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Short Communication

Laboratory Evaluation of Carbon Monoxide Exposure in CO_2 Arc Welding

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During metal active gas (MAG) welding process, several chemical and physical emissions such as welding fumes, ozone, nitrogen compounds, and ultraviolet radiation are generated. Carbon monoxide (CO) produced from the shield gas by the action of heat upon the welding flux and slag is one of the hazardous contaminants in CO_2 arc welding (also known as MAG welding). CO is a lethal poison and can overcome the exposed person without warning because it is colorless, tasteless, odorless, and non-irritating. Although CO poisoning of a welder is not as serious as pneumoconiosis due to welding fumes, it is still a common occurrence in Japanese production weld shops.

It is generally known that contaminant concentrations in stationary measurement tend to be appreciably less than those in the breathing zone. This is especially remarkable in the case of welding where the workers are close to the arc points (contaminant sources). Therefore, the exposure of a welder is better evaluated by a personal sampling method rather than by the area sampling method which is prescribed as "A-sampling" in the Japanese Working Environment Measurement Law.

According to former studies, lower concentrations of welding fumes, ozone, nitric oxide and nitric dioxide inside the welding face shield have been found[1–7]. Alpaugh *et al*.[2] suggested that the partially confined space between the welding face shield and a welder's head is a reservoir of relatively pure air, and continues to be an effective barrier to airborne contaminants during arc is struck. Hence, exposure will be overestimated if the sampler is mounted on the lapel or on the shoulder of a welder rather than in the actual breathing zone, inside the face shield. Since little data have been published regarding the true CO exposure level during CO_2 arc welding, the author attempted to compare CO concentrations inside and outside the welding face shield and to determine the extent of CO reduction afforded by the shield.

Methods

CO concentrations inside and outside a welding face shield during CO_2 arc welding were measured by means of an infrared absorption CO meter (Model CO-2, SIBATA SCIENTIFIC TECHNOLOGY Ltd.; Japan) in a laboratory. The experimental set-up is shown in Fig. 1-1. The welding was carried out with an automatic welding robot (ARCMAN-RON, KOBE STEEL Ltd.; Japan) on a 270 mm × 270 mm × 12 mm rolled steel base metal under the following conditions.

welding current: 100 A, 300 A
welding speed: 30 cm/min
filler wire: 1.2 mm ϕ solid wire (JIS Z 3312)
shield gas: CO_2, 20 *l*/min
welding position: flat
arcing time: 90 s
welding execution: bead on plate welding

A manual welding process was simulated by the welding robot and a life-size torso (dummy welder) which was fitted with a standard welding face shield. The distance between the breathing zone of the torso and the base metal was 50 cm. The CO meter was placed beside the torso and aspirated the sample atmosphere through an extended sampling line. In order to remove airborne particles from the sampled atmosphere before its introduction into the CO meter, a filter cassette was attached to the inlet of the sampling line tube. In this study, the sampling points were (1) the breathing zone of the dummy welder inside the face shield; 5 cm to the right of the mouth, and (2) outside of the face shield; on

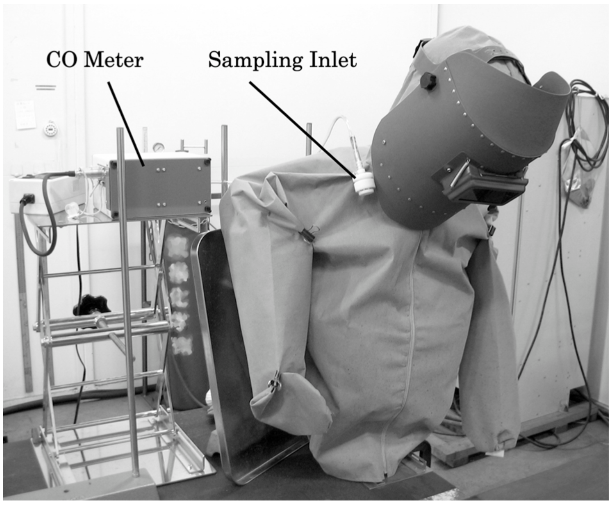

Fig. 1-1. General view of the welding experimental set-up. The sampling inlet of the CO meter is located on the dummy welder's right shoulder in this figure.

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the right shoulder of the dummy welder. The CO concentration was recorded as a time weighted average (TWA) value during the arcing time (90 s). The experimental area of approximately 2 m × 2 m was enclosed by a fire-retarding fabric curtain. A blower which could supply a uniform air flow (Model MS-01 push-hood, KOKEN Ltd.; Japan) was used as a draft generator when the effect of a head draft on CO exposure was evaluated (Fig.1-2). The head draft was regulated to 0.3 m/s at 10 cm above the arc point, and was ascertained by a hot-wire anemometer (Model 6511 CLIMOMASTER, KANOMAX Ltd.; Japan). Another small, portable CO meter (Model XC-2200 gas detector, NEW COSMOS ELECTRIC Co.Ltd.; Japan) which could not record TWA concentration was also used for measuring the maximum instantaneous CO concentration at the breathing zone inside the face shield.

Results and Discussion

The CO concentrations inside and outside the face shield are shown in Table 1. All data are reported as 90 s TWA over the arcing time and given as the geometric mean of twelve repeated tests. Naturally, different welding currents produced different levels of CO emission. In the absence of a head draft toward the welder, the CO concentrations at the actual breathing zone were reduced to 23% of the concentration outside the shield with a welding current of 100 A, and to 12% with a current of 300 A respectively. These reductions were statistically significant, thus a protection effect of the shield for CO exposure was identified. However, when a head draft was blown at the dummy welder from the front, no difference was observed between the CO concentrations inside and outside the shield. This is likely due to the fact that, to some degree, the CO plume tends to ascend along the welder' body and flows behind the shield through the opening between the shield and the chin by the head draft. As a result, the protection effect of the shield is variable and uncertain, and the actual CO exposure cannot be inferred from the concentration measured outside the face shield.

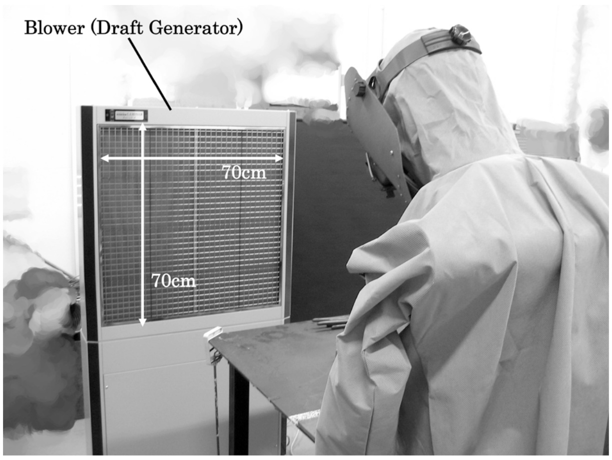

Fig. 1-2. Position of the dummy welder with respect to the blower (draft generator). The blower provides a head draft for the dummy welder. The open face of the blower is 70 cm × 70 cm in size.

In this experiment, a non-breathing dummy welder was used and breathing by an actual welder, which may affect the CO concentration inside the shield, was ignored. However, considering tidal volume and the total volume between the shield and a welder's head, the effect of breathing on the measurements can be considered quite small[1].

Compared with the results of a former study on welder's exposure by the author[8], the reduction of CO exposure provided by the face shield seemed to be less than that of welding fumes. Similar results were observed in the study by Cole *et al*[7]. A definite explanation for the lack of the exposure reduction is difficult, but the hypothesis by Cole *et al*. —the gaseous emissions may be swept farther from the arc and farther from the plume by the shield gas than the heavier particle matter—is suggestive.

The peak CO concentrations at the breathing zone during the arcing time were also measured. Without the head draft, the CO concentration reached 153 ppm at the welding current of 300 A and 58 ppm at 100 A respectively. The CO reached 325 ppm at 300 A when a head draft was blown at the dummy welder from the front.

Table 1. Comparison of carbon monoxide concentrations inside and outside the welding face shield (n=12)

Welding current [A]	Draft	Carbon monoxide concentration [ppm]				Ratio (C_I /C_O)
		Inside shield (C_I)		Outside shield (C_O)		
		GM	GSD	GM	GSD	
100	–	1.6	5.8	7.0	2.7	0.23
300	–	2.1	5.5	17.2	1.6	0.12
300	○	13.8	1.3	13.9	1.2	0.99

Fig. 2-1. Example of personal sampling of CO by means of a direct reading electrical apparatus. The sampling inlet is attached by means of head gear. The welding face shield is removed in this figure.

Fig. 2-2. Example of personal sampling of CO by means of a direct reading electrical apparatus. The welding face shield is in the down position in this figure.

Although the TWA concentrations over the arcing time were less than the Occupational Exposure Limit of CO recommended by the Japan Society for Occupational Health (50 ppm; 8-h TWA), the short-term exposure exceeded 200 ppm, the ceiling limit of CO recommended by the National Institute of Occupational Safety and Health (NIOSH).

In conclusion, a CO sampler should be placed in the welder's breathing zone and inside the face shield when one is worn rather than in the conventional position on the lapel or on the shoulder. International standard (ISO 10882-2; Health and safety in welding and allied processes —Sampling of airborne particles and gases in the operator's breathing zone— Part 2: Sampling of gases) will be instructive to measure welder's CO exposure properly. Just as other gaseous emissions from the welding arc, CO ought to be measured using a direct reading electrical apparatus or a diffusive detector tube. When the electrical apparatus is too large to be set inside the face shield, it should be fastened to a convenient position on the welder's body and the sampled air should be drawn from the breathing zone through an extended sampling tube. An example of the tubing which fulfils this requirement is shown in Figs. 2-1 and 2-2.

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