

Key factors of CO₂ emission analysis in iron and steel mill

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Abstract: Recently CO₂ emission reduction has become an imminent problem, iron and steel industry, as the third largest CO₂ emitter industry, is vital for energy conservation and emission reduction in China. Accurately quantifying CO₂ emissions is the basis for energy-saving and emission reduction of the iron and steel industry. According to the definition of carbon footprint recommended by IPCC, with a typical BF-BOF route mill as a case, we established carbon footprint model and developed a calculation method of CO₂ emissions. Based on the actual data, we calculated the CO₂ emission of the total and each process, used 1t plain carbon steel as a functional unit. The results show that the total CO₂ emission of the case mill is 2084.37kg /t-cs, of which, the largest CO₂ emission process is iron-making process that accounts for about 79%. Followed by the sintering process, which accounts for 12.7% of total. Thus, the energy-saving and emission reduction of iron-making process and sintering process is necessary to study how to reduce the carbon footprint per ton of steel for iron and steel mill in China.

Introduction

Greenhouse gas (GHGs), especially the increase of CO₂ in the atmosphere, is the culprit of global warming and Greenhouse gases have become the main issue of global environmental

protection. At the Paris Conference, the Chinese government promises that the total CO₂ emission in China will be climb the peak around 2030. Compared with carbon dioxide emission per unit of GDP in 2005, it will decrease by 60%~ 65% in 2030 and non-fossil energy will account for about 20% of the primary energy consumption. In December 2017, China's National Development and Reform Commission convened a national carbon trading system to launch a teleconference, officially announcing the formation of China's carbon market. It has become the primary task for the sustainable development of various industries to establish the accurate quantitative standards and standard reports of CO₂ emission.

As an intensive and the third-largest carbon-emitting industry, iron and steel manufacturing is vital for meeting the energy conservation and CO₂ emission reduction targets of China. According to the World Steel Association, World crude steel production reached 1,691.2 million tones (Mt) for the year 2017, of which, China's crude steel production in 2017 reached 831.7 Mt, up by 5.7% in 2016, accounting for 49.2% of the global production^[1]. Therefore, Accurate quantification and calculation of CO₂ emission for iron and steel manufacturing is the foundation of analysis and assessment of its environmental impact and various emission reduction technologies^[2].

The definition of carbon footprint

The definition of ‘Carbon footprint’ (CF), that derives from ‘ecological footprint’, is used to measure the impact of human activities on natural ecosystems, the relative size of human consumption on ecosystems, and it emphasizes on the effect of carbon emission of human energy activities on atmospheric environment. Relatively speaking, the history of carbon footprint’s concept is shorter. Different organizations have different definitions and understandings, as shown in table 1.

Table 1 Different definitions of carbon footprint

Organization	Definition
IPCC	Based on different industries, different levels have been formulated and different greenhouse gases have been considered. Six kinds of greenhouse gas emissions such as CO ₂ , CH ₄ and N ₂ O produced by human activities in the country have been estimated.
BSI ^[4]	Carbon footprint is a term used to describe greenhouse gas emissions generated by a specific activity or entity, including CO ₂ , CH ₄ , N ₂ O and other gases.
National Development and Reform Commission ^[5]	Direct emissions, indirect emissions, and deductions of six types of greenhouse gases, such as CO ₂ and N ₂ O, generated by economic and social activities of residents in the province.
WRI/WBCSD ^[6]	The carbon footprint is defined as 3 levels: the first level comes from the direct carbon emissions of the institution itself; the second level expands the boundary to the direct carbon emissions of the Department that provides the energy sector; the third level includes the direct and indirect carbon emissions of the whole life cycle of the supply chain.

It can be seen that the carbon footprint defined by IPCC is more comprehensive and more targeted. In the light of greenhouse gas emissions of iron and steel industry, "The IPCC Guidelines" based on the accuracy of data sources and the application level is divided into three levels. CO₂ emission calculation method of iron and steel industry is divided into two levels, CH₄ emissions are divided into two levels. Owing to data reliability, this paper does not consider the CH₄ emission of iron and steel industry.

Carbon footprint calculation in iron and steel mill

Based on the actual production data of the domestic Y iron and steel mill in 2016, this paper calculates the CO₂ emission of Y mill using the IPCC-based second-level thoughts and emission factors. Y iron and steel mill is a typical medium and small BF-BOF route iron and steel enterprise in China, adopting the production mode of "BF-BOF-Casting-HR", with the production scale of 5 million t-cs/year. Since most of the products are plain carbon steel, the refining process is not considered and all rolling processes are hot rolled. The production process of enterprise Y, which using purchased coke, includes sintering, pelletizing, BF, BOF, casting and HR, without coking process.

System boundary is the foundation of CO₂ emission computation; thus, its first step is demarcation. Then a carbon footprint model is built to calculate the emission. The carbon footprint system boundary of the Y iron and steel mill in this case is shown in Fig.1. System boundary Y consisted of the main process, including pelletizing, sintering, iron making(BF), steel making(BOF and casting), hot rolling.

Based on the second level of IPCC carbon footprint methodology, we established the carbon footprint analysis model to calculate the CO₂ emission of each process. The CO₂ emissions in iron and steel industry include three parts: fossil fuel combustion (E_{fos}), consumption of flux and carbonaceous in industrial production (E_{flu}), and partial carbon sequestration products (E_{seq}). The total amount of carbon dioxide E_{co_2} and the relationship between them is, as shown in Eq.1.

$$E_{co_2} = E_{fos} + E_{flu} - E_{seq}. \quad (1)$$

Where E_{co_2} is the total amount of carbon dioxide emissions per unit product, kg; E_{flu} is carbon dioxide emissions produced by the consumption of carbon containing substances and flux per unit product, kg; E_{seq} is carbon dioxide emissions of carbon sequestration per unit product, kg.

$$E_{fos} = \frac{44}{12} \sum_{i=1}^{44} (A_i \times C_i) = \sum_{i=1}^{44} (A_i \times EF_i). \quad (2)$$

Where A_i is apparent consumption of fossil fuel consumption per unit product, kg; C_i is carbon content per unit mass of fossil fuels, kgC/kg; EF_i is carbon dioxide emission factor, kgCO₂/kg.

$$E_{flu} = A_{li} \times EF_{li} + A_{do} \times EF_{do} + \sum_{i=1} (A_{ci} \times EF_{ci}). \quad (3)$$

Where A_{li} , A_{do} and A_{ci} are the consumption of limestone, dolomite and carbonaceous, respectively; while EF_{li} , EF_{do} and EF_{ci} are their emission factors, respectively.

$$E_{seq} = A_{sp} \times EF_{sp} + A_{oi} \times EF_{oi}. \quad (4)$$

Where A_{sp} and A_{oi} are the mass of steel production and offsite iron, respectively; while EF_{sp} and EF_{oi} are their emission factors, respectively.

The CO₂ emission factors used in this study are listed in Table 2. According to carbon footprint analysis model, with 1t plain carbon steel as functional unit, the CO₂ emission of each process in the boundary of the Y iron and steel industry is calculated, as shown in Fig.2. The CO₂ emission of Y iron and steel mill is 2084.37 kg-t/cs, of which, the largest amount of CO₂ emission comes from iron-making process, is 1650.92 kg-t/cs. Followed by the sintering process and hot rolling process, the CO₂ emission are 265.19 kg CO₂ /t-cs and 74.49 kg CO₂ /t-cs, respectively; while the CO₂ emission in steelmaking process and pelletizing process are smaller, which are 63.74 kg CO₂ /t-cs and 30.03 kg CO₂ /t-cs, respectively. Due to the absence of coking process at Y iron and steel mills, part of the CO₂ emission from coking process is transferred to the iron-making process. In addition, a large amount of carbon flow in the iron-making process is transferred into blast furnace in the form of coke, pulverized coal and gas, and enters the atmosphere in the form of CO₂, which makes the CO₂ emissions of iron-making process occupy the largest proportion in the total share, which accounts for about 79%.

Thus, reducing the CO₂ emission in iron-making process and sintering process is the key point to solve the CO₂ emission reduction in iron and steel industry in China.

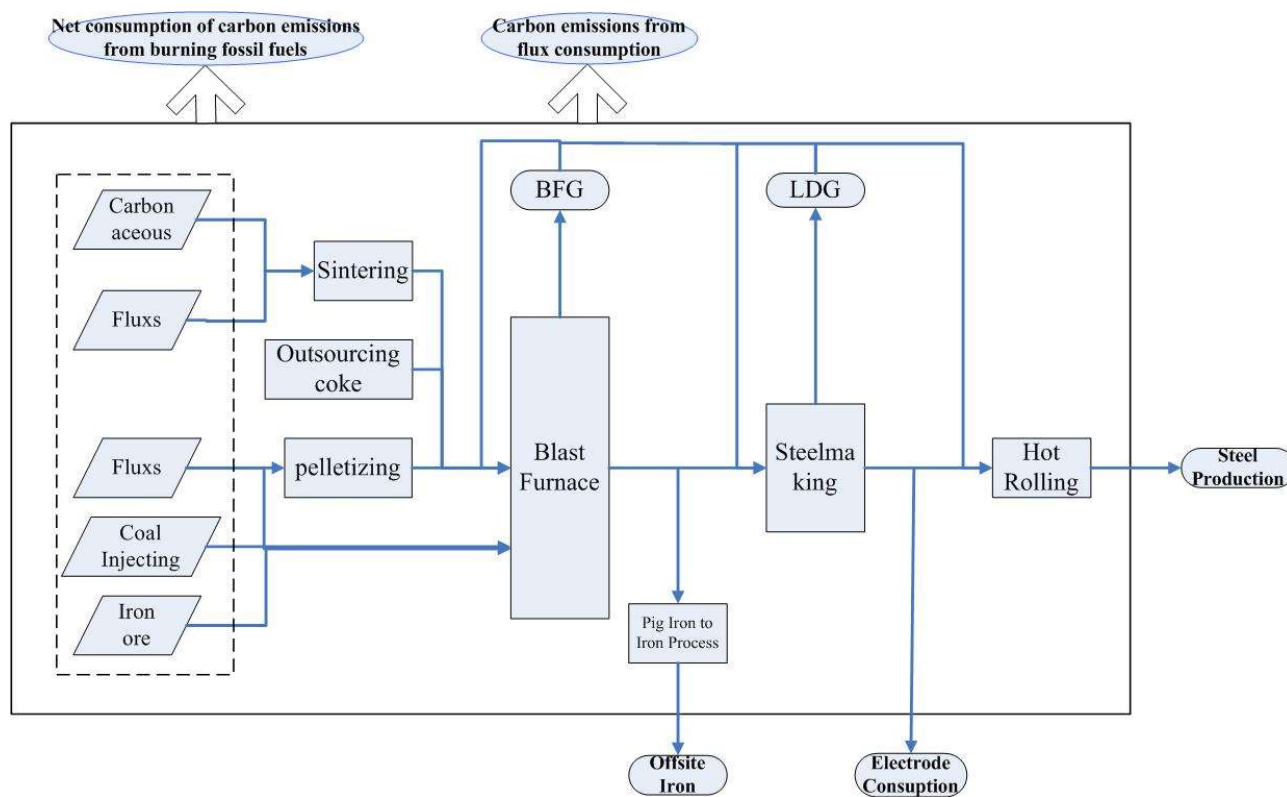


Fig.1 System boundaries of carbon footprint in A steel mill

Table 2 The main CO₂ emission factor in CO₂ emission calculator model

Project	Kind (unit)	Emission factor
Fossil fuel	Cleaned coal (kgCO ₂ /kg)	2.456
	Coke (kgCO ₂ /kg)	3.043
	BFG (kgCO ₂ /m ³)	0.623
	LDG (kgCO ₂ /m ³)	1.283
	Dolomite (kgCO ₂ /kg)	0.477
Fluxs and carbonaceous	Limestone (kgCO ₂ /kg)	0.44
	Scrap steel (kgCO ₂ /kg)	0.036
	Iron production (kgCO ₂ /kg)	0.147
Carbon sequestration production	Steel production (kgCO ₂ /kg)	0.036

Note: All CO₂ Emission factor come from 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

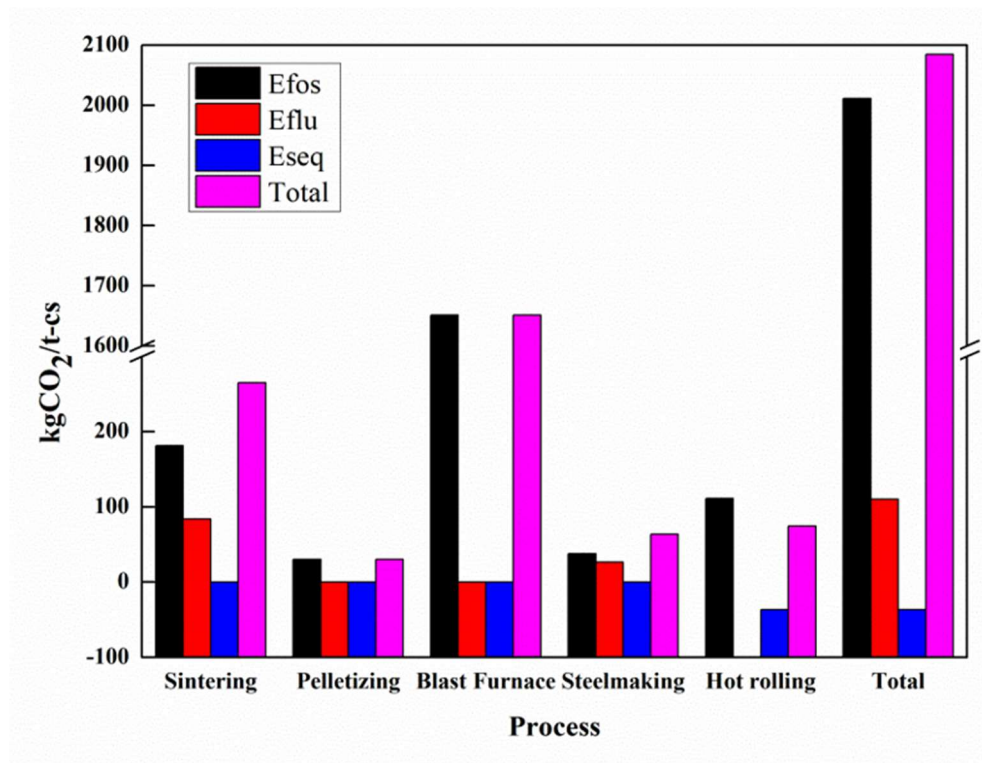


Fig.2 Carbon emission from processes in A steel mill

Conclusions

(1) According to the definition of carbon footprint recommended by IPCC, with Y iron and steel mill as a case , we establish carbon footprint analyst model and developed a calculation method of CO₂ emissions. In addition, the CO₂ emission is divided into three categories, which are respectively produced by the combustion of fossil fuel, the consumption of carbon containing substances and flux, carbon sequestration deduction.

(2) In the iron and steel production process, the CO₂ emissions produced in iron-making process account for 79% of the total emission per tons of steel, the CO₂ emissions from other processes, from top to bottle, are respectively sintering, hot rolling, steelmaking and pelletizing.

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