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Some Engineering Countermeasures to Reduce Exposure to Welding Fumes and Gases Avoiding Occurrence of Blow Holes in Welded Material

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Abstract: Recently, open-type push-pull ventilation systems have been widely employed as effective substitutes for the conventional local exhaust ventilation system, and have prevailed at many welding workshops in Japan. In this study, the effect of the uniform velocity on carbon dioxide (CO_2) shielding arc welding was examined by laboratory experiments. The ventilation system examined in the experiments successfully fulfilled the requirement for open-type push-pull ventilators prescribed in Japanese regulations (ordinances). It was proved that the velocity at any points in the capture zone fell in the range of 50 to 150% of the average capture zone velocity. Welding defects could be avoided by controlling the flow rate of shielding gas. Unless the capture velocity exceeded a 0.8 m/s, the formation of blow-holes in the welded metal could be prevented at the shielding gas flow rate of 20 L/min. If the flow rate was provided at 30 L/min and 40 L/min, blow-holes didn't form at the capture velocity of 1.2 m/s and 1.6 m/s, respectively. At a capture velocity of faster than 0.3 m/s, the fume concentration at welder's breathing zone was reduced to a level below the limit values: ACGIH (TLV) and Japan Welding Engineering Society (CLV#). These data are important for designing open-type push-pull ventilation in the welding workshop. The other engineering countermeasures currently employed in the welding work in Japan, such as fume collecting torch and general ventilation, are also concerned in this report. #: *Control Limit Value*

Key words: CO_2 arc welding, Blow holes, Uniform flow, Push-pull ventilation system, Local exhaust ventilation, Fume collecting torch, General ventilation

Introduction

Until a few years ago, countermeasures for metal fumes and gases in welding had been mainly using local exhaust ventilation, general ventilation, dust respirator and low-fume welding processes. Because it is quite difficult to apply a local exhaust system to the moving emissions sources in welding work, open-type push-pull ventilators that do not affect the efficiency of welding work have become popular. Under such circumstance, it is necessary to clarify the effect of the uniform stream on shielding performance in carbon dioxide (CO_2) shielding arc welding.

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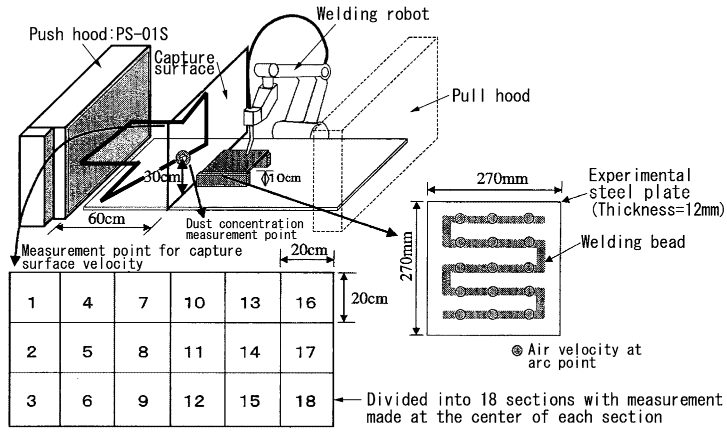

Fig. 1. Experimental apparatus and method.

Table 1. Test materials

Wire	JIS Z 3312 YGW-11	Solid wire 1.2 mm in diameter
Shielding gas	JIS K 1106 Carbon dioxide gas for welding	20 L/min, 30 L/min, 40 L/min
Material	JIS G 3101 SS400	Bead on plate for welding test 270 mm × 270 mm × 12 mm (t)

Table 2. Welding conditions

Posture joint	Welding current (A)	Arc voltage (V)	Welding speed (cm/min)	CO_2 flow rate (L/min)	Wire protrusion length (mm)
Downward bead on plate weld	300	28	30	20 30 40	20

The Technology Committee Report of the Welding Rod Committee of The Japan Welding Engineering Society[1] reported on the effects of exhaust hood in a local exhaust system on shielding performance at several fume capture velocities. According to the report, the relationship between the capture velocity at the arc point in downward bead-on-plate welding in CO_2 shielding arc welding and the welding quality are as follows: When the shielding gas flow rate was 20 L/min and the capture velocity at the arc point was at least 0.7 m/s, blow-holes occurred in the welded metal. When the flow rate of shielding gas was 30 L/min and the capture velocity at the arc point was 1.2 m/s, blow-holes also occurred. These data are useful for designing of local exhaust ventilation for welding workshop.

As described above, there are some reports on the welding quality based on the capture velocity when using local exhaust systems. However, there are no reports yet on the relationship between uniform stream by push-pull ventilator and welding quality.

Therefore, we recently conducted an experimental study[2] on uniform stream and welding quality using an open-type push-pull ventilator. In addition, we described here about some examples of push-pull ventilation, local exhaust ventilation, and general ventilation, which are currently used for countermeasures of the fume and gas from the welding work in Japan.

Experimental Apparatus and Method

Figure 1 shows an outline of the experimental apparatus and method in this study. The experimental materials are shown in Table 1 and the welding conditions are shown in Table 2. As shown in Fig. 1, the welding work was carbon dioxide gas arc welding using ARCMAN-RON, an automatic carbon dioxide gas welding robot manufactured by Kobe Steel Ltd. The push hood (existing product PS-01S) was manufactured by Koken Ltd., and was set to an open-type producing a horizontal stream pattern. The rectified air

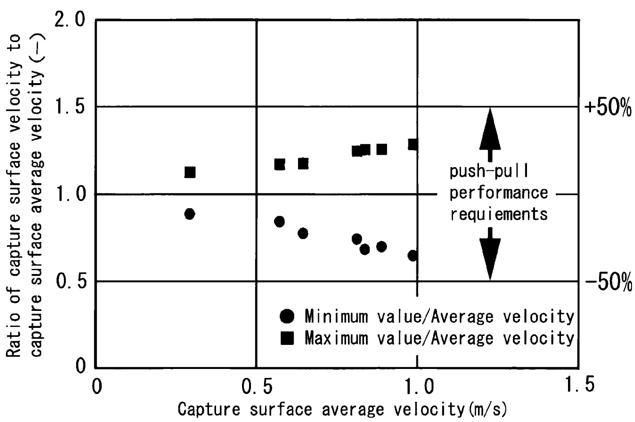

Fig. 2. Capture velocity measurement results (Capture surface).

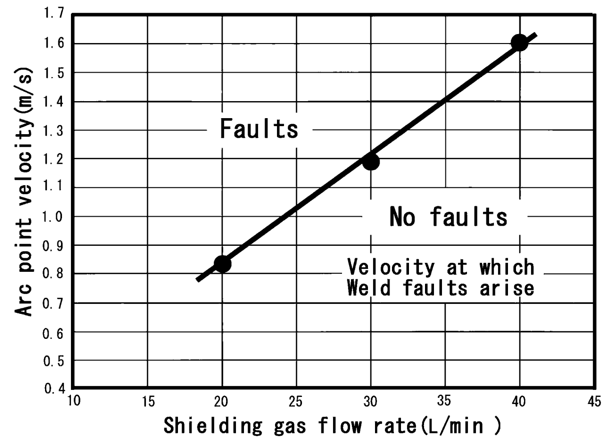

Fig. 3. The relationship between arc point velocity and shielding gas flow showing a boundary of production of weld faults.

volumes at the blowing side and the suction side are to be controlled variably by inverter regulator monitoring the velocities at the capture surface and the arc point. We measured the velocity at the capture side and the arc point using a hot wire anemometer (MODEL6521, Kanomax Co., Japan). The measurement range was from 0.05 to 2.5 m/s. The measurement points are shown in Fig. 1. The fume concentrations were measured using a TR personal sampler (Shibata Scientific Technology Ltd., Japan). The position where the sampler was settled is shown in Fig. 1. Evaluation of welding quality was conducted in accordance with JIS Z 3104: "Methods of radiographic examination for welded joints in steel".

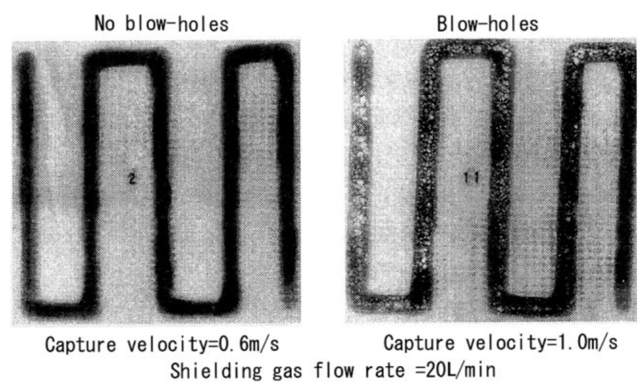

Fig. 4. Radiographs showing blow-holes (right) and no blow-holes (left).

Results and Discussion

Figure 2 shows the results of air velocity measurements at the capture surface in order to evaluate the performance of the open-type push-pull ventilator. As is clear from Fig. 2, the ratios of the capture surface air velocity to the capture surface average air velocity were proved to adequately satisfy the ±50% performance, which is required in the Dust Ordinance and other Ordinance, for the entire ranges of air velocity selected in the experiment.

Figure 3 shows the relationship between the uniform stream air velocity at the arc point and JIS ratings (welding quality) when the CO_2 gas flow rate was changed. From Fig. 3, it was found that there are welding faults at Level 2 and above. As is clear from Fig. 3, when the shielding gas flow rate is 20 L/min, 30 L/min and 40 L/min, blow-holes occur at a uniform stream air velocity of 0.8, 1.2 m/s and 1.6 m/s, respectively. Figure 4 shows the results revealed by radiograph.

From the results mentioned above, it was concluded that the open-type push-pull ventilator settled for CO_2 gas shielding arc welding had not affect on the incidence of blow-holes because the uniform stream air velocity of open-type push-pull ventilator is normally in the range of about 0.5–0.7 m/s.

Figure 5 shows the relationship between average air velocity, fumes concentration at the worker's respiratory area and production of welding faults. As shown in Fig. 5, the experiment proved that the fumes concentration at the worker's respiratory area falls to a level below the ACGIH TLV-TWA and the limit value by WES9007 at an average capture surface velocity of 0.3 m/s. Therefore, when using a open-type push-pull ventilator to CO_2 gas shielding arc welding, the uniform stream air velocity is to be set within 0.3–0.8 m/s, which reduces fumes concentration at the worker respiratory area below the limit value without any production of blow holes.

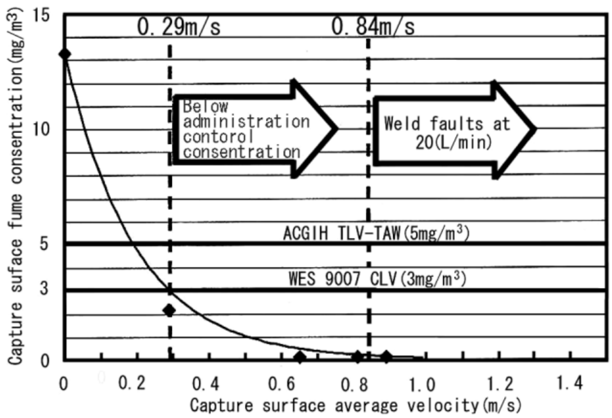

Fig. 5. The relationship between average velocity on the capture surface, fume concentration and weld faults.

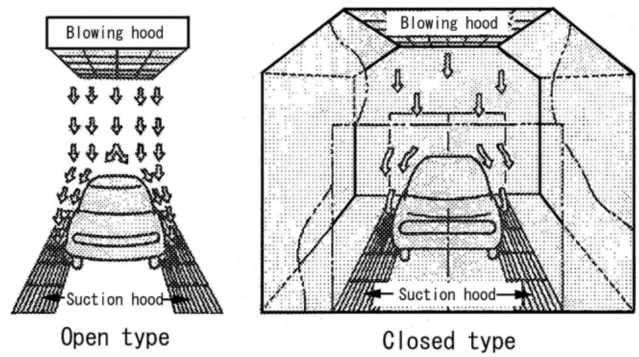

Fig. 6. Comparison of open type and closed type.

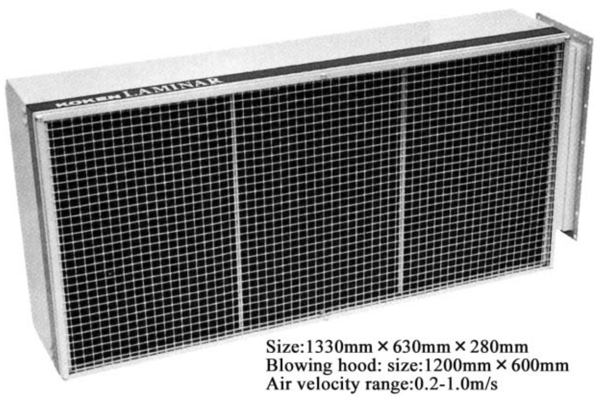

Fig. 7. A push hood (Duct connection type: PS-01S).

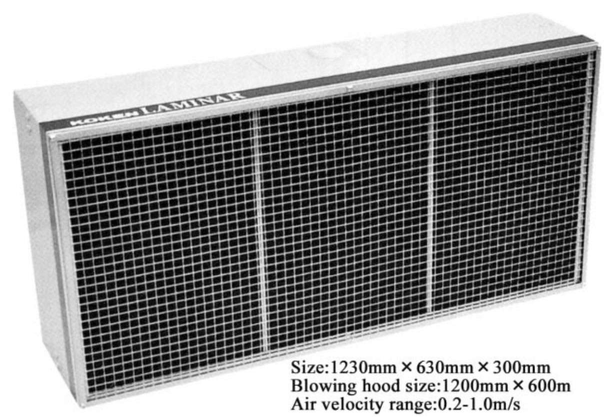

Fig. 8. A push hood (Built-in fan: PS-21H).

An Example of Open Type Push-Pull Ventilation (Push-Pull Ventilation System)

Push-pull ventilation is defined as "equipment that produces a uniform air stream (consisting of air stream from blowing hood toward the emission source of a toxic substance and withdrawing flow to the suction hood and when the direction and velocity of these air streams are uniform at the capture zone) and that capture and discharges the toxic substance from the emission source with hoods of blowing and suction side[3]". As shown in Fig. 6, equipment of blowing and suction hoods enclosed by walls is called "closed type" (right in Fig. 6) and the equipment without physical enclosure is called "open type"(left in Fig. 6).

It is the most important aspect for the open-type push-pull ventilator that the uniformity of air stream from the push hood which produces a highly stable air velocity and direction, and good performance that does not disperse toxic substances. Conventional push hoods produce a uniform air stream with rectification methods using a chamber and filter or a deformed punching metal technique. However, the air streams produced with these rectification methods are not very uniform. Moreover, the push hood is so bulky that there are sometimes problems with installation in workplaces.

The newly developed push hood realized a highly uniform air stream with a more compact size by means of an original technology by Koken Ltd., Japan employing the stream scattering method. Figure 7 shows a feature of the high performance, compact push hood (PS-01S; Koken Ltd., Japan). This push hood is a duct connecting type, and can be settled freely to the welding workspace.

Figure 8 shows another high performance compact push hood (PS-21H), which has a built-in fan, and has been used as a push hood for the standard push-pull ventilation system (WH-01unit) as shown in Fig. 9. The standard WH-01 unit consists of a push hood (PS-21H), a push hood frame (PF-

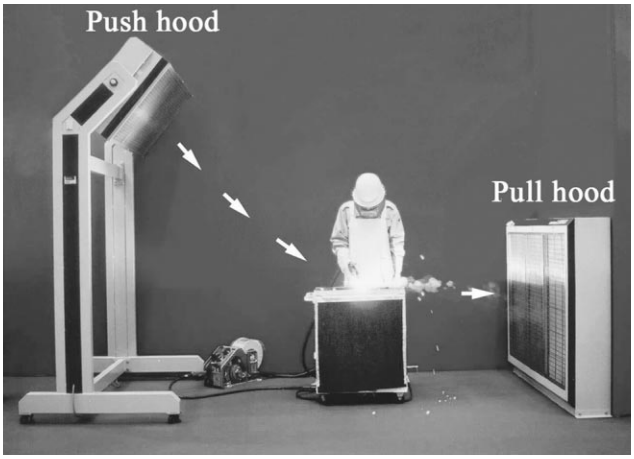

Fig. 9. A push-pull standard unit (WH-01).
It can be settled in welding workshops for ventilation of fumes and gas preventing the occurrence of blow-holes in welded metals.

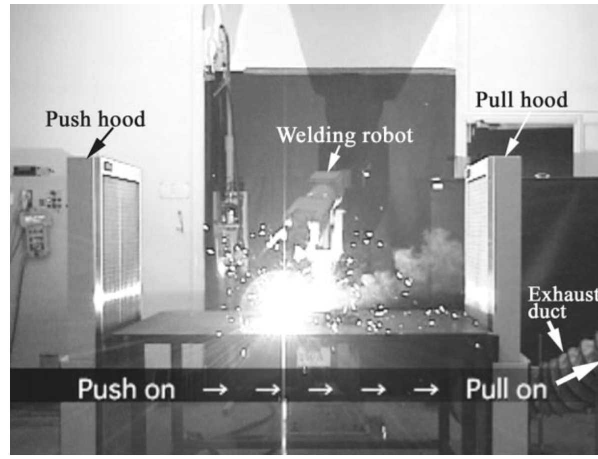

Fig. 10. A push-pull small unit model (MS-01).

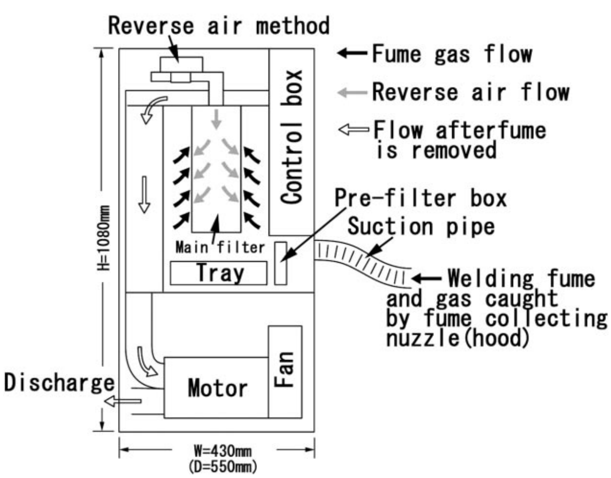

Fig. 11. Structure of welding fume collector.

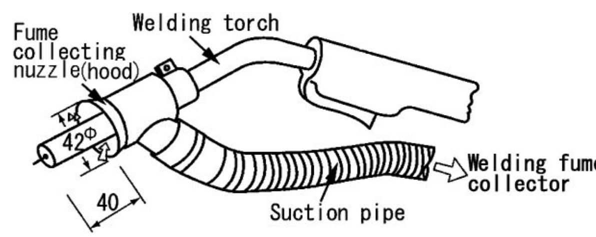

Fig. 12. Fume collecting torch.

21H), and a pull hood (PL-01). The standard unit can be settled for many workplaces, especially for ventilation countermeasures for fumes and gas emitted by welding, for organic solvents by cleaning work, and fine particles emitted by any powder works. Figure 10 shows an example of a small unit model “MS-01” which is applying to a welding robot. The small unit (MS-01) is suitable to use for a light work.

An Example of Fume Collecting Torch (Local Exhaust Ventilation System)

Local exhaust ventilation used for the welding workplace has two systems of fixed type and portable type. Local exhaust ventilation of fixed type is used mainly for countermeasures of the manual welding to a small-sized product. On the other hand, fume collecting torch also classified as a local exhaust ventilation in portable type is used for various automatic (robot) welding machines.

Figure 11 shows the structure of welding fume collector used for a fume collecting torch. A more than 99.86% welding fume is trapped by both pre-filter box of welding fume collector and main filter. A typical type of fume collecting torch installed with a welding torch is shown Fig. 12. The hood shape of fume collecting torch is a bell mouth opening. By this type of hood, almost all fume near the welding torch can be captured. When the welding fume collector was operated with a exhaust air volume 2 m^3/min, the capture velocity near arc point was measured as about 0.5 m/s. Figure 13 shows air velocity distribution near a hood opening of a fume collecting torch. The velocity distribution was obtained by computational fluid dynamics (CFD) analysis based on the velocity measurements around a hood opening of a fume collecting torch. The contour line in Fig. 14 shows a velocity of 0.5 m/s near arc point obtained by the CFD analysis as well. The velocity contour line of 0.5 m/s drawn near arc point was almost coincided

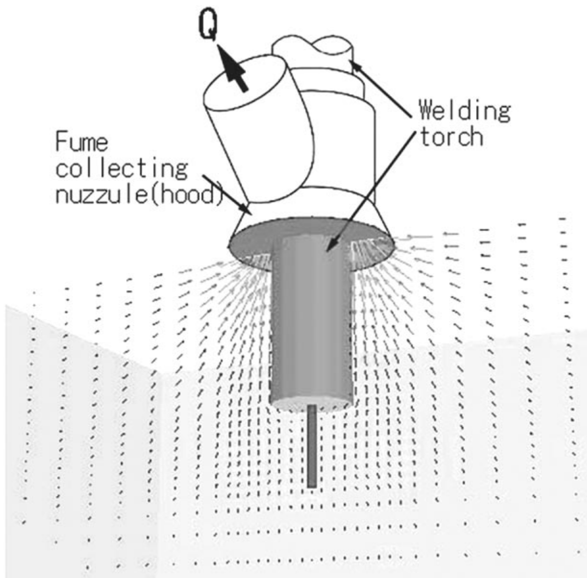

Fig. 13. The velocity distribution near an hood opening of fume collecting torch.

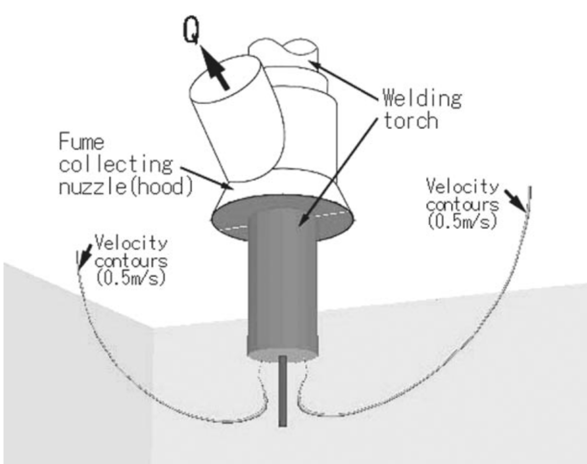

Fig. 14. The velocity contour of 0.5 m/s.

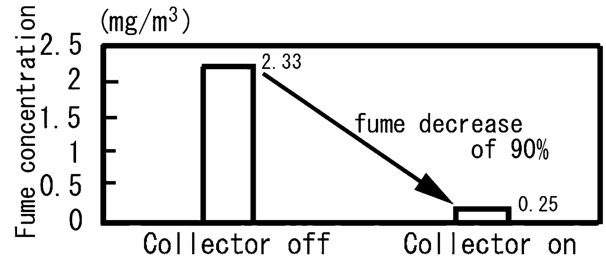

Fig. 15. Effect of fume collecting torch introduction.

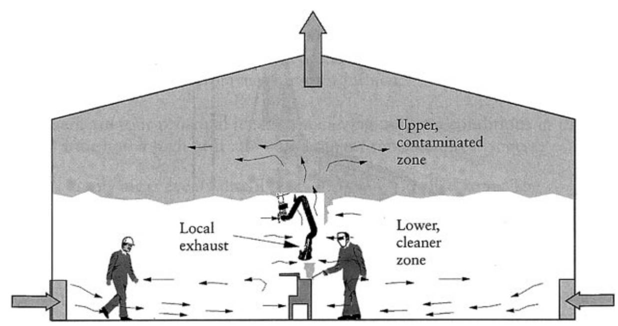

Fig. 16. Displacement ventilation in a welding shop[4].

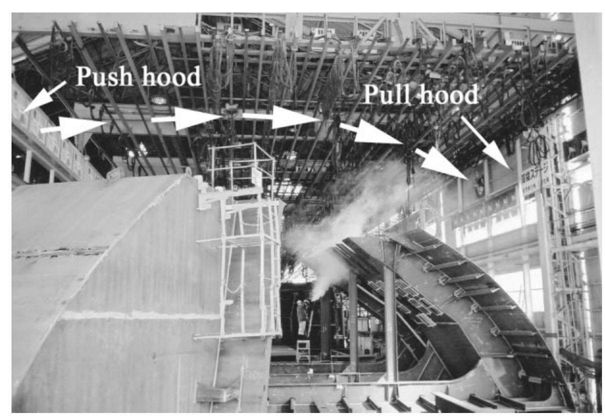

Fig. 17. Push-pull assist zone (PAZ) ventilation in a welding shop.

with the measured value of 0.5 m/s. In addition, by this air velocity, no blow hole was seen in the weld metal.

Being used in the robot welding process at a car manufacturing factory, this fume collecting torch showed an adequate ability of the exhaust control in fume collection. When welding fume collector was not operated, the fume concentration was 2.33 mg/m^3, and when operated it was 0.25 mg/m^3, as shown in Fig. 15. Therefore, a 90% reduction for fume concentration was recognized by the use of such fume collector with welding torch. This will be a satisfiable data under a current technology.

An Example of Push-flow Assist Zone Ventilation (General Ventilation System)

General ventilation is a ventilation method applied to the whole area of a working facility. In general, the ventilation air volume is quite large because the space to be ventilated is large comparing the space where a local exhaust system is used. General ventilation is a dilution method by which the air of a working environment is replaced by clean air and the concentration of airborne substance is decreased. There are a lot of applications of a general ventilation method for the welding workplace. However, to obtain a high efficiency of ventilation, the installation of displacement ventilation system is required. Figure 16 shows an example of displacement ventilation popularly applied to welding workshops in Japan[4].

Recently, the push flow assist zone (PAZ) ventilation became to be settled by which the airborne contamination staying upper part of the room is ventilated by clean air stream by a push and pull hoods for general ventilation of welding workshop in Japan. Figure 17 shows the example of the PAZ ventilation applied to a welding workshop in Japan. The PAZ ventilation system achieved a high efficiency of ventilation compared with the dilution ventilation and displacement ventilation.

Conclusion

The open-type push-pull ventilator is now treated as an equal method to a local exhaust system. The ventilators can produce a highly uniform air stream and they have become smaller overall due to recent advances in technology. The push hood producing a highly uniform air stream has become to be used for a supplement of a non-functioning local exhaust system in control emissions. In addition, a thin, small and compact open-type push-pull ventilator may also be used effectively in many kinds of dusty workplaces where are not defined as a specific dusty work by regulation and a large number of workers facing a risk of respiratory diseases, e.g. arc welding work, cutting and grinding with handheld tools, work places handling organic solvents, and etc. Since the designing method for the open-type push-pull ventilator has not yet been established and they currently rely on experience, some basic researches are anticipated in the future.

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