Analysis of Existing Problems and Carbon Emission Reduction in Shandong’s Iron and Steel Industry

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Abstract

In response to the national energy-saving and emission-reduction policy, the development status of iron and steel industry in Shandong province has been investigated in this paper. On this basis, the existing problems were analyzed and carbon emission coefficients method was used to calculate the carbon emissions in Shandong’s iron and steel industry in 2005-2008. The result indicated that the carbon emissions showed upward trend overall in 2005-2008 and there were still spaces for cutting down carbon emissions. Finally, according to the above analysis, the carbon emission reduction approaches were proposed, including improving the technical equipment and equipment capacity, optimizing process, decreasing iron-steel ratio and optimizing energy structure. It is essential for the relevant governments to make scientific and rational decision-making and further to lay a theoretical foundation for realizing the target of sustainable and low-carbon economic development in Shandong’s iron and steel industry.

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Keywords: Iron and steel industry; Carbon emissions; Shandong province

1. Introduction

Iron and steel industry is one of the most basic industries as well as a high energy consumption industry in China. Shandong has a large capacity of steel production and has made outstanding contributions to the social and economic development. However, the low-quality products, irrational structure and backward production techniques and equipments, resulting in higher energy consumption and carbon emissions of iron and steel industry and restricting the health and sustainable development of the iron and steel industry in Shandong. Therefore, in order to address the issues of serious pollution, vast

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energy consumption and high carbon emissions, and realize low-carbon economic development in Shandong’s iron and steel industry, it is significantly to analyze the existing problems and carbon emission status of the iron and steel industry in Shandong province [1-3].

2. Development status in Shandong’s iron and steel industry

2.1. Output and production capacity status in the key iron and steel enterprises

In 2008, the production of pig iron, crude steel and rolled steel was \(4657 \times 10^4\) t/a, \(4458 \times 10^4\) t/a and \(5027 \times 10^4\) t/a, accounting for 9.89%, 8.90% and 8.60% of the national’s total pig iron, crude steel and rolled steel, respectively [4]. In addition, the hot and cold rolled steel sheet, superior special steel, H-steel and other high value-added rolled steel were all increased on variety and quantity and the amount of key meaton-class iron and steel enterprises reached 16. Fig.1 shows the output trend of iron and steel products in Shandong province over the years.

![Fig.1: Output trend of iron and steel products in Shandong Province, 1958-2008](image)

In 2008, the production capacity of the pig iron, crude steel and rolled steel in Shandong was \(5545 \times 10^4\) t/a, \(5780 \times 10^4\) t/a and \(5515 \times 10^4\) t/a, respectively. The key steel production enterprises in Shandong contained 23 enterprises, including seven inland cities and three coastal cities (Qingdao, Rizhao, Weifang). The production capacity of the pig iron, crude steel and rolled steel in the inland areas accounted for 66.8%, 65.8% and 66.1% of the total pig iron, crude steel and rolled steel, respectively.

2.2. Process equipment status in the key iron and steel enterprises

According to the investigation of Shandong’s key iron and steel enterprises, Table 1 shows the main process equipment and capacity ratio of Shandong’s iron and steel enterprises in 2008.

<table>
<thead>
<tr>
<th>Category</th>
<th>Scale</th>
<th>Number &amp; Ratio</th>
<th>Volume &amp; Capacity ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Number</td>
<td>Ratio</td>
</tr>
<tr>
<td>Blast furnace</td>
<td>≥1000m³</td>
<td>30</td>
<td>34.5%</td>
</tr>
<tr>
<td></td>
<td>400-1000m³</td>
<td>25</td>
<td>25.3%</td>
</tr>
<tr>
<td></td>
<td>≤400m³</td>
<td>22</td>
<td>25.3%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>Converter furnace</td>
<td>≥120t</td>
<td>18</td>
<td>29.0%</td>
</tr>
<tr>
<td></td>
<td>30-120t</td>
<td>37</td>
<td>59.7%</td>
</tr>
<tr>
<td></td>
<td>≤30t</td>
<td>7</td>
<td>11.3%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Electric furnace</td>
<td>≥70t</td>
<td>3</td>
<td>23.0%</td>
</tr>
<tr>
<td></td>
<td>30-70t</td>
<td>6</td>
<td>46.2%</td>
</tr>
</tbody>
</table>
3. Resources and energy consumption status in Shandong’s iron and steel industry

3.1. Resources and energy consumption status

Iron and steel industry is characterized by its energy intensive. It can be seen in Table 2 that the energy consumption of Shandong’s steel industry in 2005-2008 presented a rising tendency. The total energy consumption in 2008 was 2.63 times larger than that of 2005 and the iron ore consumption reached 7030×10^4 t/a which the self-produced iron ore consumption only accounted for 23.3% of the total [5].

Table 2: Main resources and energy consumption of Shandong’s iron and steel industry, 2005-2008

<table>
<thead>
<tr>
<th>Year</th>
<th>Raw coal (10^4 tce/a)</th>
<th>Washed coal (10^4 tce/a)</th>
<th>Electricity (10^8 kwh/a)</th>
<th>Total (10^4 tce/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>355.0</td>
<td>1036.8</td>
<td>100.9</td>
<td>1876.3</td>
</tr>
<tr>
<td>2006</td>
<td>308.2</td>
<td>1294.4</td>
<td>137.3</td>
<td>1847.3</td>
</tr>
<tr>
<td>2007</td>
<td>426.2</td>
<td>1413.4</td>
<td>167.1</td>
<td>2131.7</td>
</tr>
<tr>
<td>2008</td>
<td>977.7</td>
<td>1482.0</td>
<td>272.0</td>
<td>4941.6</td>
</tr>
</tbody>
</table>

3.2. Energy efficiency analysis

Comprehensive energy consumption per ton of steel is an important index. In 2008, the average comprehensive energy consumption in Shandong was 640.37kgce/t and the average comprehensive energy consumption of the national key steel industries was 626.55kgce/t. Comparison of process energy consumption between Shandong and the national key steel industries in 2008 as shown in Table 3.

Table 3: Comparison of process energy consumption between Shandong and the national key steel industries

<table>
<thead>
<tr>
<th>Process</th>
<th>Coking</th>
<th>Sintering</th>
<th>Pelletizing</th>
<th>Ironmaking</th>
<th>BOF steelmaking</th>
<th>EAF steelmaking</th>
<th>Steel rolling</th>
</tr>
</thead>
<tbody>
<tr>
<td>A(kgce/t)</td>
<td>120.26</td>
<td>54.23</td>
<td>34.33</td>
<td>421.81</td>
<td>-6.31</td>
<td>71.51</td>
<td>54.33</td>
</tr>
<tr>
<td>B(kgce/t)</td>
<td>118.97</td>
<td>55.32</td>
<td>30.41</td>
<td>432.13</td>
<td>6.01</td>
<td>80.81</td>
<td>59.58</td>
</tr>
<tr>
<td>C(kgce/t)</td>
<td>84.60</td>
<td>44.88</td>
<td>—</td>
<td>357.42</td>
<td>-16.51</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

A: Main steel enterprises average energy consumption in Shandong; B: Average energy consumption of the domestic key enterprises; C: National advanced value of energy consumption in 2007; BOF: Basic oxygen furnace; EAF: Electric arc furnace.

Table 3 shows that the energy consumption of ironmaking and coking accounted for 56.2% and 16.0% of the total, respectively. Although the energy consumption proportion of BOF and EAF steelmaking was relatively small, it was much lower than the national advanced level in 2007. Moreover, owing to 90% CO₂ emissions were mainly caused by blast furnace (BF) [6-7] and the former process of ironmaking and the energy consumption of the ironmaking system (including coking, sintering, pelletizing and iron making) took up about 78.87% of the total, it reveals that there still exist large spaces for energy-saving and emission reduction in Shandong’s iron and steel industry.

4. Carbon emission status in Shandong’s iron and steel industry

Considering from the source, fuel composition is the main influencing factor of carbon emissions, and viewing from the technology point, the main influencing factors are process energy consumption and flow. According to the energy consumption in Shandong’s iron and steel industry in 2005-2008, the carbon emissions of iron and steel industry were calculated. The emissions caused by energy consumption and
the production of the electricity were taken into account (the standard coal consumption of 1kwh thermal power generation was calculated according to the actual consumption of Shandong in 2008).

According to the relevant data analysis and carbon emission coefficients adopted by the IPCC (2006) [8-10], combining with the energy consumption status in Shandong’s steel industry, the carbon emissions were calculated as the following formula:

$$E = \sum_{i=1}^{n} F_i C_i$$

Where, $E$ is total carbon emission; $F_i$ is the fuel consumption of $i$ (calculating by standard coal); $C_i$ is the carbon emission coefficient of $i$; $i$ is the types of fuel. Table 4 shows the carbon emission coefficients of different types of fuel and the results is shown in Fig.2.

Table 4: Carbon emission coefficients of different types of fuel

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Raw coal</th>
<th>Washed coal</th>
<th>Coking coal</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon emission coefficient ($10^4$t/10^4t)</td>
<td>0.7559</td>
<td>0.7559</td>
<td>0.8550</td>
<td>0.2522kg/kwh</td>
</tr>
</tbody>
</table>

Fig.2: CO₂ emission trend of Shandong’s iron and steel industry, 2005-2008

As shown, the CO₂ emissions showed slight downward in 2005-2006, it showed an increasing trend in 2006-2007 and the increasing trend was remarkable in 2007-2008. The results indicate that the CO₂ emissions in 2006 decreased by $129.14 \times 10^4$ t compared with 2005, it increased by $676.54 \times 10^4$ t in 2007 compared with 2006 and it was up to $13212.91 \times 10^4$ t in 2008 which was 2.51 times larger than that of 2007.

To sum up, the energy consumption structure of Shandong’s steel industry was irrational and the growth speed of the coal consumption ratio and the total energy consumption were too fast (especially in 2007-2008). Shandong is in the rapid development period of iron and steel industry, the accumulation of scrap steel is relatively little, the level of technological equipment is lower and the process mainly lies on the long process of BF, which means that the carbon emission would not reduce substantially in the near future and the responsibility of energy-saving and emission-reduction in Shandong is significant.

5. Analysis of carbon emission reduction approaches in Shandong’s iron and steel industry

5.1. Improve the technical equipment and equipment capacity

Currently, the process equipment in Shandong’s iron and steel industry has a considerable amount of backward productivity phenomenon. According to the “Steel industries adjustment and revitalization plan (2009-2011)” that proposed by Chain and Shandong. Before the end of 2011, the equipments of Shandong which be listed in the eliminated-equipments included twenty two BF whose capacity were lower than 400m³, five BOF whose capacity were lower than 30t, six EAF whose capacity were lower
than 30t which accounted for 11.5%, 11.3% and 26.1% of production capacity, respectively. Moreover, in 2008, the largest BF of Shandong was 1880 m³ which was much lower than the largest BF of Japanese and German whose capacity were 5775 m³ and 5513 m³, respectively; the largest BOF of Shandong was 120t, but in Japan there were 33 BOF whose capacity were more than 220t in 2006; in addition, the largest EAF in Shandong was 70t, but the world largest was 400t and Baogang’s largest was 150t. It reveals that there exists a great gap compare with the advanced iron and steel enterprises at home and aboard. It is essential to improve the proportion of advanced technical equipment, eliminate backward production capacity and reduce energy consumption per ton of steel for Shandong.

5.2. Optimize process, decrease iron-steel ratio

At present, there are two major processes of steel production in the world. One is a long process of BF-BOF which is based on the consumption of coal and iron ore. The other is a short process of EAF which is based on the consumption of electricity and scrap. According to the data, the CO₂ emission of BF-BOF is about 1700kg/t (steel) and the Scrap-EAF is about 400kg/t (steel) [11-13].

Industrial developed countries have lower iron-steel ratio which generally between 0.5 and 0.7. Shandong has a higher iron-steel ratio for a long time. From 1958 to 2008, excepting the year 2002 and 2003 whose iron-steel ratio was 0.96 and 0.94, respectively, the ratio exceeded 1.0 for the rest years and was far higher than the international average level. In 2008, Shandong’s iron-steel ratio was higher by 11.1 percentage points than the national average and 3.1 times more than the foreign lowest level. Estimated according to the currently situation of the national steel industry, the comprehensive energy consumption per ton of steel will rises about 20kgec when the ratio rises 0.1 [14]. The above suggests that the process of Shandong’s key iron and steel industry mainly lies on the long process and the carbon emissions are relatively high. Therefore, optimizing process and decreasing iron-steel ratio should be paid great attention for Shandong’s iron and steel industry. Table 5 shows the iron-steel ratio of Shandong compared with the domestic and foreign major countries in 2008.

Table 5: Iron-steel ratio of Shandong compared with the domestic and foreign major countries, 2008

<table>
<thead>
<tr>
<th>Area</th>
<th>Shandong</th>
<th>China</th>
<th>Japan</th>
<th>Korea</th>
<th>Germany</th>
<th>Italy</th>
<th>America</th>
<th>France</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron / Steel (%)</td>
<td>1.045</td>
<td>0.941</td>
<td>0.726</td>
<td>0.579</td>
<td>0.635</td>
<td>0.339</td>
<td>0.369</td>
<td>0.636</td>
</tr>
</tbody>
</table>

5.3. Optimize energy structure

Large part of CO₂ emissions in the steel production come from the fuel combustion. Different types of energy have different CO₂ emission intensity, the CO₂ emissions from burning per ton of coal, oil and nature gas are 170kg/t, 154kg/t and 139kg/t, respectively, it means CO₂ emissions caused by unit heat of coal are higher by 36% and 61% than oil and nature gas [15], showing that composition of the fuel is a major factor for the CO₂ emissions of the iron and steel industry.

In 2008, the total energy consumption of Shandong’s iron and steel enterprises reached 4941.6×10⁶tce which was 2.6 times larger than that of 2005, the consumption of raw coal, washed coal, coke and electricity was 977.7×10⁶tce/a, 1482.0×10⁶tce/a, 2021.8×10⁶tce/a and 272.0×10⁸kwh/a separately, and the total coal resources (including raw, washed coal and coke) consumption took up over 90% of the total energy consumption. It indicates that coal has become the major type of energy consumption and the major source of CO₂ emissions. Therefore, it is crucial for Shandong to optimize the energy structure, explore new energy resources, increase the proportion of clean energy and reduce carbon emissions.

6. Conclusion
In response to the international climate change, sticking to the increase of average temperature do not exceed the bottom line of 2 °C is the choice which every country must confront with. Based on the above analysis we can draw the following conclusions:

(1) As the national economy basic and pillar industry, Shandong’s iron and steel industry has been developed rapidly. In 2008, the output of pig iron, crude steel and rolled steel has been in the front rank of China, but the backward technology and equipment, large iron-steel ratio, irrational energy structure and others have become increasingly prominent issues which have been restricting the scale development and industrial upgrading of iron and steel industry in Shandong province.

(2) The CO₂ emissions from steel production in Shandong are mainly affected by fuel composition and process. In 2008, the total energy consumption in steel production amounted to 4941.6×10⁴t/a which was 2.32 times more than that of 2007. In 2005-2008, the CO₂ emissions showed a growth trend and reached 13212.91×10⁴t/a. Iron and steel industry in Shandong takes a significant responsibility of energy-saving and emission-reduction.

(3) Through analyzing the carbon emission reduction approaches, the results indicate that Shandong has a great potential of energy-saving and emission-reduction in the iron and steel industry. Currently, optimizing process, improving technical equipment and equipment capacity and optimizing energy structure are pivotal for carbon emission reduction in Shandong province.

References