglomerates. Characterized by a long process and numerous links, the sintering process is subject to complexity, nonlinearity, time-variance and uncertainness from the aspect of cybernetics, and thus it belongs to a typical object requiring complex control. The conventional sinter production relies more on operators' experience to judge and adjust operations, featuring low degree of intelligence and inaccurate control.

The application of the intelligent sintering control system has become an important means for pursuing "high quality, high yield and low consumption" in sinter production, and thus it is considered as the main target for improving the technical level of sintering plants at home and abroad. In the process of undertaking sintering projects, Sinosteel MECC found that more and more customers put forward more specific and higher requirements on the intelligence of the sintering process. To improve the technical level and competitiveness, Sinosteel MECC set up a scientific research program and organized a professional team in 2020 to start the R&D of the intelligent sintering control system, aiming to provide valued added service to customers.



2 Functions of the System

The system is an intelligent control system developed independently based on the production practices of steel plants, and thus owns independent intellectual property rights. The functional framework of the system is shown in Fig. 1. The software platform is designed on the basis of the Level-1 PLC system for sintering, real-time data as well as the specific requirements for better model calculations. The software architecture is shown in Fig. 2.

The system is mainly used to establish mathematical models and perform control based on the sintering process. The main functional modules of the system are detailed below.

Application of the intelligent sintering control system has become an important means for pursuing "high quality, high yield and low consumption" in sinter production.

Functional Framework of the System **Fig. 1**

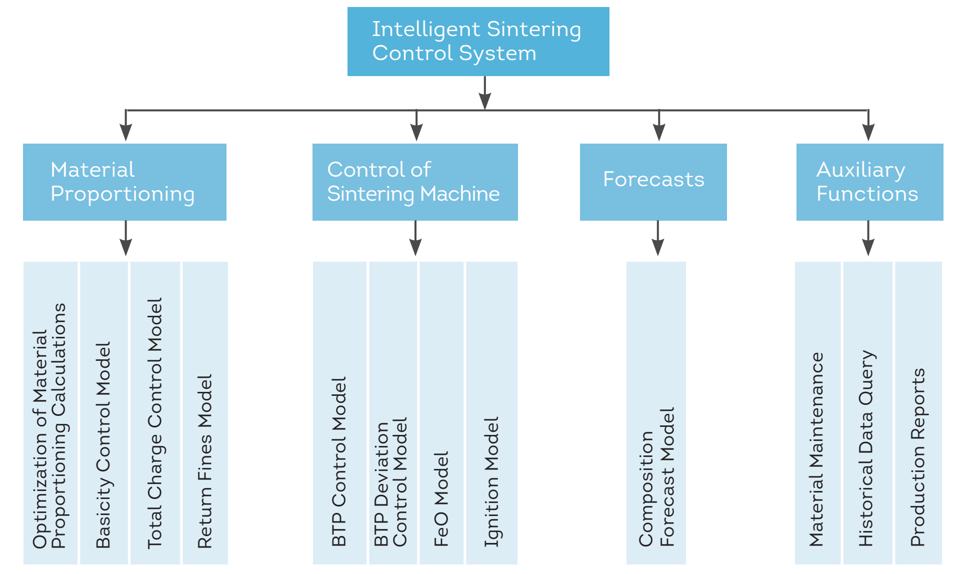
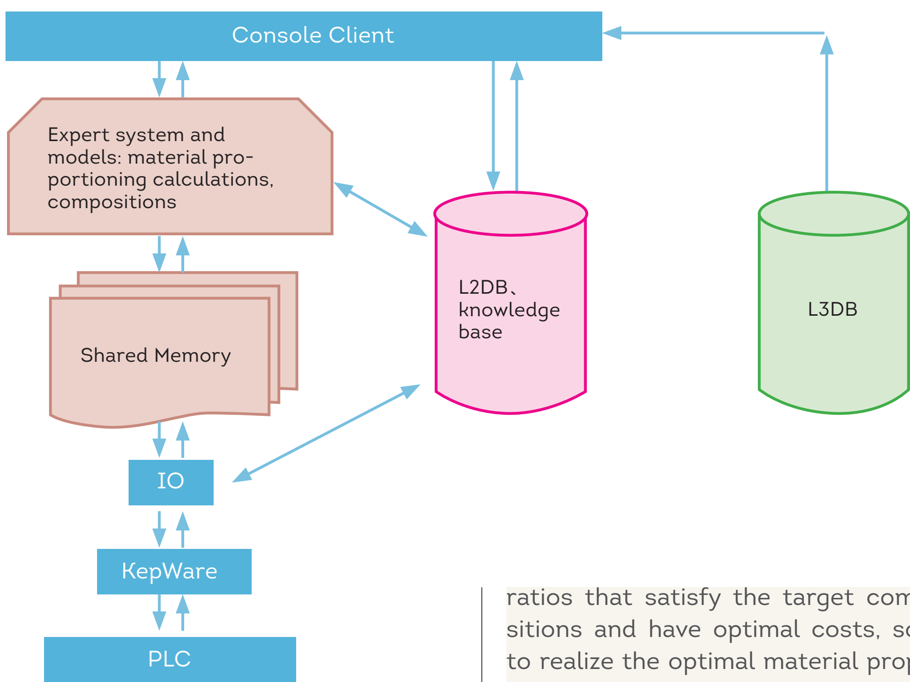


Fig. 2 Software Architecture



> The system is an intelligent control system developed independently based on the production practices of steel plants.

2.1 Material Proportioning Calculation Model

Manual calculation is applied currently for material proportioning in the industry, which features a high calculation load and complicated calculation process due to repeated checking, and its accuracy cannot meet the needs of modern sinter production as well. Besides, the matter of optimal costs is rarely considered during material proportioning. The model is primarily based on the principle of material balance to obtain the optimal ratio of various raw materials according to the target composition and output of the sinter and within the specified range of materials.

Goals achieved: the linear programming method is applied for calculations based on the composition of the raw materials and fuels as well as the proportioning target, to provide mixture ratios that satisfy the target compositions and have optimal costs, so as to realize the optimal material proportioning for sintering. It not only reduces the uncertainty of manual calculations, but also improves labor productivity.

2.2 Basicity Control Model

For the initial material proportioning, it calculates the raw material proportioning ratios that satisfy the target R according to the compositions of raw materials. In the production process, it tracks the test information of the finished sinter, and corrects the proportioning target R in case any deviation is found between the test results and the proportioning target R. The correction amount ΔR-Re depends on the deviation, and is controlled as follows:

1. In case of ΔR>0.05, one-half adjustment is made;
2. In case of 0.03<ΔR<0.05, one-third adjustment is made;
3. In case of 0.02<ΔR<0.03, one-third adjustment is made based on the mean value of three consecutive points;
4. In case of ΔR<0.03, one-fourth adjustment is made based on the mean value of four consecutive points.

The model automatically calculates the correction value for the flux ratio, and then charge is changed through the Level-1 dust discharge model, thus finally realizing the automatic control of the sinter basicity.

2.3 Total Charge Control Model

As a buffer in the entire sintering process, small material bins play a vital role in adjusting the production pace. The change of material level in small material bins is affected by many factors, including proportioned material quantity, distributing roll coefficient, speed of sinter machine and other process parameters. Through reasonable regulation by this link, a continuous and stable sintering process can be guaranteed. The material level control for small material bins is a difficult point in the sintering control, and it is subject to non-linear changes due to the influences by uncertain charge and discharge; moreover, the adjustment of the charge is lag-plagued. Therefore, manual adjustment of the total charge is adopted in most cases. This model tracks the change rate of the material level in small material bins in real time, and thus reasonably calculates the total material feeding quantity by comprehensively considering various factors affecting the feeding to the sintering machine, such as machine speed and material layer thickness.

> The gas can be saved to the maximum extent while satisfying the production requirements, thus providing considerable economic benefits for enterprises.

Goals achieved: reasonable control of the total material feeding quantity, maintenance of continuous and stable production, and improvement of labor productivity.

2.4 Return Fines Control Model

The guiding principle for return fines control is "availability-based full utilization".

In the formula of **B=RA/RE, B** refer to the balance coefficient, **RA** refers to the return fines obtained after screening, and **RE** refers to the return fines to be added into mixed materials

B=1 is realized in case of balanced production.

The actual proportioning ratio of return fines **RF_Ration_SM** is calculated according to the basic return fines rate **RF_Ratio** and burning loss under actual working conditions, and it is adjusted depending on the stock level in the return fines bin.

Goals achieved: realized the automatic control of return fines based on its rate and the stock level in the return fines bin, and thus achieved a dynamic balance of return fines in the sinter production process.

2.5 Ignition Control Model

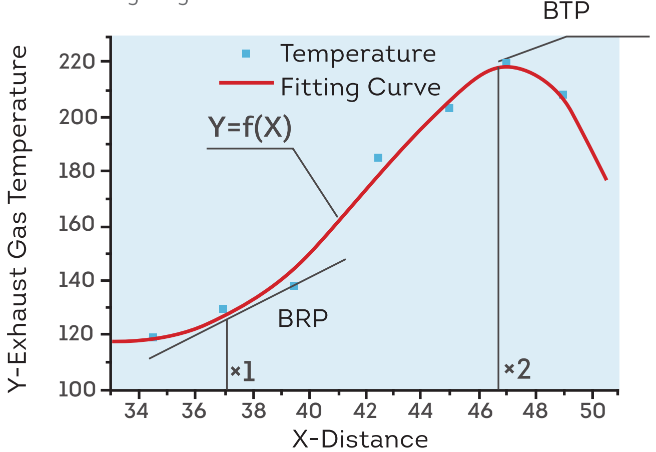
The ignition model can ensure the appropriate ignition temperature and ignition intensity by reasonably controlling the air and gas flow rate to satisfy sinter production. By taking factors such as machine speed and calorific value of gas into account, it enables intelligent ignition process by reasonably controlling the flow rate of air and gas.

With this control model, the system can finally realize automatic adjustment of the overshooting coefficient under the target ignition temperature and intensity given by the operator, so as to satisfy the ignition temperature requirements; the adjustment of gas and air flow rates in the same proportion to ensure the ignition intensity required, thus enabling intelligent control of the ignition process. Therefore, the gas can be saved to the maximum extent while satisfying the production requirements, thus providing considerable economic benefits for enterprises.

2.6 BTP Control Model

This model is mainly used to accurately judge the burn-through point (BTP) and burn-rise point (BRP), and reasonably control BTP, to realize the intelligent control of the sintering machine, stabilize the production and accordingly achieve high quality and high yield. Here, the curve regression and fitting method is adopted for analysis of exhaust gas temperature. The curve fitting effect is shown in Fig. 3. It can be seen from the sintering process theory that the X1 point corresponds to the position where the front of the combustion zone is close to the pallet grate, and the X2 point corresponds to the position where the highest temperature of the combustion zone reaches the pallet grate, i.e., the combustion process is about to end. In Fig. 3, X1 refers to BRP and X2 refers to BTP.

Fig. 3
Curve Fitting Diagram



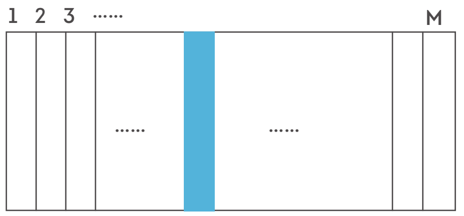
X1 is BRP, X2 is BTP

Goals achieved: performed curve fitting through the analysis of the exhaust gas temperature field to accurately judge BRP and BTP, reasonably and accurately controlled the position and temperature of BTP, and stabilized the sintering process, thus greatly improving the stability rate of BTP and making great contributions to improving the output and quality of sinter.

2.7 BTP Deviation Control Model

This model can optimize material distribution across the width of the sinter machine to make the vertical sintering rate consistent. Reasonable distribution of materials can eliminate the deviation of the BTP position along the width of the pallet. The cause for the BTP deviation is the inconsistency of the vertical sintering rate along the width. For this reason, we have studied the vertical sintering rate along the width.

For 360m² sintering machines, a plane temperature field for wind boxes is established, and each wind box is equipped with 6 temperature measuring points from No. 11 to No. 24 wind boxes. In this way, the temperature measurement value of each wind box can be averaged to fit a curve, so as to conduct further research on the sintering situation along the width



divide the sintering mixture bed into M zones

Fig. 3
Differential diagram of sintering section width

The specific modeling method is as follows: the sintering mixture bed is divided into M zones (j=1, 2, ..., M) along the width of the sintering section, and it also considers that there is no other segregation except for density along the width of the sintering mixture bed. If the vertical sintering rate in Zone j is taken as Vj, the average vertical sintering rate of the mixture in each zone is $\overline{V}$:

For easy study, the combustion rate consistency index is defined as λ =Vj/V.

In the formula, Vj refers the combustion rate at a certain column, and V refers to average combustion rate.

The combustion rate consistency index involved in this model is the consistency of the vertical combustion rate along the width of the pallet, so that the BTP of each column tends to appear at the same time, the distributed material thickness along the width of the sintering machine is quantitatively determined to achieve accurate and reasonable material distribution, the air flow distribution is reasonable, the sintering process is uniform, the combustion zones reach the pallet grate at the same time, and the BTP deviation is eliminated, which are greatly beneficial to improve the output and quality of sinter and reduce return fines.

2.8 Information Management

The information management covers report management, material maintenance, parameter modification and historical data query, of which the report management can realize the management of various production data, such as automatic tracking of energy consumption, start-up and shutdown rate, etc. The test data for this system come from the company's Level-3 system, which can ensure their real-time performance and accuracy and also enable manual parameter modification. Various parameters are continuously optimized during the operation of the system, so a parameter editing interface is specially designed for that purpose.

99%

System's operation stability rate over

3 Conclusions

Since the whole system was put into operation in January 2021, its operation has been stable and reliable, and the intelligent control of sinter production has been realized. Moreover, the operation stability rate of the system is over 99%, the main technical and economic indicators have reached or exceeded the R&D targets of the project, so the sinter production level is significantly improved. The application of the intelligent sintering control system makes the production operation process more reasonable, uniform and consistent, and avoids the influence of human factors.

Besides, its application also leads to an optimized sintering process, improved labor productivity, reduced energy consumption, as well as intelligent and closed-loop control of sintering process. The successful development of the system has improved the company's competitiveness and boasts extensive application value in the industry.

Application and Practice of Biomass Straw in Metallurgical Auxiliary Materials

04

Wang Zhenlin, Cheng Li, Jin Feng, Low-carbon Metallurgy & Energy Department, Sinosteel MECC

Abstract: The application of biomass straw resources in China is analyzed, and the application of biomass straw in the metallurgical industry is explored. Several metallurgical auxiliary materials were developed by using straw ash, which not only meet the technical requirements, but also have great significance to promote the utilization of solid waste resources, co-production of steel and chemical industry, integration of regional energy as well as building of industries for circular economy.

800 mt/a

China's annual straw resources

1 Foreword

China is a large agricultural country, where people rely on the food that grown on the non-fallow farmland. In some regions, there are two or even three farming seasons a year, and thus a large amount of rice straw, wheat straw, corn straw, etc. are produced. The data released by the National Bureau of Statistics show that China's straw resources are close to 800 million tons per year. In the previous period of traditional agriculture, straw was mainly used as fertilizer, feed, fuel and building materials. However, with the modernization of agriculture, many traditional agricultural production factors have been replaced by industrial ones, resulting in a large surplus of straw resources. Since the straw returned to the farmland can't degrade in time, which affects the cultivation and soil tilth of the next crop, the farmers would like to burn them on the spot. Straw burning may produce a large number of harmful gases such as CO_2, CO, sulfur dioxide, and nitrogen oxides as well as inhalable particulate matters, which not only are harmful to human health, but also seriously affect the environment in rural areas and surrounding urban areas. As a result, during the rush-harvest and rush-plant periods in spring and summer, some villages and towns designate people to guard against straw burning, and even use drones to monitor straw burning.

In fact, crop straw is a kind of very valuable biomass energy resources in the agricultural ecosystem. It is also a renewable carbon resource on earth and has special advantages in respects of environmental protection and resource utilization, and thus it is regarded as an important energy source and chemical fuel for human beings in the future. Therefore, it is of great potential for development. According to their application in foreign countries, especially in developed countries, various uses have been explored for the comprehensive development and utilization of crop straws through scientific and technological progress and innovation, including not only traditional ways of returning crushed straw to the farmland as an organic fertilizer, but also new ways of using straw to produce feed, gas, electricity, ethanol and building materials, which greatly improve the utilization value and rate of straw, worthy learning by us.

Biomass straw features good combustion property, and thus its simplest application is burning for heat release, which can be widely applied as a new energy source for decentralized heating, heating and energy supply in rural areas, becoming an effective means to adjust the energy structure in the rural areas. However, it has not generated any enthusiasm in industrial enterprises and farmers due to its disadvantages of light weight, large volume, inconvenient transportation, low price, low calorific value, large quantity of ash after combustion as well as difficult processing. After years of research and practice, the author of this paper has successfully developed various metallurgical auxiliary materials using biomass straw, which can be widely used in steel enterprises, thus greatly improving the comprehensive utilization efficiency of biomass straw, turning waste into treasure, and reducing comprehensive carbon emissions. Therefore, they are of great significance to promote farmers' income, environmental protection, resource conservation as well as sustainable development of agricultural economy.

2 Processing of Biomass Straw

At present, industrialized harvesting has been applied in many areas in China, and the straw is baled while harvesting (as shown in Fig. 1), and then the baled straws are stacked and stored in a centralized manner. During the subsequent industrial processing, the straw is first chopped by machines into lengths of 20~100mm. The chopped straw then enters silage tanks for silage fermentation and storage. Due to the aggregation of fermentation heat, the chopped straw after silage is dried by itself, and thus chopped straw with a moisture of 9% to 15% is obtained. The dried chopped straw is further crushed by a crusher, and then sent via a pneumatic conveying system to material bins in the form of straw fiber with particle sizes of 40~150-mesh. Then the straw fiber is transported to a ring mold pelletizer, where it is pressed into pellets by ring molds and pressing rolls. >>>

0.7 / 0.8X

Calorific value

Straw Baling **Fig. 1**

Fig. 2 Shaped Pellets

The temperature of 80℃ ~ 130℃ generated during the pressing can make the material mature, and dense rod-shaped straw pellets are obtained, with diameters of 8mm~10mm and lengths of 20mm~50mm. The straw pellets enter a cooler, where it is cooled down to ambient temperature by air cooling to obtain smooth-surfaced pellets (as shown in Fig. 2).

The testing results of shaped pellets are shown in Table 1.

The calorific value varies depending on the type of straw. Taking corn straw as an example: its calorific value is about 0.7 to 0.8 times that of coal, that is, the calorific value of fuel briquettes of 1.25t corn straw is equivalent to that of 1t coal. Biomass straw can also be further carbonized to produce biomass coal, which is an efficient, renewable and environmentally friendly biomass fuel that can be applied to various burners, biomass boilers, melting furnaces, biomass power generation units, etc.

3 Exploration in the Applications as Metallurgical Auxiliary Materials

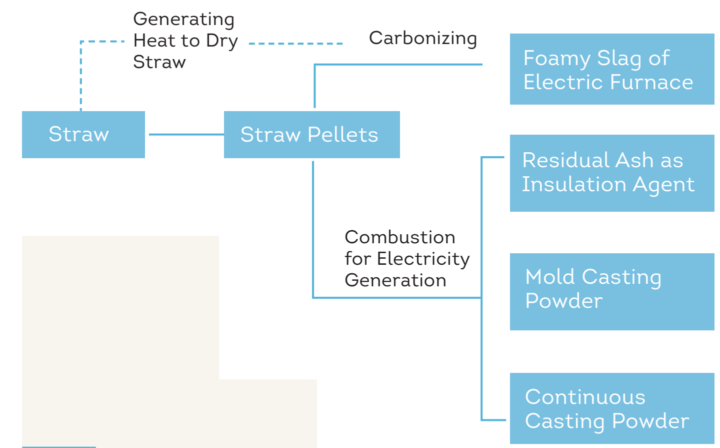
According to the special action plan for achieving peak carbon emissions and reducing carbon in the steel industry, all steelmaking enterprises using short-process electric furnaces must fully meet the ultra-low emission requirements, which needs to give full play to the consumption-wise processing and recycling of bulk social waste.

The years of research and practice by the author prove that the use of biomass straw in the steel industry can not only make full use of its thermal energy, but also further make the residual ash (commonly known as “plant ash”) after combustion into various metallurgical auxiliary materials for recycling. Therefore, the application path of carbon resources is extended. Fig. 3 shows an example of the application of biomass straw in the metallurgical industry as studied by the author.

tb. 1 Testing Results of Shaped Pellets

Parameter	Density (g/cm³)	Ash Content (%)	Moisture (%)	Calorific Value (cal/g)
Value	1 ~ 1.2	1 ~ 20	≤15	3700 ~ 4500

Fig. 3 Application Example of Biomass Straw in the Metallurgical Industry



3.1 Production of Thermal Insulation Agent for the metallurgical Industry

The author has conducted a lot of research and analysis on the thermal insulation during the metallurgical melting and casting processes. So far, acidic mineral raw materials or acidic carbonized rice husks are used at home and abroad to produce thermal insulation agents. Those products indeed have thermal insulation effect, but they all have varying degrees of defects, such as poor thermal insulation effect, waste of resources, carbonization of liquid steel, and adverse effect on the cleaning of liquid steel. Learning from the processing technology in the food industry, we used various kinds of biomass ash as the base material, selected and prepared reagents through experiments, and added appropriate amount of additives to produce a kind of high-quality micro-carbon alkaline particles as thermal insulation agent for steelmaking.

The preparation process steps are as follows:

1. Crush and grind the required raw materials;
2. Blend the raw materials of 60%-70% of carbonized straw, 30%-40% of lime, and 0.5% of the binder CMC in proportion, s shown in Table 2;
3. Add the mixed materials to the pelletizing device;
4. Press the materials into strip or cylindrical shapes through the pelletizing device, as shown in Fig. 4;
5. Feed the pellets into the crusher for crushing, and then screen it into finished product with the required particle size through a vibrating screen, as shown in Fig. 5.

After testing the composition of the finished product, its physical and chemical performance indicators are shown in Table 3.

Table 2 indicates that the use of straw ash and lime can ensure the high alkalinity of the thermal insulation covering agent, which is conductive to the cleanness of liquid steel; the low carbon content will not cause the carburization of liquid steel; moreover, the low carbon content does not affect the thermal

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tb.2 Raw Material Proportion of New Thermal Insulation Agent in Pellet

Raw Material	Straw Ash	Active Lime	Binder
Proportion (w%)	60-70%	30-40%	0.5%

tb.3 Physical and Chemical Performance Indicators of Finished Pellets of Thermal Insulation Agent

Item	SiO_2	Al_2O_3	CaO	MgO	C_{solid}	Melting Point	Melting Rate	Bulk Density (g/cm^3)
Indicator	28.9	3.89	47.69	1.8	0.5	≥1300℃	≥60s	0.5-0.8

insulation effect of the covering agent, which is because on the one hand, the porous and honeycomb-like microstructure of carbonized straw can effectively reduce thermal conductivity and play a good thermal insulation effect, on the other hand, the ash in the carbonized straw has a melting point higher than the temperature of liquid steel and thus acts as carbon skeletons. Besides, the repose angle of carbonized straw is less than 35°, resulting in good fluidity and spreadability, thus it can quickly spread on the surface of liquid steel to reduce heat loss. After an exploratory trial in the ladles and tundishes of a special steel complex in northern China, it can fully meet the requirements in terms of temperature drop, spreading and adsorption of inclusions.

The use of biomass straw in the steel industry can not only make full use of its thermal energy, but also further make the residual ash after combustion into various metallurgical auxiliary materials for recycling.

Fig. 4 After Pelletizing

Fig. 5 Finished Product

3.2 Production of Foamy Slag for Electric Furnaces

The energy released by biomass straw in the carbonization process can be used for drying particles, and the generated carbonized bio-char can be processed to produce 0.5-3mm particles, which can be added into carbon powder as an additive to form foamy slag in the steelmaking by short-process electric furnaces, playing the role of submerging arc, supplying heat, saving energy, protecting electrodes, and avoiding exposed oxidation of liquid steel. The carbonized biomass is shown in Fig. 6. The tests show that the carbonized straw can be added to 1/3 of the total amount. For the electric furnace smelting with pure scrap steel,

Fig. 5 Carbonized Biomass

the amount used per ton of liquid steel can reach 2-6kg/t. Because the alkaline residual ash is only 5-15% of its total amount used, it can guarantee the cleanness of liquid steel without increasing the consumption of lime.

3.3 Production of Mold Casting Powder

For some steel grades and castings, mold casting is still the best choice. Previously, the mold casting powder was made of power plant ash, vermiculite, float beads, graphite, acidified graphite, etc., with an addition of a certain amount of fluorite and sodium carbonate. Based on that, we started to use straw ash to develop casting powder, which was mainly prepared with soda ash, carbonized straw (100-mesh fine powder) and fluorite. The testing results are shown in Table 4.

The applications of the ground product in the casting of stainless steel, axle steel, high-manganese steel and low-carbon alloy steel in Shanxi, Inner Mongolia, Zhejiang and other places show that process-wise utilization requirements can be satisfied in terms of avoiding respective melting, eliminating mold sticking, avoiding carburization as well as thermal insulation of the riser. The mold casting process requirements can be met just by adjusting the proportioning structure or changing the proportioning formula depending on the size of ingot molds, casting speed, and casting temperature. The ingot tail, ingot body and riser are smooth and tidy, without any inclusions or spots. Thanks to the appropriate slag forming speed, the thickness of the slag coat is uniform, and the slag coat is automatically peeled off upon demolding. The on-site tracking and tests prove that the performance of the products meets the requirements of customers, thus it can completely replace the existing counterparts. The testing process and effect are shown in Fig. 7.

3.4 Production of Continuous Casting Powder

Continuous casting powder is a product developed through technological innovation in the last century. Although its specific consumption is less than 0.5kg per ton of liquid steel, >>>

1/3

Add carbonized straw

2~6kg/t

Liquid steel used per ton

tb.4 Chemical Composition and Physical Properties of Casting Powder

Item	SiO_2	Al_2O_3	CaO	MgO	C_{solid}	Melting Point	Melting Rate	Bulk Density (g/cm^3)
Indicator	44.33	5.19	22.71	3.15	0.5	980℃	68s	0.58

it plays an important role in promoting the continuous casting ratio and the steel yield. The production of continuous casting powder has to go through stages and forms such as powder material, solid material, hollow material, sintered material, pre-molten material, or their combination, and it has the basic functions of lubrication, heat preservation, and anti-oxidation. However, the use of biomass straw ash as the base material of continuous casting powder boasts natural advantages: the straw ash has a light specific gravity and a net-like microstructure, making its thermal insulation effect incomparable by other mineral raw materials; it has a high content of alkaline oxides and a low melting point, and thus the required melting temperature can be reached without adding too much flux; its loose structure causes slow combination of small droplets during the melting process, so the melting model structure of the casting powder can be guaranteed without adding too much carbon material, thus avoiding carburization of carbon-sensitive steel; and the material itself is of a ternary structure based on CaO-SiO2-Al2O3, making the formula design become easier.

> “The on-site tracking and tests prove that the performance of the products meets the requirements of customers, thus it can completely replace the existing counterparts.”

After repeated commissioning and testing, the author used biomass straw ash as the base material at a ratio of about 60%, with an addition of 10-20% alkaline oxide, about 20% viscosity modifier as well as an appropriate amount of semi-reinforced carbon black and medium and super wear-resistant carbon black. After grinding, they were made into powder with particle sizes of less than 300-mesh. Afterwards, the power was made into pulp and then into casting powder by means of spray granulation. Its composition is shown in Table 5, and its performance curve is shown in Fig. 8.

Fig. 7 Testing Process and Effect

tb.5 Composition and Performance Indicators of the Casting Powder

Item Description	SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	C_{solid}	Melting Point (℃)	Melting Rate
Powder	34.30	6.49	29.44	3.02	2.99	4.80	1020	28s

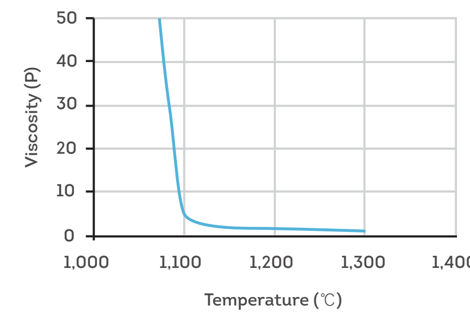

Fig. 8 Temperature and Viscosity Curve of the Casting Powder

Fig. 8 Surface Quality of Billets

Such continuous casting powder product has been tested continuously for 100t liquid steel in a stainless steel enterprise in Inner Mongolia. The surface quality of the cast billet is similar to the one for which the protective slag without straw ash is used, and there is no significant difference in grinding rate and yield rate. In the continuous casting process, the liquid level in the mold is stable, without agglomeration or slag strip, and the slag surface is active; the heat flow density curve of the mold is smooth, and the thermal image and friction force curve of the mold are stable; the oscillation marks on the billets are regular, and the billet surface is flat, as shown in Fig. 9.

4 Application Prospects of Biomass Straw

The year of 2021 marks the start of the 14th Five-Year Plan period. In the Guiding Opinions on Comprehensive Utilization of Bulk Solid Waste (FGHZ No. 381 in 2021) issued by the National Development and Reform Environment, it emphasizes improving the support policies for the development of biomass energy, and thus encourages vigorous promotion of the comprehensive utilization of straw to advance the improvement of quality and efficiency in the comprehensive straw utilization industry. Giving priority to agricultural use, the government will expand

>>>

> The surface quality of the cast billet is similar to the one for which the protective slag without straw ash is used, and there is no significant difference in grinding rate and yield rate.

1.5 mt/a

Biomass straw ash products consumed annually

15 mt/a

Biomass straw

3.75 billion ¥

Direct output value

the utilization scale of straw as a kind of clean energy, encourage the use of straw and other biomass energy for heating and gas supplying and heating, optimize the energy consumption structure in the rural areas, and promote the application of biomass natural gas in the industrial field. Besides, the government will continuously expand the utilization of straw as raw materials, encourage the use of straw to produce environmentally friendly boards, carbon-based products, polylactic acid, pulp, etc., thus promoting the transformation of straw resources into green products with high added value. The government will establish and improve the straw collection, storage and transportation system, and carry out the professional and refined operation and management services, in a bid to open up the "first mile" in the development of the straw industry. Therefore, the comprehensive utilization and development of biomass straw boast broad prospects.

Currently, China's crude steel output is 1 billion tons per year. When the total consumption of thermal insulation agents and casting powder by ladles and tundishes is calculated as 1.5kg per ton of steel, up to 1.5 million tons of biomass straw ash products will be consumed every year, equivalent to a consumption of 15 million tons of biomass straw per year. When the straw ash is calculated at an average price of 2,500 yuan/t, a direct output value of 3.75 billion yuan will be created in addition to the carbon transaction costs saved, 1.2 million tons of standard coal saved, mineral royalties, etc. Besides, the value of electricity generated during the combustion of biomass is not included. It will become a powerful tool for development in the action of achieving peak carbon emission and carbon neutrality, and play an indispensable role in promoting industrial circulation, economic structure linkage, and ecological planning. Therefore, it will not only advance the development of the metallurgical industry, but also be of great significance in promoting the utilization of solid waste resources, the co-production of steel and chemical, the integration of regional energy, and the fostering of industrial chains of circular economy.

5 Conclusions

The use of biomass straw to produce metallurgical auxiliary materials not only can technically meets the technological requirements, but also will yield great environmental benefits, thus being of significant economic benefits.

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Cold Rolling Engineering of the Baosteel Zhanjiang Iron and Steel No.3 Blast Furnace System Project

05

Wang Haidong, Chief Engineer of Steel Making & Rolling Department, Baosteel Engineering & Technology Group Co., Ltd.

1 Preface

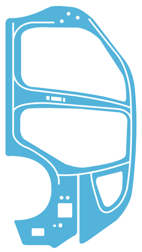
With the development of the automobile industry, fuel efficiency, low carbon emission and more focus on the safety of driving signify new requirements and challenges for the light-weighting of the car body. Light-weighting of the car body and energy saving & consumption reduction are the major development trends of the automobile industry in the future, while ultra-high strength steel remains to be the development trend of automobile steel and the core competitiveness of steel & iron enterprises in the future. At present, steel and iron take up about 65-70% of the curb weight of a domestic vehicle, so steel and iron will remain to be the uppermost material used in China for automobile production within a long time in the future, even though the use of non-steel lightweight materials as substitution is considered.

Advanced high-strength steel enables carmakers to satisfy the increasingly strict requirements for safety, emission reduction and performance, meanwhile, its cost advantage is significant. The development of high-strength steel used for automobiles and the application of light-weight technologies are important ways for automobiles to realize energy saving and emission reduction and to improve passive safety, also essential technologies being developed by all big steel and iron and automobile enterprises across the world.

> "Fuel efficiency, low carbon emission and more focus on the safety of driving signify new requirements and challenges for the light-weighting of the car body."

2 Development of ultra-high strength steel in China Baowu

China Baowu has been taking automobile sheets as one of its uppermost strategic products. It is the first steel & iron enterprise nationwide that realized mass production of the first, second and third-generation high-strength steel. It is among the first-batch enterprises passing the certification for high-strength automobile sheets by carmakers including Volkswagen, GE, and some Japanese automobile enterprises. Its ultra-high strength steel production process is sophisticated, meanwhile, by closely tracing and studying world-leading automobile sheet production technologies, it has formed its independent capability to integrate professional production technologies, which focus



1.28mt

Automobile sheets and high-strength steel products

on the production of automobile sheet products. This keeps China Baowu in a leading position nationwide in the field of automobile steel sheet application technologies.

Eighteen years have passed since China Baowu began to develop ultra-high strength steel production technologies in 2002. Due to the blockade on techniques by developed countries, China Baowu has always been reliant on independent R&D & independent integration of equipment, and became the first Chinese enterprise that developed a complete set of ultra-high strength steel production technologies and realized industrialization in 2009.

During the independent R&D and production practice over these years, it has cultivated a scientific research team with rich experience and world-leading technologies, and built an advanced and perfect system and platform used for the development and production of ultra-high strength steel products, the research of new application technologies, production management and user service.

In 2013, China Baowu became the first enterprise worldwide that developed the third-generation ultra-high strength steel --- QP steel, i.e., quenching and partitioning steel, and realized mass production.

In February 2015, China Baowu QP1180GA advanced high-strength steel for the automobile was first launched globally. The adoption of the zinc-alloying layer in high-strength steel (above 980Mpa) offers powerful support for the light-weighting development of the automobile.

In June 2015, the materials and parts made of medium Mn-TRIP steel, the third-generation automobile steel developed by China Baowu, were first launched globally. These materials include cold-rolled CR980 MPa, hot-dip galvanized GI980MPa and hot-dip galvanized GI1180MPa series, etc.

In 2019, high-performance cold-rolled quenching and partitioning steel QP1500 with a tensile strength up to 1500MPa was produced successfully by China Baowu. Its first global launch signified a sold step of China Baowu on the road to becoming the leader of global steel and iron enterprises.

In December 2021, CR1310DP ordinary cold-rolled products made of cold-rolled X-GPa steel were manufactured successfully at Baosteel's Zhanjiang base. They were featured by their strong anti-corrosion property, superior coating and high-class surface. This marked a new breakthrough of China Baowu in the R&D and manufacturing of X-GPa steel, which, as a kind of automobile steel developed by Baosteel, is leading the new global trend of material selection for light-weighting of the car body, also a green model of China Baowu on its way of practicing "double carbon".

X-GPa steel, as a kind of automobile steel developed by Baosteel, is leading the new global trend of material selection for light-weighting of the car body, also a green model of China Baowu on its way of practicing "double carbon".

3 Independent integration and engineering innovation practice of Baosteel Zhanjiang No.3 cold rolling high-strength production line

The cold rolling engineering of the Baosteel Zhanjiang Iron and Steel No.3 blast furnace system project was constructed in two steps. The first step was to build a continuous annealing/hot-dip galvanizing ultra-high strength steel production line, which was put into production on October 9, 2019. The second step, i.e., the present engineering, was to build a manufacturing shop with an annual capacity of 1.28 million tons of automobile sheets and high-strength steel products as well as supporting utility & auxiliary facilities, including a hot-rolled coils conveying system, a

pickling line coupled with tandem cold mill, a continuous annealing unit, two hot-dip galvanizing units, two recoiling units, two packing units and a grinding roller room. This engineering was commenced on June 11, 2019 and put into production by the end of 2021.

This engineering was designed independently by China Baowu, and Baosteel Engineering & Technology Group Co., Ltd. undertook the tasks of the design and supply of equipment and plant design as the general contractor of technology. "Simpleness, high efficiency, low cost and high quality" were taken as its design ideas. The construction experience, process technologies and production experience were borrowed from Zhanjiang Phase I and Phase II cold rolling engineering. Reasonable process equipment was selected, and the idea of intelligent manufacturing was practiced, so as to facilitate automatic production, including automatic unbaling, automatic slag conveying, electromagnetic slag skimming, automatic sampling, automatic labeling, automatic packing, unmanned running, automatic grinding roller room, etc. We will continue to optimize the product structure and improve the product quality to create a batch of featured products. We will also improve our system efficiency and operational performance in all aspects to build it into a low-carbon, green and intelligent cold rolling engineering featuring its advanced equipment level, superior product quality, low energy consumption, high labor productivity, good environmental protection and reasonable engineering investment.

On the premise that the production process and product program are satisfied, this engineering optimizes its configuration, making type selection of equipment fused together with process requirement, thus the engineering investment is optimized. Based on the strengthening mechanism, cooling mode and platability of ultra-high strength steel, we accomplished the following technical innovations and light spots during the design of independent integration and engineering practice:

1 The product is positioned as advanced high-strength steel used for automobiles, with reasonable process design and equipment configuration, and prospective use of the world-leading ultra-high strength steel production process.

2 Large pickling capacity is realized: the adoption of the turbulence pickling process, which is featured by its high pickling efficiency and good quality, enables it to satisfy the requirements of ultra-high strength steel for pickling.

3 Laser welders are used to satisfy the requirements of ultra-high strength steel for welding.

4 A six-roller mill is used to solve the problem that ultra-high strength steel is difficult to be rolled, thus satisfying the production requirement of 1500MPa products. This unit will become the first professional cold continuous rolling unit for ultra-high strength steel production.

5 The annealing furnace is heated with open flames, thus improving the platability and stability of steel sheets.

6 The annealing furnace is equipped with a transverse flux induction heating device to solve the problem of rapid heating when the annealing temperature is higher than 870.

7 The annealing furnace is equipped with a longitudinal flux induction heating device to meet the requirement of QP steel for temperature rise after low temperature aging.

8 An alloying furnace is adopted to meet the requirement of ultra-high strength steel GA products for production.

9 A quick cooling device with double cooling systems is adopted: the high-hydrogen cooling can satisfy the production requirements of automobile sheets and QP steel, while the powerful water spray cooling can realize low-cost production of DP steel and allows vertical arrangement in parallel. The two processes don't interfere with each other.

10 A longitudinal flux induction reheating device is adopted to meet the production requirements of QP steel and control the aging temperature of DP steel accurately. In this way, we can optimize the performance of QP steel, DP steel and other advanced high-strength steel, thus realizing a more flexible configuration of annealing process curves.

11 In order to meet the requirements of the powerful water spray cooling process for production, improve the surface quality of part of steel varieties, and improve the coatability of top coating at automobile factories, a flash nickel plating section is arranged behind the furnace section to solve the problem of surface oxidation arising from water spray cooling.

12 A comprehensive improvement is made in detecting and controlling the temperature of ultra-high strength steel strips and furnace atmosphere.

13 The waste gas system of the annealing furnace is provided with a waste heat recovery device, which is conducive to energy saving.

14 To practice intelligent manufacturing and facilitate automatic production, some intelligent devices are adopted to realize automatic unbaling, automatic slag conveying, electromagnetic slag skimming, automatic sampling, automatic labeling, automatic packing, unmanned running, automatic roll grinding, etc.

15 Advanced engineering equipment, superior product quality, low energy consumption, high labor productivity, good environmental protection and reasonable engineering investment are ensured.

16 / 17 >>>

"The development idea of circular economy is implemented to facilitate energy saving & emission reduction and comprehensive utilization of resources, thus realizing green manufacturing and clean production."

16 Emphasis is laid on the economic rationality of engineering investment and operating cost. Mature and reliable techniques are adopted as the basis and measures are taken to speed up construction progress, while independent integration design is adopted to minimize investment and shorten the period of engineering construction.

17 Importance is attached to energy saving, environmental protection and clean production to meet the requirements for energy saving and clean production, with the aim of achieving less energy and material consumption, desirable comprehensive utilization, and less waste; in terms of process and type selection of equipment, environmental protection is emphasized, in an effort to minimize pollution and realize clean production -- the emission indexes are not lower than the domestic advanced levels; the development idea of circular economy is implemented to facilitate energy saving & emission reduction and comprehensive utilization of resources, thus realizing green manufacturing and clean production.

4 Conclusion

The construction of the cold rolling engineering of the Baosteel Zhanjiang No.3 blast furnace system project gives full consideration to the requirements of ultra-high strength steel production for process and equipment configurations, making it capable of achieving large-scale and specialized production of the third-generation ultra-high strength steel – QP steel.

The Zhanjiang cold rolling engineering will be built into the most advanced, efficient and competitive ultra-high strength steel production unit, leading the development trend of the world's ultra-high strength steel.

After the engineering is completed, Baosteel Zhanjiang Iron and Steel will become the "most advanced, efficient and competitive" ultra-high strength steel production unit, a one-million-ton class one, reaching the world-class level and leading the development trend of the world's ultra-high strength steel manufacturing technologies. Its strengths are detailed as below:

1 An industrial leadership is achieved by relying on its leading "process, technologies and equipment", its pursuit of "advancedness, high efficiency, low cost and high competitiveness", and its insistence on "intelligent manufacturing, energy-saving & environmental protection, intellectual property right".

2 A technology leadership is achieved through a combination of "introduction and independent integration" to digest, assimilate and master core process technologies for ultra-high strength steel production.

3 A product leadership is achieved by laying equal stress on "the production of conventional ultra-high strength steel, the production of the third-generation ultra-high strength steel and the expansion of new ultra-high strength steel varieties", so as to satisfy the demands of the market for light-weighting, differentiation and professionalization.

Development Status & Engineering Innovation Practice of Advanced Color Coated Sheet

06

Wang Haidong, Chief Engineer of Steel Making & Rolling Department, Baosteel Engineering & Technology Group Co., Ltd.

Abstract: This paper presents the development status and trend of the advanced color coated sheet, and briefly describes the independent integration and engineering innovation practice of a typical advanced color coated sheet production line. The construction of the typical advanced color coated sheet production line by China Baowu is of great reference value and plays a demonstration and leading role in its subsequent construction or transformation of similar production lines.
Key words: Color Coated Sheet; Innovation; Practice

1 Preface

It is well known that the color coated steel sheet is a kind of organic coated steel material, with the advantages of good corrosion resistance, low cost, practicality, vivid color, good appearance, easy forming and processing, and also has the original strength of steel sheet. It provides new raw materials for the construction industry, shipbuilding industry, vehicle manufacturing industry, household appliance industry, electrical industry, etc. Replacing the woods, it has achieved a good result in improving construction efficiency, saving energy, and preventing pollution.

2 Development status & trend of color coated sheet

2.1 Development status of domestic color coated sheet in recent years

Since 2002, with the entry of a large amount of private capital, the number of production lines of the color coated sheet has increased rapidly, and the industry has entered a stage of rapid development, with the average annual growth rate of the output exceeding 10%. Domestic enterprises engaged in the production of the color coated sheet are mainly located in developed coastal areas. At present, there are three industrial clusters respectively in the Yangtze River Delta, the Pearl River Delta and the Circum-Bohai-Sea Region. There are a large number of color coated sheet manufacturers in China, but most of them are small in scale and the product price is highly market-oriented. The influence of a single enterprise on the price is limited, and the price trend has certain fluctuations.

As of 2020, the domestic production capacity of the color coated sheet had reached 43 million tons, the output in 2020 was 19 million tons, and the national average capacity utilization rate was 44%.

In terms of the production distribution, East China is the main production area of the color coated sheet, with both production capacity and output accounting for nearly 70% in the country. The second is North China, with both production capacity and output accounting for about 14%.

The downstream demand for color coated sheet in China is mainly from the construction industry. The consumption for construction (real estate and steel structure) accounts for the largest proportion, reaching 86%. In areas such as East China where steel structure enterprises are concentrated and construction is prosperous, the consumption is also large. At the same time, the application of color coated sheet in home appliance industry, automobile industry and other emerging fields is gradually on the rise.

Benefiting from the upgrading of national industrial structure and the development of strategic emerging industries, the domestic market demand for the color coated sheet is increasing on the whole. In the early years of this century, the development of downstream industries such as construction, decoration and household appliances drove the rapid growth of the demand for color coated sheet. During the 13th Five-Year Plan period, China's color coated sheet industry has increased the intensity of structural adjustment and sped up the technological upgrading, achieving remarkable results in strengthening product development and changing growth mode. In recent years, with the continuous improvement of some superior domestic enterprises in technology, R & D and product quality, most products have realized substitution of imported products, and the total import volume is decreasing. With the continuous enhancement of downstream customers' requirements for color coated sheet in all aspects, the demand for functional color coated sheet with advantages such as energy saving, environmental protection, high cleanliness, high heat resistance, high corrosion resistance and antistatic property will continue to rise.

Fig. 2.1 Domestic output of color coated sheet in recent years

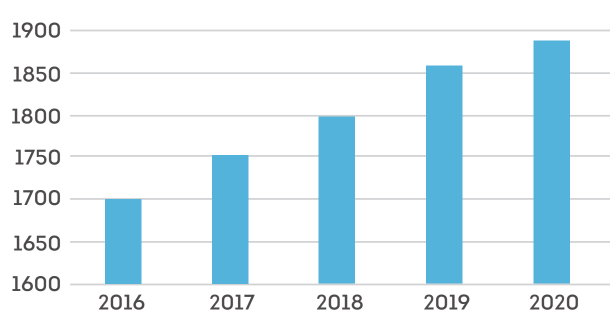
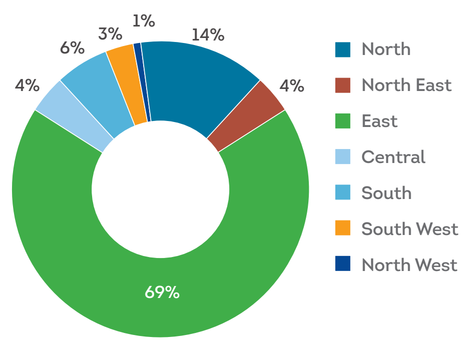


Fig. 2.2 Production capacity distribution of color coated sheet in China



2.2 Development of some new technologies of the color coating line

2.2.1 Galvanizing and color coating combined line

A kind of galvanizing and color coating combined line came into existence. The products of such combined line are mostly used in building materials and household appliances. Some of the combined lines that have been put into operation are new units, and some are the existing galvanizing units added with the color coating process section.

The galvanizing and color coating combined line has the following advantages:

1. The hot-dip galvanizing line and color coating line have the same equipment configuration at the inlet and outlet sections, so the galvanizing and color coating combined line can save a set of equipment at the inlet and outlet sections.

2. The galvanizing and color coating processes of strip steel are completed at one time in the combined line, which saves the relevant equipment and operation links such as secondary uncoiling, coiling, stitching, sub coiling, baling and rolling, as well as labor and personnel.

3. It can also save the steel coil warehouse and lifting and transportation equipment between the galvanizing line and the color coating line.

4. It can complete galvanizing and color coating at one time, which shortens the production cycle.

5. It can reduce investment and production costs.

However, the galvanizing and color coating combined line also has the following problems to be solved:

1. The variety and specification of color coating are single, and the requirement for quality is not high, so it is suitable for mass production of advantageous color coated sheet for ordinary buildings.

2. The requirements for coating are high. The baking and curing time of ordinary coatings is within 18-25s, while that of vertical induction heating furnace is shorter, so the baking and curing time is 6-12s.

3. It is necessary to comprehensively consider the production arrangement of color-coated finished products and galvanized finished products. When the color coating is switched, the finished product should be galvanized directly without stopping the machine.

4. The surface quality of the products from the combined line is slightly worse than that from ordinary color coating units.

2.2.2 Radiation curing technology

Radiation curing is a process of instant (ms-s) curing of solvent-free coatings at room temperature with the help of energy irradiation. Depending on the wavelength, there are many forms of energy irradiation, such as radio wave, microwave, infrared, visible light, ultraviolet, and high-energy electron beams (X-ray and Ray). With the decrease of wavelength, the energy increases gradually. It is common in the industry to collectively refer to the curing of ultraviolet (UV) with the maximum energy and electron beam (EB) as radiation curing technology.

43mt
Production capacity of color coated sheet

19mt
Output in 2020

44%
Average capacity utilization rate

This technology has the following advantages:

1. High efficiency: 1 ~ 2s for UV curing and less than 1s for EB curing;
2. Environmental protection: there is almost no VOCs in the solvent, and the energy is electricity with no CO2 emission;
3. Energy saving: the energy consumption of UV is about 1/5 of that of conventional hot air curing, and the energy consumption of EB is about 1/100 of that of conventional hot air curing;
4. Compactness: small equipment volume;
5. It can form a differentiated coating surface: the radiation curing coating has a high crosslinking density and can form differentiated characteristics such as high hardness, high wear resistance and high gloss.

However, there are also problems to be solved:

1. The coating has a high viscosity and general workability;
2. The volume shrinkage of the coating is large, and the combination with the substrate needs special design;
3. The flexibility of coating is poor;
4. Inert gas is required for protection, etc.

2.2.3 Ink-jet printing technology

The printing technology has experienced the following developments and changes:

1. **Single-roll engraving**
Regular and periodic patterns are achieved by engraving on the surface of the roller at a speed of 60mpm. The pattern is relatively single, the roller needs to be changed, and the engraving manufacturer is limited. In addition, there is a special solvent in the ink that is harmful to health, so the purification device is needed at a high cost.

2. **Combined printing**
With the cooperation of multiple units, the strip steel has good stability, accurate position and high pattern configuration, the ink is harmless to the human body, and the speed can reach 100mpm. The rubber roller is cheaper than steel roller engraving, but the base coating needs to be added after the initial coating.

3. **Ink-jet printing technology**
It needs no roller, no solvent, no shutdown switching, and can realize remote pattern switching with high resolution. At present, the rapidly developing ink-jet printing technology has been applied and studied in the United States, South Korea and Europe, mainly for the production of color coated products of customized patterns at low speed and in small batches.

3 Independent integration and practice of typical advanced color coated sheet production line

Baosteel Zhanjiang Iron & Steel Co., Ltd. has built a new color coating unit, and its target market is high-end building materials, with an annual production capacity of 210,000 tons. The product specification is 0.35-1.0mm * 800-1,250mm.

Adhering to the design concept of high efficiency, intelligence and low cost, the project is based on independent integration & innovation. With long-term accumulated technical advantages and engineering experience, Baosteel Engineering & Technology Group Co., Ltd. has undertaken the project and is responsible for the design and equipment supply of the project. After the completion of the project, the zinc aluminum magnesium substrate color coated sheet with excellent corrosion resistance by Baosteel Zhanjiang Iron & Steel Co., Ltd. will be further popularized and applied, and the demand potential for color coated sheet in South China market will be further released.

In order to enhance automation level, intelligence level, safety and environmental protection level and labor efficiency, the project fully draws on and absorbs the experience of many production lines of China Baowu Steel Group Corporation Limited (Baowu Group) in construction and production practice, and carries out independent integration and innovation construction in combination with the new technology of color coating and the new development of cold rolling intelligent manufacturing, so as to improve efficiency and profitability, make forward-looking practice and provide samples for the transformation of the existing color coating units or establishing of new color coating units of Baowu Group. The implementation of the project has a good reference value and plays a demonstration and leading role in its subsequent construction or transformation of similar production lines.

> “Adhering to the design concept of high efficiency, intelligence and low cost, the project is based on independent integration and innovation.”

Baosteel Engineering & Technology Group Co., Ltd. undertakes the tasks of technology assembly, equipment design and supply and factory design. Adhering to the design concept of “simplicity, efficiency, low cost and high quality”, it has the following technical innovations and highlights in independent integration design and engineering practice:

1. The project aims to expand the product structure of Baosteel Zhanjiang Iron & Steel Co., Ltd. and build a new color coating unit for construction with an annual capacity of 210,000 tons, which is characterized by hot-dip galvanizing and zinc aluminum magnesium substrate.
2. The entrance section is equipped with double uncoiling equipment, which has the functions of automatic coiling and uncoiling and thus greatly shortens the auxiliary feeding time at the entrance of the unit;

03 / 11 >>>

③ Transverse shear is adopted at the entrance, which can quickly cut off the super thick and damaged parts at the head and tail of the steel coil, and reduce the shutdown preparation time at the entrance section;

④ The sewing machine is used for double-row sewing, which can sew two layers of strip steel with a maximum thickness of each layer reaching 1.0mm;

⑤ The cleaning section adopts the series cleaning process of “alkali spraying + hot water rinsing + composite oxidation + hot water rinsing + drying” to remove the powdery impurities and grease on the surface of the strip steel and make the strip steel have a clean surface;

⑥ Chemical roller coater & paint roller coater adopt automatic operation and two-high type, which can realize closed-loop control of position or pressure;

⑦ The baking oven adopts the heating process of clean hot air + sectional small burner for heat supplement. The heat supplied to the baking furnace comes from the heat exchanger configured after RTO and the small burner configured in the mixing chamber of each section of the baking furnace;

⑧ The waste gas treatment system adopts RTO (regenerative thermal oxidizer) type with low energy consumption. The device can fully recover the heat released during the decomposition of VOC in the waste gas discharged from the baking furnace, and does not consume fuel during normal operation, with the purification efficiency exceeding 99%;

⑨ The unit is equipped with online color difference meter, online film thickness meter, viscosity meter, automatic sampling machine, automatic tape sticking machine, automatic labeling machine and other intelligent equipment;

⑩ The project attaches importance to the economic rationality of investment and operation cost. It adopts mature and reliable technologies and highlights the study of measures to speed up the construction progress. Based on mature and practical technologies, it uses the mode of independent integrated design to minimize investment and shorten the construction cycle of the project;

⑪ It emphasizes energy conservation, environmental protection and clean production to meet the relevant requirements, and strives for low energy consumption, low material consumption, comprehensive utilization and little waste. In the process and equipment selection, it highlights environmental protection, strives to reduce pollution to the lowest extent, and maintains the emission index not lower than the domestic advanced level, so as to realize clean production.

It emphasizes energy conservation, environmental protection and clean production to meet the relevant requirements

4 Conclusions

With the rapid development of the domestic color coated sheet industry in recent years, an industry chain of the color coated sheet with the combination of chemical and metallurgical industries has gradually come to being, which has brought new hope for the revitalization of the color coated sheet industry. Meanwhile, with the continuous expansion of application fields of the color coated sheet, users have raised higher and higher requirements for the quality of the color coated sheet.

The domestic market of the color coated sheet will still be dominated by the construction industry, and the color coated sheet with thin thickness, high strength and corrosion resistance will dominate the market. In addition, the thick large-span steel sheet will also have a certain market. The development of color coated sheet with high weatherability and functional color coated sheet will become the research directions with the most competitive potential.

This project is based on independent integration & innovation. After its completion, the zinc aluminum magnesium substrate color coated sheet with excellent corrosion resistance by Baosteel Zhanjiang Iron & Steel Co., Ltd. will be further popularized and applied, and the demand potential for color coated sheet in South China market will be further released. The implementation of the project has a good reference value and plays a demonstration and leading role in its subsequent construction or transformation of similar production lines.

“Projects adopt mature and reliable technologies, highlight the study of measures as well as using independent integrated design to minimize investment and shorten the construction cycle.”

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