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Short Communication

Performance of a Fume-Exhaust Gun System in CO_2 Arc Welding

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Although the incidence of pneumoconiosis has been decreasing in Japan[1], welders' health hazards due to welding fume inhalation are still serious, because effective engineering methods for controlling fumes are technically difficult to implement in many welding shops. In the 6th notification of general prevention of dust hazards issued by the Japanese Ministry of Health, Labor and Welfare (2003–2007), a fume-exhaust gun system was recommended as an effective ventilation device for welding fume control.

An ordinary fume-exhaust gun system consists of a welding torch with a suction hood which exhausts the air around the welding arc, a fume collector, and a flexible duct which connects the hood to the collector (Fig. 1). The ventilation is supposed to be performed effectively by means of the suction hood distributed around the periphery of the torch. The air contaminated with welding fumes is carried from the hood through the flexible duct to the fume collector where it is cleaned and then re-circulated to the welding shop. Since a fume-exhaust gun requires much lower air removal than other local ventilation systems[2] or a general ventilation system, it should be beneficial to the running cost of the ventilation. In addition, a fume-exhaust gun is superior to the other local ventilation systems in applicability. Unlike the fixed hood of a usual local exhaust ventilation system, a fume-exhaust gun has a hood which does not limit the size of the work piece and welder's mobility because its hood is always close to the arc point and does not require laborious repositioning or adjustment.

However, the gun performance will be affected by the geometry of the weld joint and the shielding gas flow rate. When the hood suction is distorted due to some welding position or excess in shielding gas, the fume plume may tend to rise away from the hood of the gun. In this study the author investigated the effects of welding position, elevation angle of weld line and flow rate of shielding gas on fume-exhaust gun performance.

Material and Methods

The fume-exhaust gun system investigated in this study was an adapter type. The gun system had a 42 mmø circular opening exhaust hood (60° taper) which was fitted around a welding torch. A 26 mmø flexible exhaust duct was attached to the side of the hood. The output and the static pressure of the fan equipped with the fume collector were 1.9 kw and 19.6 kPa, respectively. The velocities at the hood opening and the assumptive arc point were 2.7 m/s and 1.5 m/s respectively, and the exhaust flow rate was about 95 l/min when the exhaustion was turned on in compliance with the manufacture's operating manual. Although the velocity of 1.5 m/s at the arc point seems excessive[3], the actual velocity during the arcing time will be less than 1.5 m/s since the shielding gas flow suppresses the exhaustion flow.

The performance of the fume-exhaust gun system was evaluated in laboratory robotic CO_2 arc welding. In order to avoid warping of the base metals, the welding conditions for this study were set as follows.

welding current: 100 A
welding speed: 20 cm/min
filler wire: 1.2 mm ø solid wire (JIS Z 3312)
welding position: flat , horizontal, down hill
arcing time: 1 min

Rolled steels of the JIS G3101 SS400 standard (12 mm thick) were used for the base metals. In order to simulate an actual industrial welding operation faithfully, all the weld joints in this study were set to T joints, though previous researchers[3] had carried out several investigations with *bead on plate welding*. The layouts of the welding base metals (work pieces) are shown in Fig. 2. The torch ran normally to the weld line in all layouts, and the elevation angles of the weld line were

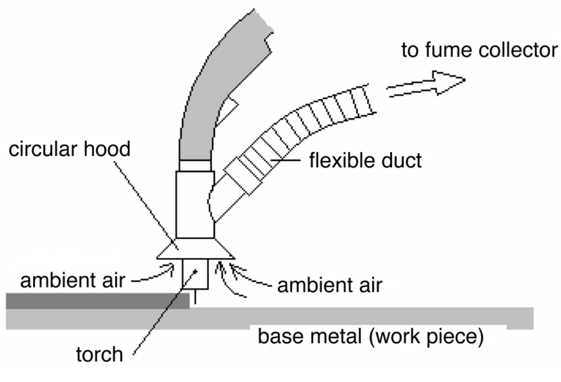

Fig. 1. Fume exhaustion by means of a fume-exhaust gun.

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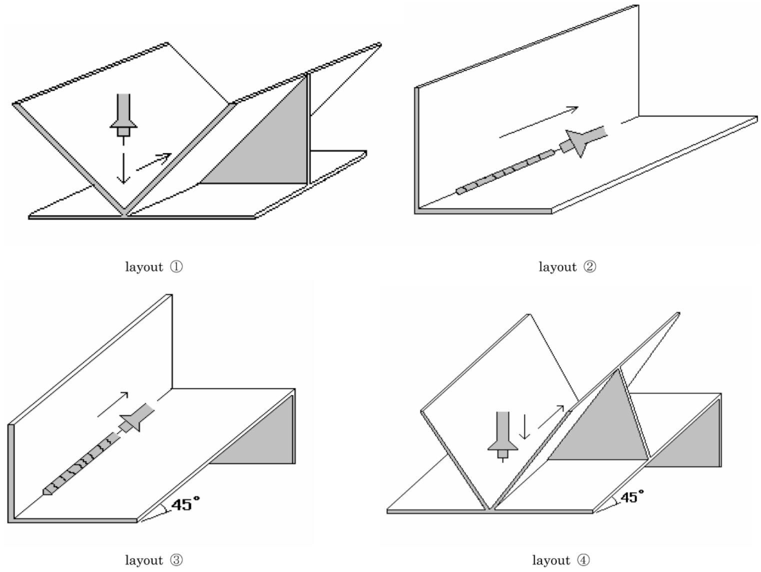

Fig. 2. Layouts of the base metals (work pieces).

Table 1. Respirable welding fume concentration during arcing at the breathing zone*

Work piece layout	Welding position	Weld line	Fume exhaustion	Fume Conc. [mg/m³] **
①	flat	0°	OFF	78.6 ± 16.6
①	flat	0°	ON	10.8 ± 2.8
②	horizontal fillet	0°	ON	20.1 ± 5.2
③	horizontal fillet, down hill	45°	ON	29.1 ± 4.1
④	flat, down hill	45°	ON	28.8 ± 8.5

* : shield gas flow rate=20 l/min, ** : Values are the mean ± S.D. (n=10)

set to 0° (layout ①, ②) or 45° (layout ③, ④). Respirable fume concentration was measured by means of a portable light scattering digital dust monitor (DUST MATE model LD-1H$_2$, SIBATA SCIENTIFIC TECHNOLOGY LTD., Japan) which was calibrated by an inertial impact dust sampler (Roken type low volume air sampler NWPS-254, SIBATA SCIENTIFIC TECHNOLOGY LTD., Japan). The calibration factor of the dust monitor was 12.4×10^{-3}. The sampling point was fixed at the assumptive breathing zone (30 cm above the arc point), and the sampling was carried out during the arcing time. Welding and sampling were performed in a draft-free enclosure.

Results and Discussion

Table 1 shows the results of the performance test in several welding layouts. Due to the impossibility of controlling the convection current completely, there was a considerable amount of scatter in the experimental results. Without exhaustion, the respirable fume concentration at the assumptive breathing zone reached 78.6 mg/m^3, but a remarkable reduction could be obtained with the fume-exhaust gun provided that the torch angle was set vertically. Although the gun could not achieve a personal exposure level below the Occupational Exposure Limit of Japan (1 mg/m^3), the respirable fume concentration was reduced to approximately 14% (10.8 mg/m^3) of the concentration of the non-ventilation condition when the gun was applied to a horizontal (0°) weld line in the flat position (layout ①). Comparing the results of layouts ① and ②, it became clear that the performance of the gun varied depending on the welding position. The exhaustion of the gun was less effective in horizontal fillet position welding than in flat position welding since the fume concentration was 20.1 mg/m^3 in the horizontal fillet position welding. This means that the fume-exhaust gun is more effective when it is angled vertically downwards. However, when the weld line was inclined at 45°, an obvious effect of welding position was not recognized since there was no significant

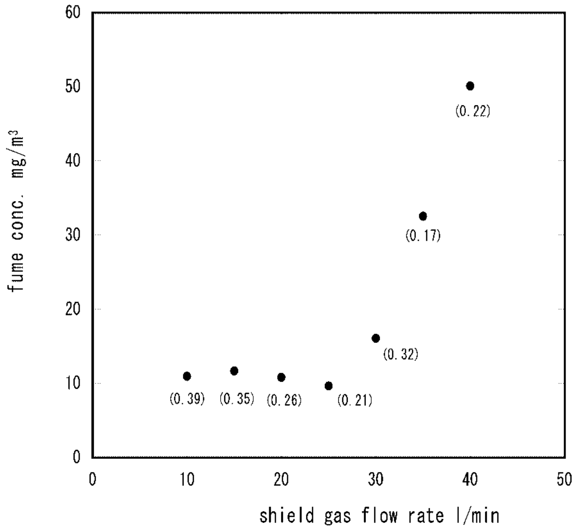

Fig. 3. The effect of the shielding gas flow rate on the fume concentration at the assumptive breathing zone. The plots are the arithmetic means of 10 measurements, and the RSD of each plot is shown in the parentheses. The work piece settings were layout ①.

difference in the fume levels between layouts ③ and ④. Comparing the results of layouts ① and ④, or the results of layouts ② and ③, an increase in the elevation angle of the weld line seemed to lower the gun performance. It would have been due to the fact that the fume plume tends to ascend along with the base metal when the weld line is inclined, and leaks out from the suction zone of the hood. Therefore, it can be concluded that the fume-exhaust gun is most effective when its hood is centered directly over the arc point.

Figure 3 shows the relation between the shield gas flow rate and the fume concentration at the breathing zone. The plots in the figure are the arithmetic means of ten measurements, and the relative standard deviation of each measurement is shown in the parentheses. The work piece settings were layout ① in this experiment. The fume level was hardly affected by the fluctuation of the shield gas flow rate, provided that the flow rate was less than 30 l/min. However, when the flow rate was over 30 l/min, the exhaustion was certainly impaired and the fume concentration rapidly increased with increase of the flow rate. In contrast, when the flow rate was reduced to 10 l/min, visible porosities (welding defects) were found on the surface of the weld metal due to the deficiency of the shield gas. Therefore, in order to avoid high level fume exposure and welding defects, the flow rate of the shield gas ought to be 15–25 l/min (16–26% of the exhaustion flow rate) at a welding current of nearly 100 A.

As might be expected, a thorough fume control can hardly be attained by a fume-exhaust gun system alone

Fig. 4. Example of a suspending unit for a fume-exhaust gun.

because the performance of the gun system can be lowered by its working condition. Another engineering method, such as auto-mobile ventilation[2] or push-pull ventilation[4], should be used together with a fume-exhaust gun system so as to complement each other.

The practical disadvantages of a fume-exhaust gun system are its weight and bulkiness owing to the additional hood and flexible duct for exhaustion. According to a questionnaire conducted by the Japan Welding Engineering Society, the fume-exhaust gun system is still not widely used in Japanese industry because of its practical disadvantages. However, some devices may reduce these disadvantages. For example, suspending the fume-exhaust gun system by a mobile boom, as shown in Fig. 4, can take the weight off the gun, increase welder's mobility, and mitigate fatigue.

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