

Development of Paint Booth: “New Paint Mist Collection Method”

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1. ABSTRACT

Inside a paint booth to spray paint on vehicle bodies, bumpers, and other parts (hereinafter referred to as “works”), air whose temperature and humidity are controlled by air-conditioner is supplied by blower fans through filters. Dust-eliminated and regulated air flow is sent downward from top to bottom (hereinafter referred to as “downflow”) in the painting booth. Conventionally, paint which does not adhere to work in spraying (hereinafter referred to as “paint mist”) is collected while flowing at a high speed through a slit opening called venturi scrubber in a mixture of air and water. However, this mist collecting system using venturi scrubber requires a large space with a large amount of pressure loss while consuming substantial energy. By radically changing the mist collecting principle, we developed a new compact system with less pressure loss aiming to reduce energy consumption by 40% in a half-size booth.

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2. INTRODUCTION

These days in the field of automobile manufacturing, reduction of environmental burden emitted from manufacturing processes such as VOC (volatile organic compound) or CO₂ (carbon dioxide), and other initiatives to solve environmental issues have been essential.

Paint in painting process exerts great impact to VOC, which is a cause of urban ozone smog. We have greatly reduced VOC by changing conventional paint to water-borne paint and improving exhaust treatment devices [1]. CO₂ emission amount, i.e. energy consumption, at paint process occupies approximately 20% of a whole vehicle manufacturing lines. It is an urgent concern to take energy saving measures at painting lines. Now, we have developed innovative technologies to reduce CO₂ by focusing paint booth in which approximately 50% of energy consumed in the whole paint shop.

In a painting booth, temperature/humidity-controlled air is supplied in an even regulated downflow in order to assure high paint quality by controlling paint viscosity adhered to work and also by preventing paint mist diffusion [2]. Paint mist is caught by mist collecting device by making high speed collision with the water flow lead to water pan placed under the work. This mist collecting device is large and the pressure loss is big. It is our concern that to supply air and water requires large energy [3]. We have radically changed the concept of mist collecting system, and developed a new compact mist collecting system with low pressure loss aiming 50% reduction in equipment size and 40% reduction in energy consumption.

2-1. Mist Collecting System and Principle of Conventional Paint Booth

Paint mist in conventional paint booth is collected by a device called venturi scrubber placed under the work (Figure 1). This device has a narrow area with steeply narrowed-down opening where paint mist in air goes through with water at a high speed of approximately 20 m/s in order to realize high collecting efficiency (Efficiency $\geq 97\%$; Mist density in exhaust air $\leq 3 \text{ mg/Nm}^3$).

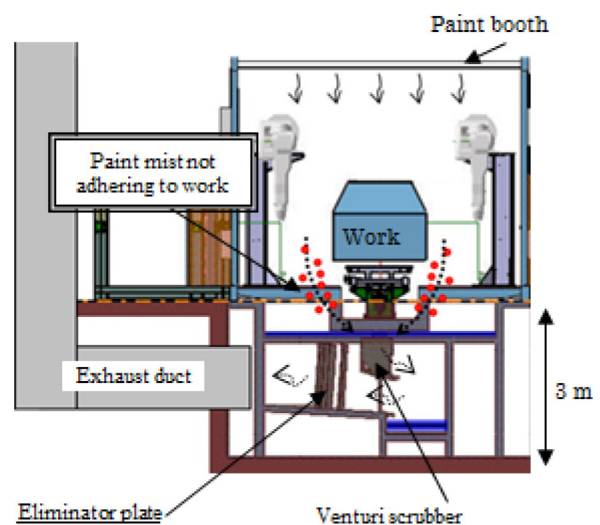


Figure 1. Outline of Conventional Paint Booth

Water going through this narrow portion is atomized with high speed air, and paint mist collides efficiently against this atomized water to be collected here (Figure 2). Big water drops involving paint mist fall down by their own weight by reducing speed in wide space after passing through the narrow portion. Water drops of small diameter are separated from air by colliding against an eliminator plate. Our concern is that the conventional mist collecting device causes big pressure loss while requiring big equipment size owing to the above mist collecting principle.

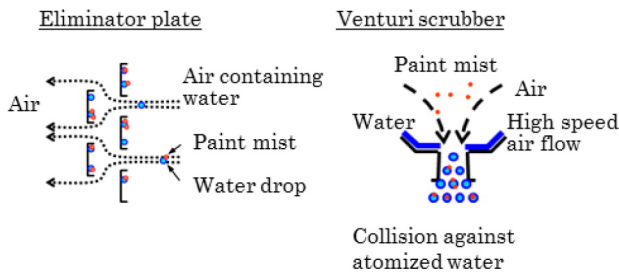


Figure 2. Eliminator Plate and Venturi Scrubber

2-2. Collecting Paint Mist with New Mist Collecting Device

In developing a new mist collecting device, we measured the paint mist diameters to collect using a laser instrument for measuring particle size distribution (Figure 3). Paint mist diameters are distributed in a range from a few micrometers to approximately 100 micrometers. It is critical how to collect small particles of a few micrometers to a few tens of micrometers, which are generally assumed to be difficult to collect efficiently. In order to collect small particle paint mist (Diameter of 20 micrometers or more is targeted here.) efficiently in a compact mechanism without a narrowed-down area, the particles are enlarged by letting them collide against the water drops sprayed from the center of the cylinder. The enlarged particles are separated from air flow by centrifugal force of swirling flow generated by the helical shaped guide in the cylinder. This device shall be installed in the midst of an exhaust duct to downsize a paint booth.

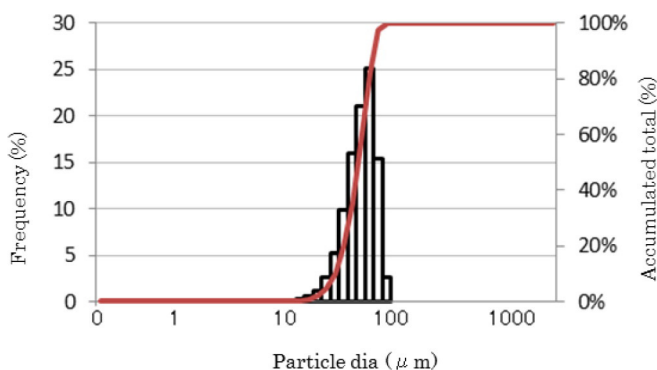


Figure 3. Particle Diameter Distribution of Paint Mist

Figure 4 shows the outline of the new paint mist collecting device (hereinafter referred as “mist collecting cylinder.”) A helical guide to generate swirling flow and water spray nozzles for enlarging paint

mist particles are set in a mist collecting cylinder. It is important to generate stable swirling air flow. The helical guide shape is optimized utilizing computational fluid dynamics (CFD), and the spray nozzle allocation and the flow rate from the nozzle are verified and optimized using data on scale model test.

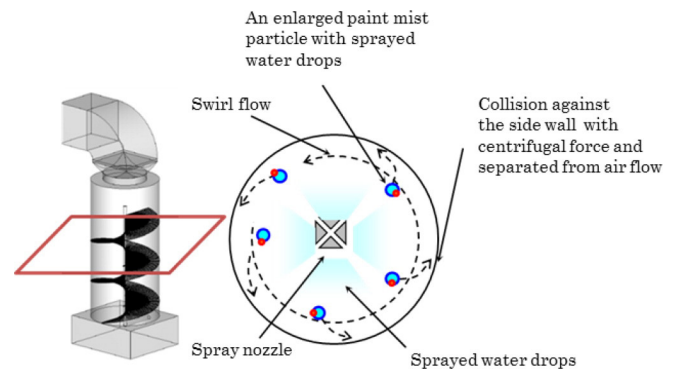


Figure 4. Outline of New Mist Collecting Device

3. FUNDAMENTAL REVIEW BASED ON THEORETICAL CALCULATION

3-1. Collision against Side Wall by Centrifugal Force

Figure 5 shows the concept of mist collecting efficiency with swirling air flow in the cylinder. Assuming that particles of diameter D_p are collected on the cylinder wall of length L , and the density of the particles is even (complete mixture) everywhere same as that at the outlet, the collecting efficiency $\Delta \eta$ is shown as follows [4]:

$$\Delta \eta = \frac{\rho_p D_p^2 \omega^2 L}{9 \mu U_z + \rho_p D_p^2 \omega^2 L}$$

Where,

$\Delta \eta$ = Collecting efficiency [-]

ρ_p = Particle density [kg/m³]

D_p = Particle dia. [μm]

ω = Angular speed [rad/s]

L = Device length [m]

μ = Fluid viscosity [Pa · s]

U_z = Axial speed [m/s]

Figure 6 shows paint mist collecting efficiency with cylinder peripheral speed assumed to be 10 m/s. In order to achieve the collecting efficiency target of 97% or more, paint mist particle dia must be enlarged to 200 micrometers or more.