
Innovative Steels for Low Carbon Economy

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Abstract

As one of the vital structural materials, steel has played an important role in national economic development. Under the background of global warming, holding back carbon footprint has become the main task of our mankind. As a giant source of CO₂ emission, it is rather a severe challenge for steel industry to develop further under *Energy Saving and Emission Reduction Policy* (ESER). This article has reviewed and envisioned such practice on steel production, and analyzed how to make innovation on steel material based on Baosteel's own practice so as to provide material solution for down-stream sectors. High strength, high toughness, long service life and versatility of steel material are the trend for material innovation.

Keywords

Steel material • Innovation • Low carbon economy

1 Introduction

With the sustainable development of China's economy, steel industry, as main raw material source for national economy, has sharply taken off. Especially over the past 10 years, substantial breakthroughs have been made in scale, and output has grown 5.4 times, which makes China the largest steel producing country. Its crude steel output share has been shifted from 15% approx. in 2000 to nearly 50% in 2009.

As an economic development engine, steel industry is also one of the main CO₂ producers. According to the statistics from International Energy Agency, the carbon emission of steel industry accounts for 4–5% [1] of global total amount. While within China, that value is 15.6%, accounting for 43.3% [2] of the steel industry the world over. Therefore, it has become a social issue. Chinese

government has solemnly committed that till 2020, CO₂ emission per GDP will be reduced by 40–50% than 2005. As the main carbon emitter, steel industry should take such social responsibility and historical mission.

Energy Saving and Emission Reduction (ESER) of steel industry shall focus on two aspects, one is ESER of steel industry itself; the other is the contribution made by innovative steel material for down-stream sectors. This article has briefly reviewed and analyzed the first scenario. Taking automobile fuel economy, power station boiler, energy transmission, oil–gas transportation and corrosion resistant materials as examples and based on Baosteel's own practices, we focus on the discussion about how to provide material solution through technology innovation for down-stream sectors.

2 ESER of Steel Industry Itself

The basic principle of steelmaking is to reduce ferrous oxide by carbon, than produce carbon saturated hot metal, which is the source to produce liquid steel with different carbon content through oxidation refining. After solidification and rolling,

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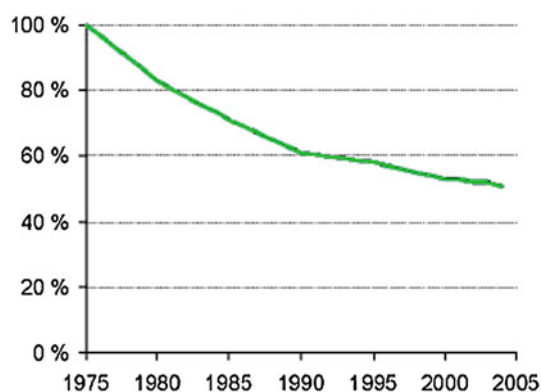


Fig. 1 Energy consumption change per ton of steel in North America, Japan, Europe (1975 = 100%)

final product is come out for different clients. Therefore, the main emission of steel industry is CO_2 .

In traditional steel production, over 90% CO_2 emission is resulted from energy consumption [3], because carbon energy is dominant in all consumptions. According to China Energy Statistical Yearbook, in 2007, coal has taken up 80% of the total primary energy, thus, energy saving is the priority for CO_2 emission reduction.

Over the past 30 years, global steelmakers have made remarkable improvement in reducing energy consumption through technology upgrade. In such developed areas as North America, Japan, Europe, etc., within the 30 years from 1975 to 2005, average energy consumption per ton of steel has decreased by about 50% [4], see Fig. 1.

According to China Iron & Steel Statistics, standard coal consumption per ton of China's steel industry is reduced from 2.04 ton in 1980 to 0.619 ton in 2009, while CO_2 emission per ton of steel is reduced from 3.22 ton in 1991 to 1.87 ton in 2007, by 42%.

Although great achievements have been made in ESER of China's steel industry, compared with those advanced steelmakers in the developed countries such as Japan, Korea, Germany, the steelmakers in China still have a long way to go in consumption control. Our unit consumption is yet higher than international advanced level by 10–20% [5], for this reason, we still have great space to improve.

In steel production, process renovation is decisive to ESER. For instance, compared to mould casting, continuous casting has saved ingot heating and blooming processes so that consumption can be sharply reduced. Likewise, compared to continuous casting, strip casting enjoys even lower consumption. The process schemes of conventional continuous casting and hot rolling, and strip casting process were shown in Fig. 2. As for the former, two thermal cycles are needed when hot metal is altered into steel plate, while the latter needs only one cycle. Therefore, the consumption for the latter is much lower.

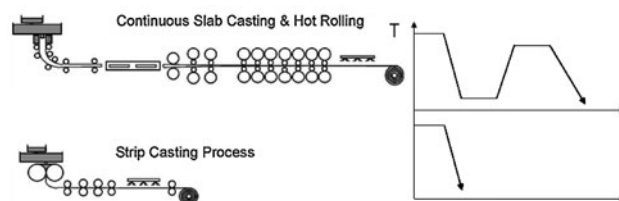


Fig. 2 Schemes of conventional continuous casting and hot rolling and strip casting process

With 10 years' research, Baosteel has successfully developed a brand new low carbon production process in 1,200 mm strip casting pilot line. This year, Baosteel has announced to build an industrial strip casting model line in Ningbo Iron & Steel with annual capacity of 500,000 ton.

3 Innovative Steel Materials Provide Solution for Low Carbon Economy

As a fundamental raw material of national economy, steel is obliged to provide necessary material for technological improvement of other sectors as transportation, energy power, and infrastructure in particular. In the mean time, the development of these sectors raise higher demand for steel materials, this becomes a motive power for its innovation. Then, in the light of fast developed industries such as automobile, oil–gas transmission, power transmission, and power plant boiler, combined with Baosteel's own practices, we will come to the topic of steel material innovation.

3.1 Fuel Economy of Automobile and High Strength of Steel Plate

Among such measures as oil consumption reduction and emission cut in automobile industry, more attention has been attached on lightweight of car body. Statistically speaking, each 10% weight losing could save 3–7% fuel and 13% CO_2 . Figure 3 has shown the relations between car weight and fuel efficiency [6].

According China Automotive Lightweight Union, our own-brand passenger cars are 10% heavier than overseas ones of its kind, while larger gap exists in commercial vehicles. In 2010, sales volume of China automobile market expects to exceed 17,000,000, and continues to maintain World No. 1. Rapid increase of automobile ownership results in boosting demand on petroleum. Now, automobile oil consumption accounts for one-third of total oil consumption in China, and is estimated to rise to 57% in 2020 [7]. Therefore, promotion of lightweight research is significant to low carbon society.

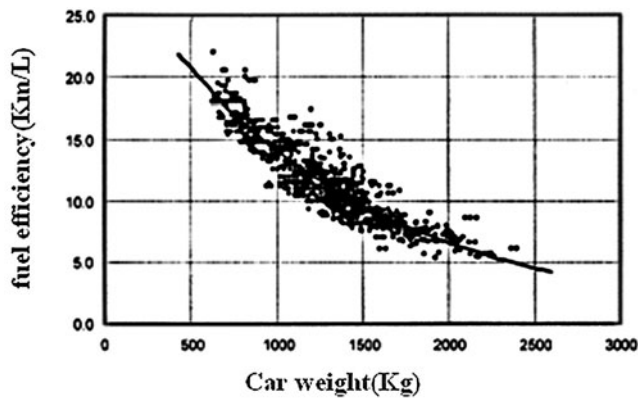


Fig. 3 The correlation between car weight and fuel efficiency

The research result of IISI Automotive Lightweight Project ULSAB-AVC shows [8], massive application of high strength steel and advanced manufacturing technologies (mainly including tailor welded blank, hydraulic forming and hot stamping) are the shortcuts to reduce weight for automobile. Compared with conventional steel, the application of high strength steel could reduce the car weight by 20–25%. In 2009, the application proportion of high strength plate in Chinese automobile industry was only about 25%, while that value abroad was over 50%, while even larger gap exists in application of advanced manufacturing technology. Why these effective solutions are not widely applied in China? On the one hand, China automobile industry needs stronger design capability; on the other hand, domestic steel makers need to capture more core technologies in stable production, application and advanced manufacturing technologies of high strength steels.

In order to promote Weight Reducing & Energy Saving in China automobile industry, Baosteel always stresses R & D in high strength steel and advanced manufacturing technology. Based on lab research, Baosteel has successively built dedicated production lines for ultra high strength plate, tailor-welded blank, hydraulic forming, and hot stamping. Till 2009, Baosteel had owned annual capacity of 200,000 ton ultra high strength plate, 20,000,000 tailor welded blanks, 460,000 hydraulic forming parts and 1,000,000 hot stamping parts. In particular, the dedicated line for ultra high strength steel, started construction in early 2009, has applied fast cooling technology and multi-functional production process which are jointly developed by Baosteel and MITSUBISHI-Hitachi. After that, the available strength level for cold rolled plate is upgraded from 800 to 1,500 MPa, while for galvanized plate is from 800 to 1,200 MPa. Recently, Baosteel has trial-produced third generation high strength steel—Q&P steel [9], which enjoys higher plasticity than first generation.

High strength material solution is not only fit for automobile industry, but also for other sectors as construction, machinery, container, etc. For instance, screw threaded steel is shifted from Level II (345 MPa) to Level III (400 MPa) and Level IV (500 MPa), which container steel from 345 to 600 MPa and 700 MPa, etc. High strength has become the main trend for innovative steel materials.

Greater efforts shall be made in the field of material science to produce stronger steel to reduce the material consumption, which will not only reduce energy consumption in production, but also make due contributions to ESER for down-stream sectors.

3.2 Oil-Gas Transportation and Pipeline Steels with High Strength and High Toughness

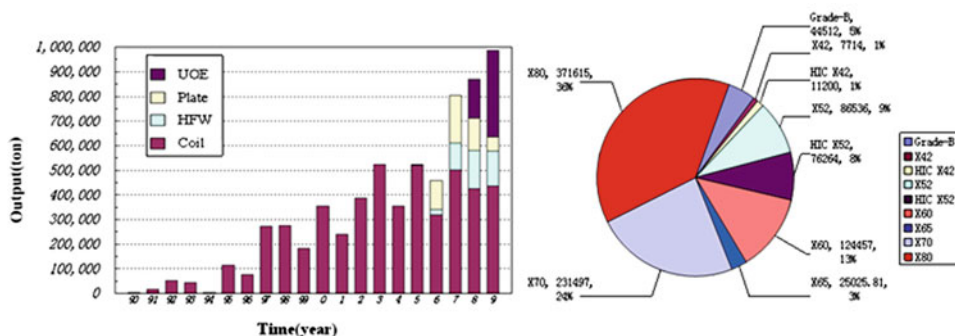
Oil and gas is the crucial energy in modern society. Since the oil and gas fields are usually located in remote areas, long distance pipelines are the most economic, safe and environmental friendly delivery system to transport the oil and gas from field to consumers. In order to save construction investment of pipe line project, enhance transmission efficiency and reduce transportation cost, the operating pressures and diameters of pipeline continue to increase, which requires higher reliability of the pipelines. To handle the demand, the pipeline steels with high strength, high crack propagation arrest toughness at low temperature, excellent weldability are necessary. As for those applied in special areas, H₂S resistance is required. The increasing demand on comprehensive properties of pipeline steel has tremendously promoted the development of modern pipeline steels.

Baosteel's pipe line steel develops at the same pace with the construction of oil and gas pipelines in China. Table 1 has shown the main characteristics of Baosteel's pipe line steel developed over the past 20 years. It indicates that high strength and toughness has become the main theme of Baosteel's pipe line steel development. Steel grade shifted from X42 and X52 20 years ago to X80; impact toughness upgraded from 90 J impact energy to over 240 J at −20°C; maximum thickness increased to 33 mm from 10 mm; available products diversified to coil, heavy plate and welding pipe so as to provide enough material for West-east Natural Gas Transmission Project in China.

Figure 4 shows Baosteel's pipeline steel output in history and grade distribution in 2009. It indicates that the output increases year by year and up to 1,000,000 ton in 2009. Meanwhile, high grade pipeline steel is the main demand in the market. In 2009, the share of the steels of X70 grade and higher is 60%.

Table 1 Baosteel pipe line steel development in variety, grade and product form

Year	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09
Steel grade	X42					X52														
						X60														
						X65														
						X70														
						X52(HIC), X60(HIC), X65(HIC)														
						X80														
						X100, X120														
CVN-20°C	≥30 J		≥90 J						≥190 J				≥240							
Thickness	≤10 mm					Up to 17.5 mm										Up to 33 mm				
Variety	Coil															Coil, heavy plate, welding pipe				

Fig. 4 Baosteel pipe line steel output in history and grade distribution

Same as automotive materials, the developing trend for pipe line steel is the high strength. However, besides high strength, the customers require excellent ductility and toughness also. Therefore, further efforts shall be made by experts in steel material to develop high strength material with excellent ductility and toughness.

3.3 Corrosion Resistance and Long Service Life Design of Steels

Steel is naturally subject to corrosion in service environment. According to the statistic data from Chinese Corrosion Survey Report, the direct economic loss caused by corrosion accounted for about 2–4% of GDP in developed countries, while accounted for about 5% of GDP in China. Meanwhile, the indirect economic losses were immeasurable caused by corrosion-induced equipments damage, mechanical downtime, product quality decline, pollution, and accidents such as explosion and fire. According to the statistic data, about 70% of the failures of oil/gas pipeline were due to corrosion. If the corrosion-resistant steels and appropriate protective measures were adopted, 30–40% of losses caused by corrosion could be retrieved. Therefore, the investigation on the

mechanisms of corrosion and the development of long service life steels become the important issues which are urgently needed to be solved.

Demand for corrosion-resistance of steels varies according to service conditions. After a 20-year development, Baosteel has established a product line of corrosion-resistant steel, including weather-resistant steels, H₂S-resistant pipeline and well tube steels, CO₂-resistant 13Cr steels and Ni-based alloys for well tube. These products have been widely applied in various industries, such as containers, railway rolling stocks, automobiles, buildings, off-shore structures and oil and gas field equipments.

There is still a lot of work to do on long service life steels, which contributes a great deal to the construction of the low-carbon society. For instance, the new type corrosion-resistant steel plate recently developed in some country for oil tanker and VLCC exhibits five time higher corrosion resistance than the former product, which not only can dispense with the coating process, but also can promote the safety and the environment conservation of the ships. In order to reach the goal, the material researchers must innovate continuously to develop the steels suitable for various service conditions with longer service life.

Table 2 Relations among vapour parameters, power plant efficiency and coal consumption

Unit type	Vapour pressure (MPa)	Vapour temperature (°C)	Power plant efficiency (%)	Coal consumption for power supply (g/kW h)
Medium pressure unit	3.5	435	27	460
High pressure unit	9	510	33	390
Super-high pressure unit	13	535/535	35	360
Subcritical unit	17	535/535	38	324
Supercritical unit	25.5	566/566	41	300
Ultra-supercritical unit	27	600/600	44	278
Ultra-supercritical unit	30	600/600/600	48	265
Ultra-supercritical unit	30	700	57	215
Ultra-supercritical unit		>700	60	205

3.4 Energy Efficiency of Power Plant Boiler and Ultra-Supercritical Boiler Tube

Electricity is a safe, efficient and clean secondary energy sources, which plays a decisive role in the national economy. It is estimated that until 2020, the total installed capacity of power generators in China will reach 1.186 billion KW. Since the primary energy source in our country is mainly dominated by coal, coal-fired power generation will certainly cause enormous pressure on the environment. Table 2 reveals the relations among vapor pressure, temperature, power efficiency and coal consumption of different units. It is evident that along with the increase of vapour pressure and temperature, the thermal efficiency of power plant boiler improves, while the coal consumption decreases. For instance, the efficiency of the supercritical unit with a vapor pressure of 25.5 MPa and a vapor temperature of 566°C is 41%, and the coal consumption is 300 g/kW h. While the efficiency of the ultra-supercritical unit with a vapour pressure of 30 MPa and a vapour temperature of 700°C can reach 57%, and the coal consumption is reduced to 215 g/kW h. Therefore, the ultra-supercritical unit with high-capacity, high vapor pressure and high vapor temperature represents the direction of future development of power plant boiler.

With many years' unremitting efforts, China has increased the main vapor temperature of power unit to 600°C, and pressure to 26.5 MPa. In the next 10 years, it is estimated that the vapour parameters of coal-fired power generation in China will increase to 700°C and 30 MPa or higher. This will raise a severe demand on the high-temperature strength and oxidation resistance of boiler tubes. Therefore, whether the steel plant is able to produce such boiler tubes becomes one of the restrictions on the development of ultra-supercritical coal-fire power units.

From 1999, Baosteel has been engaged in the study of key materials for supercritical and ultra-supercritical

coal-fired power unit with high parameters. The high-pressure boiler steels such as T91, T23, T92, S30432 have been developed one after another. Furthermore, through the demonstration on the application of T91, T92 made by Baosteel on Baosteel's 350,000 kW subcritical unit, and performance tests and assessments in the industry of boiler, the high-pressure boiler tube and the inside screw tube of Baosteel's T91, T23, T92 have been widely used in supercritical and ultra-supercritical coal-fire power unit in China. Up to 2009, accumulated production of high-pressure boiler tube has reached 184,000 tons. Generally speaking, Baosteel is able to supply materials for the whole unit heated surface of boiler at 600°C main vapour in the ultra-supercritical power plant. The following Fig. 5 shows the development of the power plant boiler and the development of Baosteel's boiler tube products.

Steel industry should make greater efforts to develop boiler tubes with higher high-temperature strength and higher oxidation resistance, and supply more competitive steel material for power plant boiler sector.

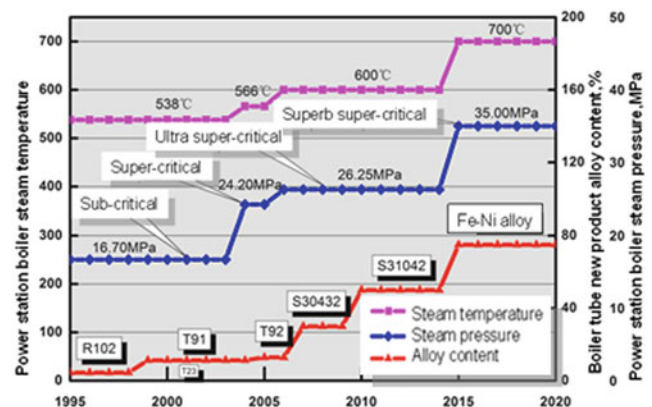


Fig. 5 Developments of the plant boiler and Baosteel's boiler tube products

3.5 Energy-Saving of Transmission and Distribution and Oriented Silicon Steel with High Magnetic Induction

Transformer is one of the key equipments in power sector. Silicon steel is the indispensable material in making the transformers. The transformer made of ordinary oriented silicon steel can cause a power loss of about 1% of the total transmission and distribution capacity. With the transformers made of oriented silicon steel with high magnetic induction, the power loss can be reduced by 40%. If we make a calculation based on the national total power generation capacity of 3 650.6 billion kW in 2009, it means 14.6 billion kW power is saved, which accounts for one-fifth of the national nuclear power generating capacity in 2007 and which is close to one year's power generation volume of Gezhouba Hydropower Station. Besides its energy efficiency, the oriented silicon steel with high magnetic induction can save more than 15% steel consumption for making a same transformer comparing to the ordinary material. Meanwhile, it can cut down copper consumption.

Baosteel has spent 10 years in self-development of the oriented silicon steel production technology. Finally, the production technology of high magnetic induction (HiB) grain-oriented silicon steel with low reheating temperature has been captured. The commercial production of grain-oriented silicon steel has been started from 2008, and 42,000 tons of HiB have been produced in 2009. It is estimated that around 70,000 tons will be produced in this year, thereinto, laser-notched products will fill the domestic gap.

4 Conclusions

The ESER can be implemented in two aspects: the steel industry itself and the contribution made by innovative steel material for down-stream sectors. As an irreplaceable material for the current and foreseeable future human society, there is a great potential for material innovation. We hope great efforts shall be taken by the steel industry staff to make continuous innovations on the material of high strength, high toughness, long service life, and functionalization, etc. so as to provide competitive steel material solutions for downstream users, and make due contributions to the low-carbon society.

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