Study on the Calculation Method of VOCs Emission Index per Unit Coating Area of Automobile

Jiabao Ren*, Xuefeng Liu, Lei Wang and Wei Liu

China Automotive Technology and Research Center, Tianjin, China

*Corresponding author e-mail: renjiabao@catarc.ac.cn, liuxuefeng@catarc.ac.cn, wanglei2015@catarc.ac.cn

Abstract. Volatile organic compounds (VOCs) are the important factors causing complex air pollution. Strengthening the prevention and control of VOCs pollution is the key work of energy saving and emission reduction in the 13th Five-Year Plan period in China. Automobile industry is a typical VOCs emission industry. A series of VOCs emission standards for automobile manufacturing links have been formulated at home and abroad. However, due to the complex production and emission links of automobile products, the VOCs accounting methods are various. In this paper, the method of VOCs emission accounting based on material balance is introduced in detail. The advantages and disadvantages of this method and its application scope are described. The parameters needed in the method are collected and summarized, which can provide reference for total VOCs control in automobile industry.

1. Introduction

Volatile organic compounds (VOCs) are one of the important precursors of ozone, PM$_{2.5}$ and other severe weather pollution [1]. Some VOCs have a strong toxic effect on the respiratory and nervous system of human body, and become the focus of supervision in the world. It is required to improve the standard system, strengthen the whole process management and control, and achieve the expected goal of 10% emission reduction in five years. However, at present, the use of solvents in China is still increasing year by year, the VOCs produced by unorganized emissions are difficult to control, and the regional composite air pollution caused by VOCs is increasingly prominent. The definitions of VOCs vary from country to country. The classification of VOCs is shown in Table 1.

| Item                               | Boiling point          |
|------------------------------------|------------------------|
| High volatile organic compounds(VVOC) | Boiling point<50℃     |
| Volatile organic compounds(VOC)    | 50℃≤Boiling point<260℃ |
| Semi volatile organic compounds(SVOC) | 260℃≤Boiling point<400℃ |

VOCs emission per unit coating area is one of the important technical indicators for VOCs emission control of vehicle products. Developed countries of foreign automobile industry have achieved the total...
VOCs emission control in manufacturing process by formulating this indicator. At present, the technical indicators of some countries are as follows:

| Country or region | laws and regulations(Implementation year) | Index requirements |
|-------------------|-------------------------------------------|--------------------|
| Europe            | SMP (1993)                                 | 45                 |
| Germany           | TA-Luft                                    | 35                 |
| Britain           | EPA (1990)                                 | 60                 |
| the United States | CAA (1990)                                 | 50                 |
| Japan             | Regulation of Automobile Industry Association | 60                 |

(1) SMP: Solvent Management Law, TA-Luft: Technical Instructions on Air Quality Control, EPA: Environment Protect Law, CAA: Clean Air Action
(2) The VOCs limit in the table is the VOCs emission requirement of unit coating area, in g/m²

Some areas in China have formulated VOCs emission index for unit coating area of automobile surface coating process, and given accounting principles [2]. Domestic scholars have also conducted in-depth research on this, but have not formed a standardized accounting method [3-4]. Therefore, in the current process of environmental supervision, it involves the calculation of VOCs emission index of automobile products, which has certain randomness and subjectivity. The calculation results of different personnel are quite different, which makes it difficult for environmental law enforcement. For this reason, this paper starts from the emission link of automobile products, gives the VOCs accounting method of unit coating area, and combined with relevant accounting cases, gives the specific parameter data, providing reference for the subsequent enterprise emission accounting.

2. Calculation method of VOCs emission per unit coating area

The VOCs emission index per unit coating area is calculated by material balance algorithm, which is a method to analyze and calculate the materials used in the production process according to the principle of mass conservation, so as to obtain the index or emission index.

2.1. Accounting method

The calculation method of VOC emission index per unit coating area is as follows:

\[ O = \frac{E_o}{A} \]  
\[ E_0 = E_i - C \]  

Where

- \( O \) VOC emission index per unit coating area, in g/m²
- \( E_o \) VOCs emission in the statistical period, in kg
- \( E_i \) VOCs production in the statistical period, in kg
- \( A \) Coating area of automobile products, in m²
- \( C \) VOCs reduction in the statistical period, kg;

2.2. VOCs Production

Most VOCs emitted in the manufacturing process of automobile industry are from solvents, mainly solvent based coatings, diluents, adhesives, etc. the production of VOCs is calculated by material balance method, and the calculation formula is as follows:

\[ E_i = \sum_{i=1}^{n} W_i \times W' F_i \]
Where
\( W_i \) usage of material i containing VOCs in a certain period, in kg;
\( WF_i \) mass percentage of material i containing VOCs, %. If the given solvent content is expressed by range, the median value shall be taken as the basis; if there is no channel to get the VOCs index of the product, the content given in Table 3 below shall be calculated.

Table 3. VOC content index of vehicle process materials

| Category         | Materials                        | VOCs content |
|------------------|----------------------------------|--------------|
| Coating materials| Water based electrophoretic primer| 2%           |
|                  | Intermediate painting (including curing agent) | 45%          |
|                  | Color painting (including curing agent) | 80%          |
|                  | Varnish (including curing agent) | 55%          |
| Others           | Adhesive Diluent                 | 100%         |

2.3. VOCs Decrement

2.3.1. Calculation method of absorbed. If the product is collected and treated by traditional physical adsorption, the removal amount of VOCs is equal to the amount absorbed by the product.

2.3.2. Calculation method of combustion treatment. The industrial general equipment is used to detect the concentration at the import and export of VOCs treatment equipment, calculate the VOCs treatment efficiency of different links, and further combine and calculate the total VOCs reduction, and the calculation formula is as follows:

\[ C = \sum_{i=1}^{n} D_i \]

Where
\( D_i \) VOCs reduction of the ith treatment facility, in kg

It should be noted that when using the runner adsorption concentration and catalytic combustion to process VOCs waste gas, the VOCs processing data of the burner should be used, and the adsorption and desorption efficiency of the runner should be considered comprehensively. If there are some waste gas treatment systems that cannot be tested, the coefficient in the table below can be used as the removal efficiency of the device.

Table 4. VOCs processing equipment efficiency

| Waste gas treatment technology                        | \( \eta \) |
|-------------------------------------------------------|----------|
| Direct combustion method                              | 1.0      |
| Direct catalytic combustion                           | 0.9      |
| Regenerative combustion                               | 0.95     |
| Adsorption concentration-catalytic combustion method   | 0.85     |

3. Actual case calculation

3.1. Basic information

According to the accounting principle determined in the second part, the single car coating area of some enterprises is accounted. The situation of vehicle manufacturing plant is as follows:

A) The electrophoresis surface area of the vehicle is 87.6\( \text{m}^2 \).
B) 3 wet spraying process with high solid content is adopted.
C) Waste paint liquid and detergent recovery device are installed.
D) The drying link of the factory has a heat oxidation treatment device.
3.2. VOCs emission in manufacturing process

In the whole vehicle manufacturing process, VOCs are mainly generated from the use of solvent products such as coating, cleaning agent and adhesive. According to the process flow, VOCs emission of different production and emission nodes is as follows.

3.2.1. VOCs emission during electrophoresis. The VOCs emission in the electrophoresis process is divided into two parts, in which the VOCs are not contained in the electrophoretic paint or the VOCs content is very low. This part of solvent will be released to the atmosphere before the electrophoretic drying. The other part is the electrophoresis drying process. Some products will react and generate some volatile substances, which will directly enter the electrophoresis drying furnace for combustion.

\[
O_{e_1} = \frac{(E_{ier} + E_{iep})}{A}
\]

Where
- \(O_{e_1}\) VOCs reduction of the \(i\)th treatment facility, in kg/m\(^3\)
- \(E_{ier}\) Total volatile components of electrophoresis resin, in kg
- \(E_{iep}\) Total volatile components of electrophoretic pigment, in kg

VOCs contribution of heating reduction part of electrophoretic paint

\[
O_{e_2} = \frac{(E_{ieh} \times 4\% + E_{ieh} \times 96\% \times (1-\eta))}{A}
\]

Where
- \(O_{e_2}\) VOCs contribution of heating reduction part of electrophoretic paint, in kg/m\(^3\)
- \(E_{ieh}\) VOCs produced by heating reduction of electrophoresis link, in kg

According to the actual situation of coating used by enterprises in Table 5, the contribution of electrophoresis to VOCs of single vehicle shall be calculated.

\(O_{e_1} = 1.3\, \text{g/m}^2\) \hspace{1cm} \(O_{e_2} = 4.77\, \text{g/m}^2\)

**Table 5.** Relevant parameters of coating

| Material                | Usage quantity/Kg·Vehicle \(^{-1}\) | Solid content/\(\%\) |
|-------------------------|-------------------------------------|---------------------|
| Electrophoretic paint   | 6.0(resign)                         | Resign: VOCs content 1\%; pigment: VOCs content 4.50\% |
|                         | 1.2(pigment)                        |                     |
| Medium paint 1          | 0.8                                 | 57                  |
| Medium paint 2          | 2.5                                 | 68                  |
| Colour paint            | 2                                   | 51                  |
| Varnish                 | 1.7                                 | 58                  |

3.2.2. VOCs emission during painting. VOCs in spraying process mainly come from two aspects, one is VOCs emitted from typical solvent, and the other is VOCs emitted from cleaning solvent.

In the spraying process, VOCs in raw materials, unless burned by RTO and other equipment, will enter the atmospheric environment in various forms. Therefore, all VOCs components will be treated in the form of full emission. Refer to the table below for VOCs emission proportion of each process in intermediate coating and painting and varnish spraying.

**Table 6.** VOCs emission proportion of different process sections

| Item                    | Spray booth | Leveling room | Drying room |
|-------------------------|-------------|---------------|-------------|
| Middle painting section | 60%         | 25%           | 15%         |
| Colour painting section | 85%         | 5%            | 10%         |
| Varnish painting section| 60%         | 25%           | 15%         |
According to the three process stages of intermediate coating, color coating and varnish, calculate the VOC emission per unit coating area, and the contribution of VOCs emission in the three processes of intermediate coating, color coating and varnish to the VOCs emission per unit coating area of the whole vehicle is:

\[ O_m = \frac{W_{pm} \times (60\% + 25\%) + W_{pm} \times 15\% \times 95\% \times (1-\eta) + W_{pm} \times 15\% \times 5\%}{A} \]  
(7)

\[ O_c = \frac{W_{pc} \times (60\% + 25\%) + W_{pc} \times 15\% \times 95\% \times (1-\eta) + W_{pc} \times 15\% \times 5\%}{A} \]  
(8)

\[ O_v = \frac{W_{pv} \times (60\% + 25\%) + W_{pv} \times 15\% \times 95\% \times (1-\eta) + W_{pv} \times 15\% \times 5\%}{A} \]  
(9)

Where
- \( O_m \) VOCs contribution of middle coating section, in kg/m³
- \( W_{pm} \) Amount of paint used for middle painting, in kg
- \( O_c \) VOCs contribution of color coating section, in kg/m³
- \( W_{pc} \) Amount of paint used for colour painting, in kg
- \( O_v \) VOCs contribution of varnish section, in kg/m³
- \( W_{pv} \) Amount of paint used for varnish painting, in kg

Combined with table 5 and table 6, the VOCs emissions in the middle painting, colour painting and varnish stages can be calculated respectively:

\( O_m = 3.38 \text{g/m}^2 \quad O_c = 8.28 \text{g/m}^2 \quad O_v = 7.01 \text{g/m}^2 \)

3.3. Result analysis

Refer to 3.2 calculation results, VOCs emission index per unit coating area of the whole vehicle product coating link is as follows:

\( O = O_{e1} + O_{e2} + O_m + O_c + O_v = 24.74 \text{ g/m}^2 \)

The proportion of VOCs contribution rate in different links is shown in the figure below:

**Figure 1.** The proportion of VOCs contribution.

4. Conclusion

The calculation of VOCs emission per unit coating area is a basic research work, and it is also an important index for the total VOCs control in the automobile industry. The calculation method mentioned in this paper fully refers to the production process links and basic data of domestic automobile enterprises. At the same time, the calculation method may also have some general problems. In the next step, the research work can be continued from the following aspects:

1. Carry out basic research, find out the emission links of domestic automobile enterprises and relevant basic emission data, and establish the national general product VOCs accounting coefficient index.

2. We will promote the research on automobile emission standards, release VOCs accounting methods in the form of standards, and further promote the development of VOCs reduction in the industry.
(3) By comparing the VOCs accounting indexes of different regions and different processes, the most economical and applicable technical route of VOCs reduction is found to support the air pollution prevention and control of automobile industry.

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