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Comparison of Welding Fumes Exposure during Standing and Sitting Welder's Position

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Abstract**—**Experimental study was conducted to assess personal welding fumes exposure toward welders during an aluminum metal inert gas (MIG) process. The welding process was carried out by a welding machine attached to a Computer Numerical Control (CNC) workbench. A dummy welder was used to replicate welder during welding works and was attached with sampling pumps and filter cassettes for welding fumes sampling. Direct reading instruments to measure air velocity, humidity, temperature and particulate matter with diameter size 10µm or less (PM_{10}) were located behind the dummy welder and parallel to the neck collar level to make sure the measured welding fumes exposure were not being influenced by other factors. Welding fumes exposure during standing and sitting position with and without the usage of local exhaust ventilation (LEV) was investigated. Welding fume samples were then digested and analyzed by using inductively coupled plasma mass spectroscopy (ICP-MS) according to ASTM D7439-08 method. The results of the study showed the welding fume exposure during sitting was lower compared to standing position. LEV helped reduce aluminum and lead exposure to acceptable levels during standing position. However during sitting position reduction of exposure was smaller. It can be concluded that welder position and the correct positioning of LEV should be implemented for effective exposure reduction.

Keywords**—**ICP-MS, MIG process, personal sampling, welding fumes exposure.

I. Introduction

WELDING is a common industrial process. A hazard that has both acute and long-term chronic effects is welding fume. Fumes are solid particles that originate from welding consumables, the base metal and any coatings present on the base metal. In welding, the intense heat of the arc or flame vaporizes the base metal and electrode coating. This vaporized metal condenses into tiny particles called fumes that can be inhaled. The thermal effects can cause agglomeration of the particles into particle chains and clusters that can be deposited in the human respiratory tract [1]-[3].

Most of the particles in welding fumes are less than 1µm in diameter when produced, but they appear to grow in size with time due to agglomeration [4].

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There are two main acts in Malaysia for occupational and safety; the Factories and Machinery Act (Act 139) [5] and the Malaysian Occupational Safety and Health Act (Act 514) [6]. Department of Occupational Safety and Health (DOSH) is the only government agency responsible for administrating, managing and enforcing legislation pertaining occupational safety and health in Malaysia. It is essential in order to ensure the minimum level of exposure is maintained as required by the prevailing standards. The hazards of welding depends on several factors, 1) type of welding being performed, 2) material the electrode being made, 3) type of material being welded, 4) presence of coatings on the metal, 5) voltage and current used and 6) type of ventilation [7], [8]. Thus, this study was carried out by focusing on the objective of investigating the personal welding fumes exposure towards aluminum MIG welders. In this paper, the personal welding fumes exposure during standing and sitting position with and without the usage of LEV was compared and investigated

II. Related Researches

Research related to welding fumes are diverse into certain areas such as a fume generator for laboratory animal experiments [9], welding fumes morphology and nano particles research [4], [10], [11], welding aerosol sampler design [12], controlled experiment of welding fumes [13], [14], welding fume concentration related to human health [15]-[20] and welding fumes monitoring [21]-[23]. However there is still a limited experimental study related to personal sampling of welding fumes mainly because welders are not a homogeneous group, the potential adverse effect of welding fume exposures is oftentimes difficult to evaluate. Differences exist in welder populations, such as industrial setting, types of ventilation, type of welding processes and materials used [9].

Experimental studies by using dummy, mannequin or also called manikin was carried out by several researchers [13], [24]. The dummy welder was chosen by means to replicate the actual welder's body position in experimental/laboratory works conducted. Reference [13] conducted a laboratory investigation of the concentration of carbon monoxide in the CO_2 arc welding process. The sampling inlet were put inside and outside the face shield for comparison. Reference [24] conducted a study in nickel production industry by comparing the inhalable and the total aerosol exposure between actual worker and dummy welder to prove the usability of dummy welder to predict the actual aerosol exposure.

In our case, the comparison between standing and sitting welder were investigated through laboratory experiment by using dummy welder. Our dummy welder was designed by incorporating the anthropometry data of Malaysian industrial male workers. Interested readers should refer to our publication in [25] for further details.

III. Methodology

The welding was carried out by a welding machine attached to a Computer Numerical Control (CNC) workbench (SG-7090DS) for a programmable welding route. The welding machine was connected to software for monitoring welding parameters such as voltage, current and wire feed speed parameters during each welding route programmed. The welding machine (EWM Hightec Welding) was set to 19 volts with 105 ampere which is suitable for a welding work on a 5 mm aluminum plate (Type 6061 T6). The MIG welding machine used argon gas and AlSi5 (ER4043) wire feed with a diameter of 1.2mm. Personal sampling of welding metal fumes was taken according to the National Institute of Occupational Safety and Health (NIOSH) method by using 0.8 µm cellulose ester membrane filters [26]. Sampling pump connected to sampling media was attached to the breathing zone (0.3m in radius hemisphere extending in front of the human face) or usually on the welder neck collar during sampling. Sampling pump was calibrated and set to 3L/min for each investigation.

During the experiment, a dummy welder was set-up with 20 degrees bending spine posture to replicate standing welder's posture. In sitting position, the spine posture was also adjusted to 20 degrees to replicate welder posture during sitting position. Fig. 1 shows the picture of the experimental set-up during standing position and Fig. 2 shows the position of dummy welder during sitting position. Fig. 3 shows the direct reading instrument (TSI Dustrak Aerosol Monitor type 8520 and TSI Velocicalc type 8386) for measurement of air speed, humidity, temperature and particulate matter size 10µ or less (PM_{10}). The equipments were located approximately 1m behind the dummy welder and 140cm from the floor parallel to the neck collar level to make sure the measured welding fumes exposure were not being influenced by other factors. LEV hood was positioned approximately 70cm above the material being welded.

During the experiment, MIG welding was conducted on an aluminum plate size 12cm wide and 12cm length. The CNC bench was programmed to weld a horizontal line of 8cm in length. Each plate can be weld up to 12 horizontal lines and overall 18 aluminum plate will be used with total of 210 horizontal lines. This welding procedure was repeated for each case investigated. The welding fume sample collected during the experiment was sent to the certified laboratory and analyzed according to ASTM D7439-08 method.

Currently there are only two standard method for determination of elements in airborne particulate matters by using inductively coupled plasma mass spectroscopy (ICP-MS), which is ASTM D7439-08 [27] and BS-ISO 30011:2010 [28]. The samples were tested for 15 elements (Be, Al, Cr, Mn, Fe, Co, Ni, Cu, As, Mo, Ag, Cd, Sb, Pb and Sn).

Due to limitation on the operation of the automatic welding work bench, each experiment duration was approximately 180 to 195 minutes. The calculation of 8 hours time weighted average (TWA) compliance consider only 180 to 195 minutes of exposure and no exposure were consider for the rest of the 8 hours duration.

There are 4 cases investigated in this study; standing welder position with LEV, sitting welder position with LEV, standing welder position without LEV, and sitting welder position without LEV. It is predicted that the usage of LEV will reduce the personal exposure of welding fumes effectively. It is also predicted that different concentrations of exposure was detected prior to welder position.

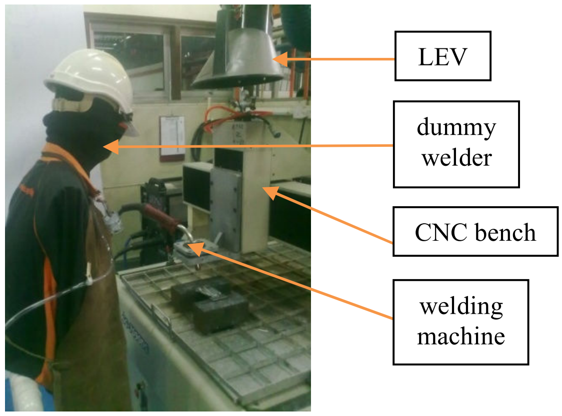

Fig. 1 Experimental set-up during standing position

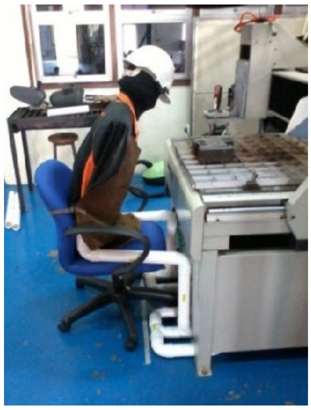

Fig. 2 Dummy welder in sitting position

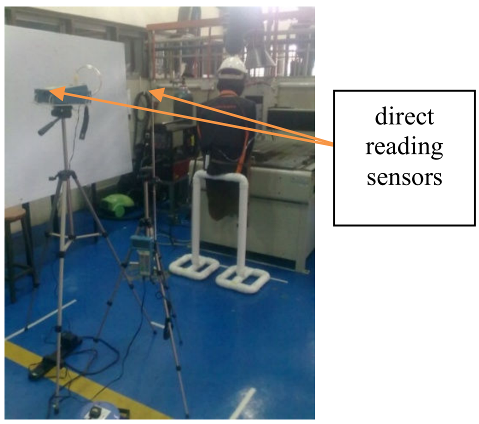

Fig. 3 Direct reading instruments set-up

IV. Results and Discussion

Results from the direct reading instrument were tabulated in Table I. There was significant reduction of PM_{10} during the usage of LEV for both standing and sitting positions. Air velocity was detected during the usage of LEV caused by air suction during LEV operation. There was also slight temperature and humidity difference influence by weather during the experiment conducted.

TABLE I
The Average Reading of Direct Reading Parameters

Position	*LEV*	*Temp. (^oC)*	*Humidity (% rh)*	*Air velocity (m/s)*	*PM_{10} (mg/m^3)*
Standing	Off	30.9	69.1	0.00	0.218
Standing	On	29.6	76.1	0.01	0.043
Sitting	Off	30.9	69.1	0.00	0.218
Sitting	On	30.9	69.6	0.01	0.033

Table II shows the welding fume concentration of three most highest concentration out of 15 elements investigated for each case. These elements show alarming concentration of metals that exceeded the Occupational Safety and Health Association permissible exposure limit (OSHA PEL) within only in 180 to195 minutes duration.

Due to limitation in terms of height and size of automatic welding bench and limited positioning of dummy welder during sitting position, the exposure investigated during sitting position in this study was lower compared to standing position.

During standing and sitting position, LEV helped reduced aluminum, chromium and arsenic concentration. During standing position, the parallel positioning of material being welded, breathing zone and LEV helped reduce welding fumes exposure effectively.

Exposure during sitting position only slightly reduced with the usage of LEV. During sitting position, the breathing zone of the welder were not directly above the material being welded resulting a lower exposure of welding fumes. The usage of LEV was also not effectively reduce the exposure during sitting because the LEV was not put close enough to the welder's breathing zone.

V. Conclusion

Experimental studies were conducted to investigate welding fumes exposure towards welders in an aluminum MIG process. The results from direct reading instrument confirm that the concentration of PM_{10} was reduce significantly (80% to 84%) during the usage of LEV. During personal sampling, the degree of welding fumes exposure during sitting is less compared to exposure during standing position. The usage of LEV was more effective during standing position compared to sitting position. Welder's position and LEV position prior to the material being welded play important part in the reduction of welding fumes exposure.

TABLE II
Welding Fumes Concentration

No	*Element*		*TWA-8hr (mg/m^3)*	*OSHA PEL TWA-8hr (mg/m^3)*
		Standing position without LEV		
1	Aluminum	Al	6.67	5.0 (resp.)
2	Chromium	Cr	2.70	0.5
3	Arsenic	As	0.08	0.01
		Standing position with LEV		
1	Aluminum	Al	0.89	5.0 (resp.)
2	Chromium	Cr	1.17	0.5
3	Arsenic	As	0.07	0.01
		Sitting position without LEV		
1	Aluminum	Al	0.14	5.0 (resp.)
2	Chromium	Cr	1.78	0.5
3	Arsenic	As	0.09	0.01
		Sitting position with LEV		
1	Aluminum	Al	0.03	5.0 (resp.)
2	Chromium	Cr	1.49	0.5
3	Arsenic	As	0.08	0.01

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