IRON AND STEEL INDUSTRY DEVELOPMENT AND TECHNOLOGICAL INNOVATION IN CHINA

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ABSTRACT

China's iron and steel industry enjoys accelerated development thanks to the booming demand in domestic market and more local production of major equipment. It has become the largest country in stainless steel consumption and production in the world. The major progress in technology during last decade in China includes: equipments growing larger in scale; longer life of blast furnaces and converters, coal-powder injection for blast furnace, slag splash technology for converter, and the high ratio of continuous casting for steelmaking process; comprehensive energy consumption and productivity in large and medium steel plants getting closer or reaching the world's advanced level. China's iron and steel industry is constrained by resources and environment. China has to form an industrial chain of circular economy with steel plants as its core, which carries out three functions of producing high quality steel products, high efficient energy transformation, and utilizing wastes of society.

INTRODUCTION

At the turn of the century, China became a net exporter from a net importer, producing one third of world's steel. While its production capability keeps expanding, introducing larger equipment with more advanced technologies and improving in process uplift the technology in China's major large and medium steel plants to the level compatible with the world's similar ones.

Constrained by resources, energy and environmental bearing quantity, China's iron and steel industry sets its target as meeting the domestic demand. The main driver of the development is the increasing demand in quantity, in varieties of products, and in quality of steel during the course of industrialization and urbanization in China.

Major Progress in the Beginning of the Century

In 2006, China's steel output exceeded 400 million tons (Figure 1). The time spans for increasing 100 million tons output of steel kept shorten. China had been a net importer of steel before 2004. It was until 2006 that the output of steel slightly exceeded the apparent consumption so that China turned to be a net exporter of steel. However, China will not become a true steel exporter. The objective of the development of iron and steel industry in China is mainly for domestic demand.

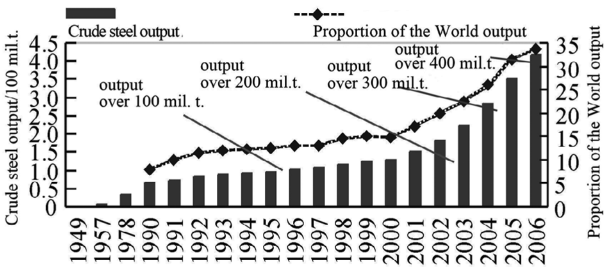

Figure 1: Rapid growth of steel output in China

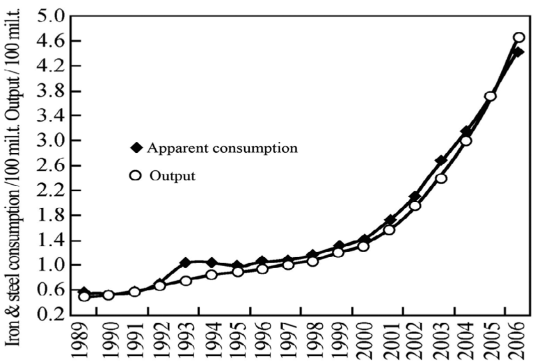

Figure 2: Iron and steel consumption and output from 1989 to 2006 in China

In the first six years of this century, China's iron and steel industry mainly focused its study on enlarging facilities and the rationalization of process. Currently, the producing capacity of large facilities has exceeded 130 million tons (Table 1). Introducing large facilities is one of the key reasons in the improvement of productivity in China's iron and steel industry, especially when these large facilities basically being produced domestically which reduced cost and time for technical upgrading in steel plants. Despite of a small amount of import, steel plate in China can meet the demand and the supply of strip exceeds slightly the demand. Therefore, the producing capacity appears to be sufficient in general.

Table 1: Production capacity of large facilities

Name		2002		2006	
		Quantity	Capacity (10,000t.)	Quantity	Output (10,000t.)
Blast Furnace	3000 m^3+	3	930	12	3576
	2000-2999m^3	17	3149	37	7009
	Subtotal	20	4079	49	10585
Converter	300t. or more	3	819	3	819
	100-299t.	32	4819	91	12464
Electric Furnace	100t. or more	7	673	14	1186
Total (electricand converter)		42	6311	105	13650

In technology and process, the technical progress and innovation include:

- The application of slag splash technology extends the average life of converters to 8,000-10,000 taps from 700-800.
- The continuous casting rate is lifted to 99.7% in 2006 from 25% in 1990, so it can be said that China has built up an iron and steel industry of totally continuous casting.
- The comprehensive energy consumption of iron and steel products has been reduced from 1,611 kg/t to 754 kg/t, with 650 kg/t in some key large enterprises according to the most updated statistics.
- The complete producing process has become modernized. The utilization rate of blast furnace in 2006 was 2.675 t/(m^3•d), and life was 8-12 a. The annual productivity in iron mill was 3,433 ton pig iron per worker.

The above figures demonstrate that the performance indexes of blast furnace in China have become advanced internationally.

Extending life of blast furnace results is significant improvement in economic benefit in iron and steel enterprises. Take an example of 5 blast furnaces of 1000-2000 m^3, 5 of 2000-3000 m^3, and 3 above 4000 m^3. Saving one intermediate repair means saving 1.35 billion yuan RMB. And less stop production for maintenance means more time for production, which generates benefits of 420 million yuan RMB. Therefore, if blast furnaces require no mid-term maintenance in 10 years, it would save 1.77 billion yuan RMB in total.

Another technical innovation of blast furnace is oxygen enriched blast and coal powder injection, which brings a continuous reduction in charge coke ratio annually. Coal injection rate has reached 135 kg/t iron from the average of 50 kg/t iron in early 1990. The charge coke ratio has been reduced from 560 kg/t to less than 400 kg/t.

More in-depth studies on slag splash technology have been conducted in China. It is found that for high FeO slag, tiny FeO particles and MgO in the slag can form a slag splash layer on the surface of lining. The layer contains 58.4% of MgO so as to act like a fire-resistant material. For low FeO slag, its slag splash layer contains high alkalinity C_2S and C_3S phases, which combine with MgO in the lining (Figure 3, Figure 4). In both cases, the layers protect the lining. The slag splash technology not only can extend the life of converters, but also significantly reduce the time of mixture in the converters. It is because that the slag *cone* is formed on the breathable bricks around the bottom-blown lance and it can also reduce splashing (Table 2).

Another innovation in China is to use hot metal as raw material charged in EAF, since China is lack of scrap and the cost is low in iron-making. When EAF is charged with 20% - 30% of hot metal, the consumption of electricity can be reduced from 334 kw•h/t to 267 kw•h/t, or a decrease of 70 kw•h. The consumption of oxygen is slightly increased. The consumption of electrodes will be reduced from 2.5 kg to 1.6 kg. The smelting period will be shortened significantly.

Process Features	**High FeO Slag (300 t converter, Bao Steel)**				
	MgO	**T.Fe**	**SiO_2**	**CaO**	**MnO**
Slag Composition/%	10.2	19.8	12.7	42.4	5.2
Slag-splashed Layer Composition/%	58.4	16.0	2.6	10.0	1.4
Characters of Mineralogical Phases	Sintering layer: large-sized MgO particles as main phase: MF and C_2F as adhesive phase. Combining layer: MgO crystals as main phase, containing less C_2S and C_3S				
Combining Mechanism	(MgO)+(FeO)→ (MgO·FeO) Chemical Combination				

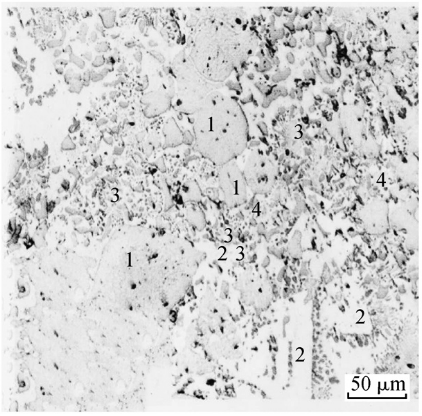

Figure 3: High FeO Slag splash technology

Process Features	**Low FeO Slag (30 t converter, Tianjin Steel)**				
	MgO	**T.Fe**	**SiO_2**	**CaO**	**MnO**
Slag Composition/%	10.88	7.6	22.04	49.68	2.11
Slag-splashed Layer Composition/%	12.63	10.92	16.08	50.69	1.43
Characters of Mineralogical Phases	Sintering layer: large-sized MgO particles as main phase; C_2S and C_3S permeating through blowholes condensed and mosaic with MgO crystals as adhesive phase. Combining layer: C_2S and C_3Sas main phase; a small amount of MgO crystals and C_2F, RO phase uniformly distributed				
Combining Mechanism	Condensed C_2S and C_3S phase mosaic with MgO, Mechanical Combination				

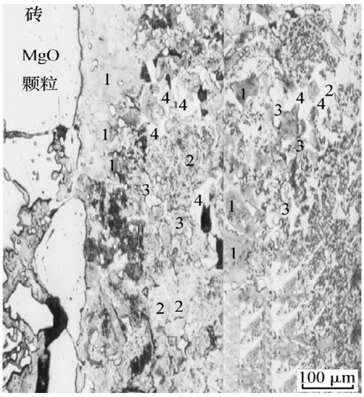

Figure 4: Low FeO slag splash technology

Table 2: Technical comparisons between two types of *cones*

Item	**Slag *Cone***				**Metal *Cone***		
Shape	Large in volume, tiny holes on the surface				Small in volume, relatively big central holes, side tiny holes		
Composition /%	CaO	SiO_2	MgO	T.Fe	Fe	C	Others
	47.9	13.78	11.6	15.18	≥ 91	1.48	4.7
Forming Mechanism	Slag condensed by gas				Metal condensed by gas		
Interaction with Molten Bath	Gas flow in small streams and float in tiny bubbles; permeable area increased, and mixing time shortened by 50%; the molten bath remains stable with few splashing when stirring				Gas flow relatively strong, and floating big bubbles form gas column; the molten bath is not stable with more splashing when stirring		

China also develops most rapidly in thin slab continuous casting and continues rolling technology. There are 13 production lines in China with a total capacity exceeding 30 million t/a. An ASP production line solely developed by Anshan Steel Corporation can process continuous casting billets of 120-150 mm thickness. Therefore, it can match with high efficient production of large converters. The production capacity can exceed 2 million t/a.

The current structure of iron and steel products in China is that 65% are carbon steel. Low alloy steel is about 28%, and alloy steel is only 6% of total steel output. Since China is in the course of large scale of urbanization and infrastructure building, products for construction takes a large share, i.e., 40%. In recent years, the shares of plates and wide strips are increasing faster, thanks to the development of automobile industry and shipbuilding industry.

Building a Resource-Saving and Environmentally-Friendly Iron and Steel Industry

Being a high energy consumption industry, the iron and steel industry in China has realized that it has to fully use the heat and chemical energy generated during the metallurgical process in order to save energy. In the past decade, the iron and steel corporations in China realized that iron and steel plants are not only producers of iron and steel, but also places of energy transformation with high efficiency. Therefore, major iron and steel enterprises have set up Energy Management Centers to maximize the use of gas which differ in thermal value, temperature, and pressure in the most rational way.

China is lack of water resources and its per capita fresh water possession is only one third of the world's average level. Iron and steel corporations are large consumers of water. In 2000, the water consumption per ton of steel was 25 tons. In recent years, the rate of water reuse has been increased to 95%, bringing the water consumption per ton of steel down to 6.5 tons from the previous 25 tons (Figure 5).

The recycle and reuse of solid wastes in iron and steel industry is shown in Table 3.

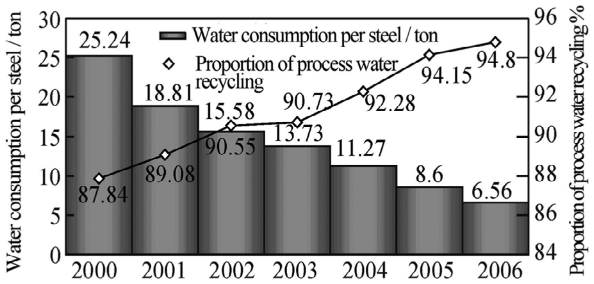

Figure 5: Water consumption per ton of steel and rate of water reuse in key large and medium enterprises from 2000 to 2006

Table 3: Solid wastes recycling in 2006 in China

Name	Output /10,000t	Recycling /10,000t	Recycling /%	Uses
Blast Furnace Slag	13216	11851	89.67	cement; admixture to concrete
Steel Making Slag	4872	4210	86.41	return alloy, fill materials for road construction, steelmaking slag cement, admixture to concrete
Dust	3743	3683	98.40	sintering, return alloy
Iron scale	617	615	99.68	return alloy for sintering, some coolants

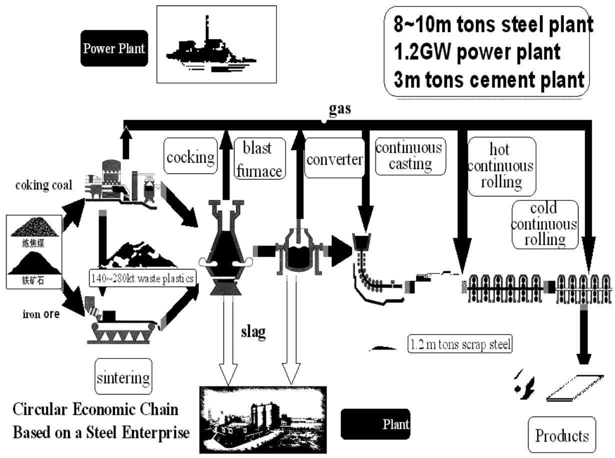

Figure 6: New generation of iron and steel manufacturing process

At the turn of century, Chinese engineers and scientists in iron and steel industry proposed a new generation of iron and steel manufacturing process through integrated innovation, which is based on the scientific concept of development and the principle of circular economy. The core of the process is expanding iron and steel production from a single function of steel production into triple functions including solid wastes recycling and high efficient energy transformation. For example, a large iron and steel corporation with production capacity of 8 million to 10 million tons can use 140,000 – 280,000 t/a solid waste plastics in its converters and blast furnaces, despite of producing high quality steel. And 1.2 million tons of scrap can be used as cooling agent in converters. In the meantime, all the gas from coke ovens, blast furnaces, converters and other sources can be collected and used for heating and major parts for power generation as well. It is not simply a reusing of gas that was emitted in the past. More important, it is much cleaner than coal-fired power generation since its very low CO_2 content in the waste gas. To use the waste slag from blast furnaces and converters to produce cement can reduce the exploitation and utilization of limestone.

Another innovative idea is to produce hydrogen through the waste gas in metallurgical process. The components of the waste gas are shown in Table 4. Take coke oven gas as an example. The process is to dry the gas first, then desulfurize, reform methane, and produce hydrogen by introducing CO to steam methane. Since coke oven gas is high in temperature, the process can be designed into steps of autothermal reforming (ATR) and decomposition, which means to produce pure hydrogen without any input of heat from outside. The schematic diagram is shown in Figure 7 and 8. In this way, iron and steel plants not only can generate electricity, but also produce hydrogen in industrial scale so as to meet the demand of hydrogen fuel cell electric vehicles.

Table 4: Component of gas produced in the process of steel making

Type	H_2	CO	CO_2	CH_4	N_2	CNHM
Coke Oven	52~55	7	2	27~30	5	3
Blast Furnace	0.6	26	15		Others	
COREX	15-20	35~45	30~35	1	1	

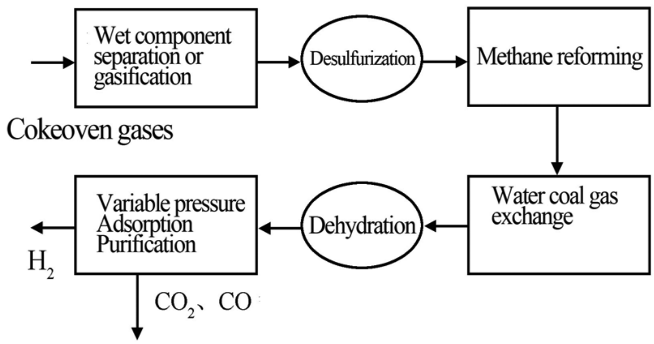

Figure 7: Hydrogen production with coke oven gas

Steam Methane Reforming (SMR)

$CH_4 + H_2O = 3H_2 + CO \Delta H = 206$ kJ

Partial Oxidation Reforming (POX)

$CH_4 + 0\ 5O_2 = 2H_2 + CO \Delta H = -36$ kJ

Autothermol Reforming (ATR)

$CH_4 + \alpha O_2 + \beta H_2O = (2+\beta)\ H_2 + (2\alpha+\beta) CO \Delta H \approx 0$

Figure 8: Methane reforming reaction

CONCLUSIONS

Large facilities and the application of advanced technologies have improved the comprehensive competitiveness of China's iron and steel industry, and it will do so in the future.

The core of new process in iron and steel production is short in process, better continuity, low energy consumption, high productivity, and environmental friendly. All innovations regarding the process should be considered from these aspects.

It is a necessary requirement for the sustainable development of iron and steel industry to develop a green industry and turn the plants into a base for producing high quality steel, recycling wastes from society, and high efficient energy transformation.

Increasing the degree of integration in iron and steel industry is the guarantee of achieving the above three functions. China should form several super-large iron and steel groups with annual capacity of 50 million to 100 million tons.

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