Application of Aeration Spray Technology in China and Its Reduction Effects in VOCs Control

Zhida He¹, Maoshen Ye²*, Qingwei Ni² and Junqi Ding²

¹Tongzhou Municipal Commission of Development and Reform, Beijing, China
²China Eastern Route Corporation of South-to-North Water Diversion, Beijing, China

*Corresponding author

Abstract. The impression of paint spraying operation is that the paint mist is flying and it can pollute the environment and endanger the human health. The Airmix® spray technology invented by Chemlin completely changed the working conditions of the painting operation. This painting technology is called “mixed air spraying”. Although the technology is still little known in China, aeration spray has become a newcomer in the field of spray technology. It not only has the advantages of good atomization effect of traditional air spraying, high surface quality of paint film, convenient use, etc., but it also has many excellent process characteristics: it can spray paint with high viscosity, high spraying efficiency, save paint and reduce cost, and get a thicker film. In particular, “mixed air spraying” inhibits the scattering of paint mist; it not only improves the spraying environment, occupational health and safety production guarantee, but also effectively reduces the pollution of VOCs and greatly promotes the development of productivity. The China’s government should promote the application of this new technology and gradually phase out some backward technology equipment.

1. Introduction

The earliest painting process was to apply a brush to paint or dip the work piece directly into a paint-filled container. In order to improve the coating quality and work efficiency, various coating processes have emerged such as air spraying, HVLP (low pressure and large flow) spraying, electrostatic spraying, electrostatic powder coating, electrophoretic coating, high pressure airless spraying, aeration spraying, and electrostatic mixing spraying. The research objective is comparing aeration spray technology to the normally used air spray methods and point out its superiorities.

| Painting type                  | Gas pressure (Bar) | Paint pressure (Bar) | Paint transmission efficiency [1] |
|-------------------------------|-------------------|----------------------|----------------------------------|
| Air spray gun                 | 2.5~6.0           | 0.5~3.5              | 30~45%                           |
| Environmentally friendly air spray gun | 0.5~1.5     | 0.1~2.0              | 45~75%                           |
| Airless spray gun             | 0                 | 100~500              | 40~60%                           |
| Aeration spray gun            | 0.5~1.5           | 60~120               | 50~85%                           |
| Electrostatic spray gun       | 2.0~4.0           | 0.5~3.5              | 70~90%                           |
| Aerated electrostatic spray gun | 0.5~1.2         | 60~120               | 75~95%                           |
Table 2. Parameters and efficiency of different spray atomization technology equipment

| Atomizing spray gun          | Maximum sprayable consistency (Ford Cup 4) | Paint thickness | Painting efficiency[2] |
|-----------------------------|-------------------------------------------|-----------------|------------------------|
| Environmentally friendly air spray gun | 15 sec                                    | Very thin       | Very slow              |
| Air spray gun               | 30 sec                                    | Thin            | Slow                   |
| Aeration spray gun          | 90 sec                                    | Thick           | Fast                   |
| Airless spray gun           | > 90 sec                                  | Very thick      | Very fast              |

Table 1 compares the process parameters and transmission efficiency of different paint spray guns, and Table 2 lists the parameters and efficiency of different spraying atomization technology equipment. The main advantages of the air-mixing spray gun are as follows:
(1) Controllable spray effect makes the paint quality higher;
(2) Higher paint efficiency and improved production efficiency;
(3) Reduced overspray and save up to 40% of paint;
(4) It can use high viscosity paint to save 80% of thinner material;
(5) To control the scattering of paint mist, and greatly improve the working environment and reduce pollution.

If the rules and new products or technologies work together, it will have a very large impact on the industry; if there is sufficient market capacity (to support his R&D investment), all companies will follow the rules. When the rules are strictly enforced, only those companies with long-term goals will get the most profit and get a lasting development.

2. Theory and Methodology
As early as 1975, the German company Kremlin created the Airmix ® aeration spray technology, which is still considered to be one of the most outstanding inventions in the field of spray application technology. Aerated spray began to become a new type of spray technology recognized in the industry. The inspiration for creating a gas-blown spray technology comes from combining the advantages of traditional air spray and airless spray, complementing the blank areas that are applied to the paint output.

The aeration spray technology combines the technical advantages of traditional air spray and airless spray. First, at a low paint pressure of 30 to 100 bar, the paint is subjected to preliminary atomization through a nozzle similar to airless spray. Second, through the positioning of the precise air outlet hole on the air cap, the pressure of the atomizing air is very low, usually 0.5 to 1.2 bar; this process makes the fan shape uniform and the paint particles become fine. Third, because the speed of the coating particles is very low at only 0.7 m/s, which is less than one tenth of the speed of the conventional spraying particles, the scattering and rebound of the coating are effectively suppressed, the pollution hazard of VOCs is greatly reduced, and the production environment is improved. Reduce the investment and management costs of the company for occupational health, safety and environmental protection.

3. Experiments and Results
3.1. Experimental Design of Aeration Spray Technology
The test used a full set of imported air-mixing equipment: two Xcite spray guns from Kremlin and two paint supply devices from Wagner, Germany. In the engine-painting booth, the air-mixing spray engine test was carried out. The Beijing Municipal Institute of Labor Protection and the German
Wagner Corp. conducted on-site inspection and training. Weichai Power Corp. provided more than 150 engines and related technicians and operators.

3.2. Test Results

3.2.1. Spray quality. After repeated trials, the viscosity of the paint was set at 37 to 43 seconds, which was higher than the paint viscosity of $22 \pm 5$ seconds required by the air spray process, which created favorable conditions for improving the thickness of the single spray paint film.

A. Film thickness

**Table 3.** Comparison of the average thickness of air spray and air spray paint film

| Part type          | Paint film thickness process requirements | Average thickness of air spray paint film | Average value of mixed spray paint film thickness | Difference | Thickness increase$^{[3]}$ |
|--------------------|-------------------------------------------|------------------------------------------|-----------------------------------------------|------------|--------------------------|
| Primer casting parts | $\geq 90 \mu m$                           | 97.8                                     | 147.5                                         | 49.7       | 50.8%                    |
| Primer ribbed parts | $\geq 60 \mu m$                           | 80.4                                     | 117.5                                         | 37.1       | 46.1%                    |
| Primerless parts   | $\geq 55 \mu m$                           | 73.75                                    | 89.75                                         | 16         | 21.7%                    |

Average percentage of thickness 39.5%

It can be seen from Table 3 that the paint film thickness of the two sprayed diesel engines meet the process requirements because the operation mode of the new spray gun is different from that of the air spray gun. The operation habit of the paint sprayer is difficult to change at one time, and the paint film thickness is mixed. The average value is thicker than the average thickness of the air spray paint film of 39.5%. That is, the performance of the aeration spray method is better than the air spray method. Moreover, no flow lacquering occurs at this thickness, mainly because the painting equipment can accommodate higher paint viscosities.

B. Appearance quality of paint

Due to the small particle size and less diffusion of the mixed spray paint, the appearance of the sprayed surface in the diesel engines was more delicate than the air sprayed ones, and the gloss is better. In particular, peripheral components such as a cylinder head cover and a supercharger are more obvious.

![Figure 1. Comparison of the appearance of air-sprayed(left) and aerated-sprayed(right) diesel engine cylinder head covers](image-url)
Figure 2. Comparison of appearance of air spray(left) and aerated spray(right) diesel exhaust pipe

3.2.2. Analysis of spray material usage and production cost

| Paint, curing agent, thinner consumption | Air spray gun | Aeration spray gun | Difference | Price per kilogram(¥) | Saving price per unit[^4] |
|-----------------------------------------|---------------|--------------------|------------|------------------------|--------------------------|
| Thinner consumption of single diesel engine (kg) | 0.95 | 0.47 | 0.48 | 13 | 6.24 |
| Single diesel engine paint consumption (kg) | 1.37 | 1.31 | 0.06 | 29.5 | 1.77 |
| Single diesel engine curing agent consumption (kg) | 0.1377 | 0.1311 | 0.0066 | 63 | 0.4158 |
| Total cost per unit | 8.4258 |

It can be seen from Table 4. If compared with air spraying method, the air-mixing spray method can save 8.4258 yuan per unit. Considering an annual output of 500,000 diesel engines and the film thickness factor, using the current paint film thickness requirements, the total annual savings is about 8.4258*500000*(1+39.5%)=5876995.5 yuan, or 5.877 million yuan.

3.2.3. Improvement of air quality in the workplace. During the test, the BMILP was commissioned to test the ambient air quality of the two painting equipment. In the manual painting room, paint mist concentration sample in the air spray site and the sample in aeration spray site were collected. The concentrations of benzene, toluene, xylene, butyl acetate, and non-methane total hydrocarbons (VOCs) in the air were tested. The test results are shown in Table 5.

From the above comparison, the aeration spray gun reduces the pollutant emissions of the air spray gun by more than 50%; the air quality of the workshop is greatly improved. In addition, the paint mist image generated from two different spraying methods on the spot can also visually compare the difference in paint mist concentration[^6-7].

On-site robots and artificial air spray guns are used to spray paint. The paint mist is flying, and the pollution is serious. The difficulty of harmful substances is harmful to the health of the operators on the site, and it incurs the fire safety risks of the workshop[^8-9]. See Fig. 3, 4.
Table 5. Comparison of workshop air quality test

| Serial number | Test items                  | Concentration value(mg/m³) | Comparative Results[5] | Remarks  |
|---------------|-----------------------------|----------------------------|-------------------------|----------|
|               | Air spray gun               | Aeration spray gun         | Decrease the number     | Reduction rate | Remarks         |
| 1             | Non-methane total Hydrocarbon | 175.3                      | -                       | -         | Artificial      |
| 2             | Non-methane total Hydrocarbon | 79.4                       | 9.7                     | 69.7      | 87.78%          | Artificial      |
| 3             | Butyl acetate               | 7.58                       | 1.92                    | 5.66      | 74.67%          | Artificial      |
| 4             | Xylene                      | 1.60                       | 0.30                    | 1.30      | 81.25%          | Artificial      |
| 5             | Toluene                     | <0.03                      | <0.01                   | 0.02      | 66.67%          | Artificial      |
| 6             | benzene                     | <0.02                      | <0.01                   | 0.01      | 50.00%          | Artificial      |

Figure 3. Robot spraying on-site paint fog condition (air spray)

Spraying with a mixed air spray gun, the paint rebounds little, the paint mist has no obvious traces, and it is beneficial for on-site equipment maintenance and workers health. As shown in Fig. 5.

Figure 4. Artificial air spray on-site paint fog condition

Figure 5. Artificial aeration spray painting scene paint fog condition
It can be seen from the above figure. Due to the technical characteristics of the air-mixing spray gun, there is a paint mist restraint zone formed by the air-assisted pressure. So, the paint spray concentration on the air-mixed spray site is weakened much compared to the air spray method, and reduced the damage to the field operator. There is a sharp difference or promotion between air-mixing spray method and the air spray gun in the environmental pollution and the paint waste. The operator's experiences of the operation process were collected on site. The operator was very satisfied with the improvement of the working environment brought about by the reduction of the paint mist. The reduction in the concentration of flammable substances in the air also reduces the risk of safety accidents such as fires\cite{10-12}.

3.2.4. Comparison of spraying operation speed. The average time taken by a skilled painter to use a gas-blown sprayer and the average time spray a diesel engine using a conventional air spray gun are shown in Table 6 \cite{13-15}.

| Gun type           | Aeration spray gun | Air spray gun |
|--------------------|--------------------|---------------|
| Spraying time      | 4'47"              | 5'46"         |

Table 6. Average time of air spray gun and air spray gun painting

The fastest and slowest spraying times of the two painters are shown in Table 7:

| Painter           | Fastest spraying time | Slowest spraying time | |
|--------------------|-----------------------|-----------------------| |
| Liu guoqiang       | 3'20"                 | 5'06"                 | |
| Ma Ruiwei          | 4'20"                 | 5'50"                 | |

In addition, in order to compare the paint spraying time efficiency of different painters, we selected two spray painters Liu and Ma on May 16, 2018 to compare the spray time of 10 diesel engines sprayed with a mixed air spray gun. The contrast curve is shown in Figure 6\cite{16-17}.

![Figure 6. Spraying time curve of different sprayers](image)

In table 6, 7 and figure 6, from the data obtained from 40 diesel engines, regardless of the skill difference of the painter, the spray rate of the aeration spray gun is higher than that of the air spray gun. The spraying rate of different painters is different. In this test, under the premise that the thickness meets the requirements of the process quality, the painter Liu Guoqiang sprays a diesel engine for a maximum of 3 minutes and 20 seconds, which is 1 minute faster than the last time for Ma Ruiwei to spray one. The painting speed is faster. Significantly higher than air spray. It can be seen from the spray time curves of the two painters in Figure 6. As the painter gradually becomes familiar with the operation of the spray gun, the spraying time tends to be shortened.

Through the case study of the paint production line of the engine of Weichai Power Co., Ltd., the aeration spray technology has the following obvious technical advantages.
First, the increase of the viscosity of the paint reduces the use of organic solvents and reduces the pollution of harmful substances; the measured use of thinners is reduced by 50%, and the total amount of VOCs emissions is reduced by 75%;

Second, it reduced the rebound of paint fog, improved the utilization of paint, saved paint (paint, thinner, etc.) 20%; according to the annual output of 50 units, it can save 5.777 million yuan;

Third, it significantly reduced the scattering of paint mist and reduced noise; effectively reduce the health hazards of operators. The VOCs content of the spray booth is more than 100 mg/m$^3$ when air sprayed and less than 10 mg/m$^3$ when air spray is applied;

Fourth, the dust and aerosol in the discharge gas of the spray booth are greatly reduced, the use time of the filter material is prolonged, and the total amount of organic gas emissions (VOCs) is reduced several times;

Fifth, the surface quality of the engine spray paint is smooth and smooth, and the thickness of the paint film is generally improved, which increases the market competitiveness of the engine products.

4. Conclusion

Recently, the Ministry of Environmental Protection and the State Administration of Work Safety of China have attached great importance to the occupational health hazards and safety hazards of organic gas (VOCs) emissions and organic waste gases. Cities such as Beijing and Shanghai have developed more stringent VOCs emission standards. In the spring of 2014, the surrounding eastern part of Beijing caused persistent severe smog weather, forcing the Beijing Municipal Government to propose the corresponding measures for VOCs reduction. In the future, it is necessary to limit the backward spraying process of the paint spraying industry, and eliminate the backward spraying process and device. The technical advantage of the aeration spray technology is that it can suppress the occurrence of paint mist, improve the use efficiency of paints (paints, thinners, additives), reduce the consumption of compressed air, improve the surface quality of spray products, lift production efficiency, depress emissions of VOCs, and cut down the production cost and environmental protection cost of an enterprise. It is an effective technical means and worth promoting.

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