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Research on Quantitative Method of Carbon Emission from Container Terminal Equipment

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Abstract

In order to build a green port, this paper quantifies the energy consumption and carbon emission of the main mechanical equipment in the land area of the port, namely quay crane, container truck and yard crane, so as to find out the reasons for the large amount of carbon emission of port equipment. Taking a container terminal in Zhejiang Province as an example, the results show that the quay crane accounts for the largest proportion of carbon emissions and the largest proportion of electricity in the use of energy in the port equipment.

Keywords

Container terminal; Port equipment; Green port; Carbon emission.

1. Introduction

Since the 21st century, human society has paid more and more attention to global warming. As a gathering place of intensive energy, the consumption of fossil energy and carbon emission caused by combustion are very high, which leads to serious environmental pollution problem [1]. Due to the huge volume of container freight, large number of large-scale equipment, complex loading and unloading process, large energy consumption in the process of port operation, and a large amount of carbon dioxide and other harmful gases are produced, which is one of the main reasons for the rising of environmental pollution and PM2.5. Due to the rising fuel price and China's requirements for energy conservation and emission reduction, the port and shipping industry's demand for energy conservation and emission reduction is reduced Carbon emission is one of the important tasks of building a green port. There are two main ways to reduce carbon emissions: one is to improve fuel efficiency, reduce fuel consumption and indirectly reduce carbon emissions; the other is to use other low-carbon and environmental friendly energy to replace.

In this paper, from the perspective of green emission reduction, aiming at the three major port equipment resources, namely quay crane, container truck and gantry crane, the carbon emission generated in the operation process is quantified, and the energy consumption proportion of port equipment is analyzed, so as to put forward effective countermeasures for energy conservation and emission reduction.

2. Production and operation system of container terminal

The main facilities of container port include: berth, yard, quayside handling machinery, horizontal handling machinery and yard handling machinery. The events and activities of the port's production process constitute the whole process from the container entering the container terminal to leaving. This process can be roughly divided into three types: after the import container unloading pile is stored in the yard, it will leave the terminal through container truck picking operation; the export container will leave the terminal after being loaded in the container terminal; the transfer container

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will leave the container head after unloading through loading operation. This paper mainly studies the carbon emission of mechanical equipment from loading and unloading operation and truck operation.

As an important collection and distribution node, container port plays an important role in international logistics, including berths, quay fronts, container yard and other facilities. Meanwhile, various container handling equipment and transportation equipment are needed to maintain the normal operation of the port. In the whole operation process of the port, the energy consumption and carbon emission generated by container handling operation occupy an important proportion in the total energy consumption, accounting for about 80% of the total [4]. Therefore, in order to reduce the energy consumption and carbon emissions of container ports, it is necessary to quantify the carbon emissions from the operation level and find out the causes. At present, China's main energy sources are still diesel and electric power, and clean energy such as solar energy still exists as auxiliary energy. In port equipment, the power consumption mainly comes from the use of quay crane, while the consumption of diesel mainly comes from truck and tire crane.

The calculation of port carbon emission is mainly through calculating the fuel consumption of container tractor, gantry crane and other loading and unloading equipment, and converting it into carbon emission. In addition, the carbon emission caused by electric energy consumption of port quayside crane and other electrical equipment is also calculated, and then the carbon emission caused by electric energy and carbon emission caused by fuel oil is added to calculate the total carbon emission of port.

3. Quantitative method of carbon emission from Wharf

3.1 Method introduction

According to the design ideas, the calculation methods of carbon emission can be divided into macro and micro categories. The macro estimation model mainly gives the concept explanation and method of carbon emission accounting from a large scale, while the micro model estimates carbon emission according to different emission sources. At present, there are three methods which have both macro and micro characteristics and are widely used, including emission factor method, mass balance method and measurement method.

3.1.1 Emission-Factor Approach

Emission-Factor Approach is a carbon emission estimation method proposed by IPCC, which is widely used at present. Its basic idea is to use the product of activity data of each emission source in the list of carbon emission inventory and its carbon emission factor as the estimated value of carbon emission of the emission project. Calculation formula of emission factor method:

$$\mathrm{E}mission = AD \times EF \tag{1}$$

Where emission is the estimated value of the carbon emission of the carbon emission project; ad is the activity data of carbon emission sources in the carbon emission inventory; EF is the emission factor, that is, the amount of greenhouse gases released per unit of emission source use. Among them, the main way to obtain the carbon emission activity data is the monitoring and investigation data of carbon emission sources by carbon emission projects or relevant national statistical data; the main way to obtain the emission factors is to adopt the default value given in the IPCC report or construct according to the actual situation of carbon emission projects. At present, many countries give carbon emission calculator based on this method, which is convenient for users to estimate carbon emissions, which reflects the wide use of this method in the world.

3.1.2 Mass-Balance Approach

Mass-Balance Approach is a new method proposed in recent years. The basic idea of this method is to calculate the share of new chemical substances consumed to meet the capacity of new equipment or replace the removal gas according to the new chemical substances and equipment put into national production and life every year. This method can reflect the actual carbon emissions in the place where

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carbon emissions occur, and can effectively distinguish the differences between various types of facilities, and distinguish between individual and partial equipment. When the equipment is updated frequently, this method is more convenient.

3.1.3 Experiment Approach

Experiment Approach is a method to obtain the carbon emissions of emission sources by monitoring the carbon emissions of emission sources. In the actual operation process, the samples collected on site are generally sent to relevant testing departments for quantitative analysis through special testing equipment and technology. Due to the lack of intermediate links, the results are relatively accurate, but due to the large investment, data acquisition is relatively difficult [5]. In addition, the method is greatly affected by the representativeness of sample collection and processing, measurement accuracy and other factors. At present, the actual measurement method is less used in actual production and life.

As the container port operation system is relatively stable and the emission source is not complex, considering the convenience and accuracy of collecting relevant data for container terminal enterprises, it is generally believed that the value of carbon emission factor remains unchanged in the use process [6]. In this paper, the calculation is based on the type of energy, the carbon emission coefficient of different types of energy is different, and then the accurate energy consumption is calculated according to the equipment parameters, so that the carbon emissions of various equipment and various energy types can be calculated.

3.2 Relationship between energy consumption and carbon emission

"2006 IPCC guidelines for national green house gas inventories" makes a quantitative study on carbon emissions from related activities in industry, agriculture and energy. The carbon emission of container port belongs to the category of energy, and the energy consumption includes the carbon emission from direct fuel oil of machinery and indirect carbon emission generated by mechanical power use.

The calculation formula of carbon emission from mechanical direct fuel is shown in formula (2)

$$\text{Carbon emission(kg)} = \text{Fuel consumption(kg)} \times \text{Fuel carbon emission coefficient}(kg/kg) \quad (2)$$

The calculation formula of carbon emission indirectly generated by machinery using electric power is shown in formula (3)

$$\text{Carbon emission(kg)} = \text{Power consumption(kWh)} \times \text{Power carbon emission coefficient}(kg/k\text{wh}) \quad (3)$$

3.3 Selection of carbon emission coefficient

3.3.1 Fuel carbon emission coefficient

According to China Energy Statistical Yearbook (2010), the low calorific value of diesel in China is 42652kJ/ kg. According to the 2006 IPCC guidelines for national greenhouse gas inventories, the default value of the emission coefficient per calorific value of diesel is 74100kg / TJ. In order to simplify the calculation process and calculation results, assuming that the oxidation rate of fuel consumption is 100%, and the specific gravity values of gasoline and diesel are 0.72kg/L and 0.85kg/L respectively, the emission coefficients of gasoline and diesel are 2.15kg/L and 2.65kg/L respectively.

3.3.2 Carbon emission coefficient of electric power

According to the announcement on emission factors of China's regional power grid baseline in 2015, the carbon emission coefficient of thermal power generation converted into each regional power grid is shown in Table 3.1; the carbon emission coefficient of clean energy power generation is shown in

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Table 3.1. Therefore, according to the East China power grid, the carbon emission coefficient is 0.8112 kg / kWh.

Table 1. China regional power grid emissions factor in 2015(kg/kWh)

Area	Carbon emission coefficient of electric power
North China Power Grid	1.0416
Northeast Power Grid	1.1291
East China Power Grid	0.8112
Central China Power Grid	0.9515
China Southern Power Grid	0.8959

4. Case analysis

In this paper, a container terminal in Zhejiang Province is taken as an example. There are five container berths in the port, with a total length of 1399m. The mechanical equipment for loading, unloading and transportation in the port are as follows: 11 quayside cranes, 41 rubber tyred cranes and 70 container trucks. The quayside cranes are driven by electric power, while the rubber tired cranes and trucks are driven by diesel oil. The utilization rate of quay crane is 60%, the utilization rate of container truck is 70%, and the utilization rate of rubber tired crane is 40%. The carbon emission coefficient of electric power of the port is taken as 0.8112 of East China power grid, as shown in Table 1.

The container area is mainly divided according to the berth. Generally, each division area is equipped with a quay crane, and each quay crane can lift two containers in one operation. Taking the unloading process as an example, the whole operation process of the container in the port is ship, quay crane, container truck and yard in turn. After the container truck arrives at the yard, if there are containers to be exported, the container truck is also responsible for transporting the container to the designated storage area of the quay crane, waiting for the quay crane to be loaded, otherwise, the container will be empty. The energy consumption and corresponding carbon emissions of quayside cranes, truck mounted trucks and wheeled cranes in the port operation stage are calculated as follows.

4.1 Annual power consumption of quay crane

In this paper, the quay crane with external power supply is used. External power supply is widely used because of its less cleaning and maintenance, less noise and less pollution. The annual operation times of the K quay crane are shown in formula (4), and the annual power consumption of the I quayside crane is shown in formula (5).

$$N_{qc}^{k} = \frac{24\rho_{qc}^{k} \cdot 365}{T^{k}} \tag{4}$$

$$F_{qc}^{s,k} = N_{qc}^{k} \cdot \left(\frac{2H_{qc}^{u,k} + p_{qc}^{u,k}}{v_{qc}^{u,k}} + \frac{D_{qc}^{k} \cdot p_{qc}^{l,k}}{v_{qc}^{l,k}} \right) \tag{5}$$

N_{qc}^{k} represents the annual operation times of the kth quay crane, which is the ratio of annual operation time to single operation time of quay crane; ρ_{qc}^{k} represents the utilization rate of quayside bridge, 60%; T^{k} represents a cycle operation cycle, h; $F_{qc}^{s,k}$ represents the annual power consumption of the i-th quay crane; $H_{qc}^{u,k}$ is Lifting / lowering height, 0.045km; $p_{qc}^{u,k}$ is power of lifting / lowering motor, 500kW; L_{0}^{k} represents the extension distance of quayside bridge, 0.06km; D_{qc}^{k} represents the distance between offshore side track of quayside bridge and truck channel, 0.01km; $p_{qc}^{l,k}$ is motor

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power of trolley, 250KW; $v_{qc}^{u,k}$ represents lifting / descending speed, 5.4km/h; $v_{qc}^{l,k}$ represents the speed of the car, 12km / h.

$$T^k = 2t_{ui} + t_{li} = \frac{2 \times H_{qc}^{u,k}}{v_{qc}^{u,k}} + \frac{D_{qc}^k}{v_{qc}^{l,k}} = 0.0175(h)$$

$$N_{qc}^k = \frac{24\rho_{qc}^k \cdot 365}{T^k} = \frac{24 \times \rho_{qc}^k \times 365}{2t_{ui} + t_{li}} = 300343$$

The power consumption of each quay crane is W_i:

$$W_i = \frac{1}{60} \times N_{qc}^k \times \left(\frac{2H_{qc}^{u,k} \times p_{qc}^{u,k}}{v_{qc}^{u,k}} + \frac{D_{qc}^k \times p_{qc}^{l,k}}{v_{qc}^{l,k}}\right) = 2878287kwh$$

It can be seen from the above that the total power consumption of the port bridge is W:

$$W = \sum_{i=1}^{n} W_i = 11 \times 2878287 = 31661157kwh$$

4.2 Annual fuel consumption of truck

It is assumed that the truck is overloaded when working and unloaded when returning. Obviously, the carbon emissions generated by the truck are determined by the heavy and no-load travel, driving speed, idle driving time and so on. The annual fuel consumption of truck is given by formula (6).

$$C_j = 8760 \cdot E \cdot \sum_{i=1}^{N} (\rho_L d_{Li} + \rho_E d_{Ei} + \eta t_i) \tag{6}$$

Where: C_j is carbon emission, kg; E_c is the carbon emission coefficient. According to the default value of CO2 emission coefficient per unit calorific value of diesel in the 2006 IPCC guidelines for national greenhouse gas inventories, and assuming that the oxidation rate of fuel consumption is 100%, the carbon emission coefficient is 2.65, kg / L; d_{Li}, d_{Ei} are the heavy load and no-load travel of the truck, km; t is the idle driving time of truck, h; η is the fuel consumption rate of idling, 2.14l/h; ρ_{L}, ρ_{E} are the fuel consumption rates of heavy load and no-load of truck, which are 1L / km and 0.7l/km respectively.

The annual fuel consumption of all trucks is as follows:

$$C_j = 8760 \cdot E \cdot \sum_{i=1}^{N} (\rho_L d_{Li} + \rho_E d_{Ei} + \eta t_i) = 4110874L$$

4.3 Annual oil consumption of yard crane

The annual operation times of the ith yard crane are shown in formula (7); the total annual oil consumption of the rubber tired crane is shown in formula (8):

$$N_{ci} = \frac{24 \times 365 \times \rho_{ci}}{2t_{cui} + t_{cli}} = \frac{525600\rho_{ci} \times V_{cui} \times V_{cli}}{2H_{cui} \times V_{cli} + S_{ci} \times V_{cui}} \tag{7}$$

$$C_c = \sum_{i=1}^{n_c} C_i = \frac{N_{ci}\eta_{ci}}{3000} \times \left(\frac{2H_{cui} \times P_{cui}}{V_{cui}} + \frac{S_{ci} \times P_{cli}}{V_{cli}}\right) \tag{8}$$

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Where N_{ci} represents the annual operation times of the ith rubber tired crane; C_c represents the total annual fuel consumption of the rubber tired crane; ρ_{ci} represents the utilization rate of the rubber tired crane, 40%; η_{ci} represents the fuel consumption rate of the crane, 450g / kwh; H_{cui} represents the lifting / descending height, 0.0153km; P_{cui} represents the ascending / descending power, 110KW; V_{cui} represents the ascending / descending speed, 0.756km/h; S_{ci} represents the average horizontal transportation distance of the trolley, 0.03km; P_{cli} represents the motor power of the trolley, 40kW; V_{cli} represents the trolley speed, 2.4km/h; n_c represents the number of rubber tired cranes, 41

$$N_{ci}=\frac{24\times 365\times \rho_{ci}}{2t_{cui}+t_{cli}}=\frac{525600\rho_{ci}\times V_{cui}\times V_{cli}}{2H_{cui}\times V_{cli}+S_{ci}\times V_{cui}}=66143$$

The fuel consumption of 41 rubber tyred cranes is:

$$C_c=\sum_{i=1}^{n_c}C_i=\frac{N_{ci}\eta_{ci}}{3000}\times(\frac{2H_{cui}\times P_{cui}}{V_{cui}}+\frac{S_{ci}\times P_{cli}}{V_{cli}})=2948088L$$

4.4 Annual carbon emission intensity of container terminals

$$M_{co_2}=E_c\times(C_j+C_c)+E\times W=2.65\times(4110874+2948088)+0.8112\times 31661157=44389780kg$$

Among them, $E_c\times(C_j+C_c)$ is the direct carbon emission of diesel, E_c is the carbon emission coefficient of diesel oil, 2.65kg/L; C_j is the annual fuel consumption of truck, 4110874L; C_c is the annual fuel consumption of all rubber tired cranes, 2948088L; E is the carbon emission coefficient of East China power grid, 0.8112; W is the annual power consumption of quayside crane, 31661157kg. According to the above calculation results, the carbon emission of quay crane is 25683530kg, that of truck is 10893816kg, and that of rubber tired crane is 7812433kg, as shown in Figure 1. From this, we can get the carbon emission proportion of port equipment, as well as the carbon emission proportion of diesel and electric power.

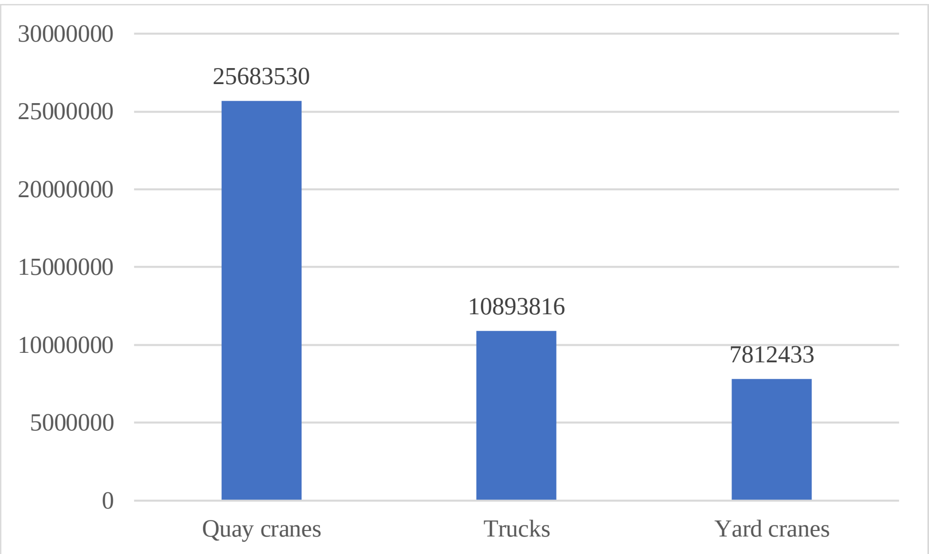

Figure 1. Comparison of carbon emission of equipment

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5. Conclusion

It can be seen from the above results that the energy consumption of container port is the largest, accounting for 58%, while the carbon emission of yard bridge and truck is relatively small, which is 24% and 18% respectively. In order to ensure the efficiency of port operation and reduce energy consumption and carbon emission, we should try our best to improve the cooperation efficiency between loading and unloading equipment and optimize the scheduling scheme of different equipment, including optimizing the truck transportation path, improving the scheduling operation sequence of quay crane and yard crane, so as to reduce the waiting time of loading and unloading equipment and reduce the energy consumption of equipment And the purpose of carbon emissions. In this case study, there are 11 quayside cranes, 41 rubber tyred cranes and 70 container trucks. The number of equipment is also one of the important factors affecting the port energy consumption. Therefore, how to determine the appropriate number of equipment is one of the problems to be solved in optimizing the port operation scheme. In the process of port operation, the loading and unloading transportation equipment is idle without task allocation, resulting in the waste of port equipment resources. In addition, container trucks transport containers to the yard, after arriving at the yard, a large part of the trucks do not receive the task of container export, which leads to empty trucks to drive back, which is also very unfavorable to improve the utilization rate of resources and equipment. On this basis, the port must pay attention to the allocation of equipment idle time, as well as truck scheduling, so as to reduce unnecessary carbon emissions and waste of resources. In addition, in the container port different kinds of energy consumption accounted for 58%, because China's power source is mainly through thermal power generation, and ultimately converted into carbon emissions and other harmful gases, modern ports need to use clean energy or new energy to replace the original energy, so as to truly achieve the ultimate goal of green port construction.

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