Journal of Clean Energy Technologies, Vol. 2, No. 2, April 2014

Pulmonary Function Status among Welders in Malaysian's Automotive Industries

Azian Hariri, N. Azreen Paiman, A. M. Leman, and M. Z. M. Yusof

***Abstract*—Welding process has potential physical and chemical health hazards. Welding fumes, toxic gases and metal particles are the chemical hazard that leads to long-term and chronic lung function effects. This study investigates the effects of duration of exposure and smoking status on pulmonary function status among welders of two automotive assembly plants in Malaysia (Plant 1 and Plant 2). This study assesses 61 male welders by pulmonary function test (PFT) using spirometer. These welders worked with spot, metal inert gas (MIG) and robotic welding without the benefit of fume control ventilation or respiratory protective devices. Welding workers in both plants showed significant reduction in lung function parameters relative to controls. The results of the study also showed that in Plant 1, smoking status influence significantly on pulmonary function status. However, in Plant 2, duration of work and smoking status both influence significantly on welders pulmonary function status. This study provides information to welders on chemical hazard effects among Malaysia's automotive industries.**

***Index Terms*—Pulmonary function test, spirometry, welding process.**

I. Introduction

Welding is the common process in manufacturing industries. Welding involved inhalable exposures that may lead to chronic respiratory disease. In welding, the intense heat of the arc or flame vaporizes the base metal and/or 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]. Toxic gases also produce from welding processes which include nitric oxide, nitrogen dioxide, carbon monoxide and ozone. These toxic gases can cause pulmonary oedema, headache and drowsiness [4].

Researchers have done various works in evaluating the effects of welding chemical hazards to the pulmonary function of welders. However, there are disagreements among these studies mainly due to bias from inclusion and exclusion criteria (smoking status, type of welding process, duration of exposure, ventilation control) [5], [6].

In Malaysia, only limited study had been done. The aim of the present study is to evaluate the pulmonary function status of welders by taking into account the smoking status and duration of exposure. This study provides information for welders and the company's management about the hazards of welding fumes.

Manuscript received April 6, 2013, revised July 4, 2013. This work was financially supported by the Exploratory Research Grant Scheme (ERGS) vote E003 under the Malaysian Ministry of Higher Education (MOHE).

The author are with Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia (e-mail: azian@uthm.edu.my, nuurazreenpaiman@yahoo.com, mutalib@uthm.edu.my, mdzainal@uthm.edu.my).

II. Related Researches

Previous studies had been conducted in evaluating the effect of chemical exposure to the pulmonary function of welders. Some of the studies have shown a reduction of pulmonary function value in welders' population compared to control group [5]-[7].

Reference [8], concludes that smoking and occupational exposure to welding fumes are both associated with increased risk of chronic bronchitis. Reference [9] showed that symptoms of expiratory flow obstruction were more than double in welders compared to non welders. Reference [10] studied on shipyard welders and caulker-burners and concluded that FEV_1 of smoking welder decrease three times greater than non smoking control. Reference [8], [9], [11] suggest that there is a synergistic relation between the effects of smoking and welding causing lung disease and increased respiratory symptom.

On the other hand, differences exist in welder populations, such as industrial setting, types of ventilation, type of welding processes and materials used [12], hence this study was conducted to obtained data on welders working in Malaysian automotive industries. It is expected that a better understanding of welding exposure in Malaysia automotive industry will be obtained in order to promote the protection through legislation, health communications strategies or behavioral intervention where such data are needed.

III. Methodology

Pulmonary function test (PFT) was conducted in two automotive plants in Malaysia. Plant 1 was an automobile assembly plant with 32 welders working on spot welding. Plant 1 operated 8 hours per day with 2 hours overtime work if applicable. All the welders were locals people with 21 welders had been working less than 10 years and 11 welders had been working for more than 10 years. Plant 1 has adequate workstation spacing and plenty of non-barrier free space.

Plant 2 was an automotive parts manufacturer with 29 welders working with spot welding, metal inert gas (MIG) welding and robotic welding. Plant 2 operated 12 hours daily. 90% of the welders were from Nepal, Bangladesh and Indonesia. These welders worked on contract for 2 to 3 years and renew their contract if applicable. Thus, out of 29 welders, only 3 welders worked more than 10 years. The

DOI: 10.7763/JOCET.2014.V2.102

workstation spaces in Plant 2 were cramped and welding area was situated in the middle of the plant surrounded by metal pressing machine.

Welders on both plants worked without the benefit of fume ventilation or proper respiratory protective devices. Fans were located at each work station by means of controlling exposure. From the observation of the condition of workplace area and type of welding process conducted, it is expected that pulmonary function values for welders in Plant 2 is much more decreased compared to Plant 1.

Before conducting PFT, welders were first interviewed on their background information (age, education, working duration, work history, smoking status etc.). PFT were performed on handheld spirometer (Micro Medical DL, UK) connected to spirometer software (Care Fusion, San Diego) on computer. Spirometer was calibrated daily with a 3L calibration syringe. The manoeuvre was explained with the help of short video clip demonstration. Manoeuvre were performed in standing positions without nose clips. Tests were conducted according to forced vital capacity procedure of the American Thoracic Society recommends [13]. Measured parameters were forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1) and peak expiratory flow (PEF) were all expressed as a percentage of the predicted value and FEV_1/FVC ratio. The predicted set used in this study was taken from Pneumobile Project, Indonesia [14].

For controls subjects' purpose, healthy male workers (normal spirometry results) were selected from similar plants that did not have exposure to welding. They were primarily of technicians, engineers and administrators.

Statistical analysis was conducted by SPSS software (SPSS Inc., Chicago version 18). An independent sample t-test was used to compare pulmonary function parameters in welders and control. Linear regression analysis was done to get association between working duration and smoking status with pulmonary function parameters. The level of significance was taken as $p<0.05$.

TABLE I: DESCRIPTIVE STATISTIC FOR PLANT 1

Plant 1						
PFT status	n=32					
normal	21 (64%)					
abnormal	11 (36%)					
	Less than 10 years			More than 10 years		
normal	14 (67%)			7 (64%)		
abnormal	7 (33%)			4 (36%)		
	smoker	ex smoker	non-smoker	smoker	ex smoker	non-smoker
normal	7 (33%)	2 (10%)	5 (24%)	4(37%)	1 (9%)	2(18%)
abnormal	4 (19%)	3 (14%)	0	3(27%)	1 (9%)	0

IV. RESULTS AND DISCUSSIONS

Table I and Table II show the descriptive statistic for Plant 1 and Plant 2 respectively. The descriptive statistic show frequencies and percentage of welder with normal and abnormal PFT results according to duration of work and smoking status. Apparently welders worked less than 10 years in Plant 2 had a higher percentage of abnormal PFT status compare to Plant 1. The non-smoker welders in Plant 2 also have a higher percentage of abnormal PFT status compared to Plant 1. Welder in Plant 2 expose to higher doses of chemical exposure due to different type of welding (spot, MIG and robotic welding) and longer working shift (12 hours) compare to Plant 1.

TABLE II: DESCRIPTIVE STATISTIC FOR PLANT 2

Plant 2						
PFT status	n=29					
normal	14 (48%)					
abnormal	15 (52%)					
	Less than 10 years			More than 10 years		
normal	14 (54%)			0		
abnormal	12 (46%)			3 (100%)		
	smoker	ex smoker	non-smoker	smoker	ex smoker	non-smoker
normal	8(31%)	0	6(23%)	0	0	0
abnormal	5(19%)	1 (4%)	6(23%)	1(33%)	1(33%)	1(33%)

Pulmonary function data (mean ±standard deviation (SD)) of welders for both plants and control groups was analyzed by using independent sample t-test as shown in Table III. Pulmonary function results showed that the mean of all pulmonary function parameters of welders were lower than control. However, the difference of means was significant for FEV_1 (p=0.014) for Plant1 and FVC (p=0.022), FEV_1 (p=<0.001) and PEF (p=0.002) parameters for Plant 2. Results for Plant 2 were consistent with finding by [10]. Reduction of FEV_1, FEV_1/FVC and PEF relative to control indicates an obstructive ventilator defect. Reduction of FEV_1 and PEF can be a sign of airway narrowing or obstruction [5]. Apparently, pulmonary function parameters in Plant 2 are lower than Plant 1 except for FEV_1/FVC indicating welders in Plant 2 was at higher risk of pulmonary function problems.

TABLE III: PULMONARY FUNCTION DATA IN WELDERS AND CONTROLS

Criteria	Controls n=15 (mean±SD)	Case study 1 n=32 (mean±SD)	P-value	Case study 2 n=29 (mean±SD)	P-value
Age (year)	35.2±8.6	29.8±9.2	0.061	31.2±5.6	0.072
FVC (% pred)	91.8±9.3	86.2±14.1	0.169	81.7±14.9	0.022
FEV_1 (% pred)	99.7±10.0	90.0±12.9	0.014	85.5±11.6	<0.001
FEV_1/FVC	108.3±8.1	105.2±7.7	0.205	105.8±10.1	0.404
PEF (% pred)	82.3±8.4	79.5±15.6	0.522	69.14±13.8	0.002

Table IV and Table V show the pulmonary function data (mean ± SD) of welders according to less and more than 10 years of working duration for Plant1 and Plant 2 respectively. The mean value of pulmonary function parameter for both Plant 1 and Plant 2 showed the same trends of decrease mean value of FVC and FEV_1 parameters in more than 10 years working welders. Comparison of means based on working duration was significant for FEV_1/FVC ratio (p=0.027) in Plant 1. However in Plant 2, parameters FVC (p=0.001), FEV_1 (p=0.001) and FEV_1/FVC (p=0.014) show significant mean comparison. Normally the increase value of FEV_1/FVC was associated with a restrictive ventilator effect, however the number of subjects investigated for more than 10 years

working experience was rather small and influence the mean value of FEV_1/FVC parameters. It can only be confirmed by increasing the study size.

TABLE IV: PULMONARY FUNCTION DATA IN LESS AND MORE THAN 10 YEARS WORKING DURATION FOR PLANT 1

Criteria	Less than 10 years n=21 (mean±SD)	More than 10 years n=11 (mean±SD)	P-value
Plant1			
Age (year)	24.5±5.3	39.3±5.9	<0.001
FVC (% pred)	89.1±13.7	80.7±13.9	0.115
FEV_1 (% pred)	91.3±12.7	87.6±13.8	0.458
FEV_1/ FVC	103.1±5.9	109.3±9.3	0.027
PEF (% pred)	80.8±18.0	77.0±9.8	0.540

TABLE V: PULMONARY FUNCTION DATA IN LESS AND MORE THAN 10 YEARS WORKING DURATION FOR PLANT 2

Criteria	Less than 10 years n=26 (mean±SD)	More than 10 years n=3 (mean±SD)	P-value
Plant 2			
Age (year)	30.7±5.5	36.0±4.4	0.122
FVC (% pred)	84.6±12.3	56.7±12.2	0.001
FEV_1 (% pred)	87.8±9.5	66.0±10.8	0.001
FEV_1/ FVC	104.3±9.3	119.0±7.8	0.014
PEF (% pred)	68.0±14.0	79.3±6.0	0.180

Linear regression analysis was as shown in Table VI and Table VII for Plant 1 and Plant 2 respectively. The pulmonary function parameters for Plant 1 welders had significant association with smoking status (FVC (p=0.023), FEV_1 (p= 0.031) and FEV_1/FVC (p=0.02). However, pulmonary function parameters for Plant 2 associate well for both working duration and smoking status for all parameters except for PEF in working duration. This association proves that decreased pulmonary function was directly proportional to the duration of exposure and smoking in Plant 2. However, the decreased pulmonary function was only proportional to smoking in Plant 1. The association between welding exposure duration and decreased pulmonary function were in agreement with other investigation [5], [15]. Previous studies on welders also suggest a cumulative relation between the effects of smoking and welding, hence causing increase respiratory symptom and lung disease [8], [9], [11].

TABLE VI: LINEAR REGRESSION ANALYSIS OF PULMONARY FUNCTION AT PLANT 1

Plant 1		
Criteria	Working duration	Smoking status
	P-value	P-value
FVC (% pred)	0.826	0.023
FEV_1 (% pred)	0.907	0.031
FEV_1/ FVC	0.462	0.002
PEF (% pred)	0.180	0.158

TABLE VII: LINEAR REGRESSION ANALYSIS OF PULMONARY FUNCTION AT PLANT 2

Plant 2		
Criteria	Working duration	Smoking status
	P-value	P-value
FVC (% pred)	0.024	0.002
FEV_1 (% pred)	0.003	0.003
FEV_1/ FVC	0.012	0.001
PEF (% pred)	0.301	0.058

V. CONCLUSION AND FUTURE WORKS

In this study, a comparison was made between pulmonary function parameters of welders and control groups. Results of PFT reveal that welders in both plants suffered from decrease pulmonary function compared to control group. However, obstructive ventilator defect of welders were statistically significant only in Plant 2.

Decreased of mean value of FVC and FEV_1 in more than 10 years welders compare to less than 10 years working welders in both plants were obtained. Conversely the FEV_1/FVC value of both plants increased due to the small size samples of welders for more than 10 years working duration. It is suggested in future works that selection of case study with balance number of samples for low and high exposure welders should be considered for accurate results.

Linear regression analysis of pulmonary function parameters reveals that the decreased pulmonary function was only proportional to smoking in Plant 1 but proportional to duration of exposure and smoking in Plant 2.

It can be concluded that welders in Plant2 were at risk for pulmonary disease due to welding exposure comparing to welders in Plant 1. Thus it is advisable that welders and company management work together to adopt technical preventive and control measures to reduce exposure of welding (using a less hazardous welding agent, installation of local exhaust ventilation, wearing suitable respiratory protective equipment). It is also suggested for the welder to undergo medical surveillance tests periodically.

ACKNOWLEDGMENT

The authors gratefully acknowledge the cooperation given by the company management and all the welders that had took part in this study.

REFERENCES

[1] H. S. Ashby, "Welding fumes in the workplace: preventing potential health problems through proactive controls," *Professional Safety,* pp. 55-60, 2002.
[2] E. Ravert, "Controlling chromium fumes," *Welding Journal,* 2006.
[3] S. R. Fiore, "Reducing exposure to hexavalent chromium in welding fumes," *Welding Journal*, pp. 38-43, 2006.
[4] J. Blunt and N. C. Balchin, *Health and Safety in Welding and Allied Processes*, Cambridge: Woodhead Publishing Limited, 2000.
[5] S. A. Meo, M. A. Azeem, and M. M. Subhan, "Lung function in Pakistani welding workers," *J Occup Environ Med*, vol. 45, pp. 1068-1073, 2003.
[6] S. A. Sharifian, Z. Loukzadeh, A. Shojaoddiny-Ardekani, and O. Aminian, "Pulmonary Adverse effects of welding fume in automotive assembly welders," *Acta Medica Iranica,* vol. 49, pp. 98-102, 2010.

[7] Z. Loukzadeh, S. A. Sharifian, O. Aminian, and A. Shojaoddiny-Ardekani, "Pulmonary effects of spot welding in automobile assembly," *Occupational Medicine*, vol. 59, pp. 267-269, 2009.
[8] M. Holm, J.-L. Kim, L. Lilienberg, T. Storaas, R. Jogi, C. Svanes, V. Schlunssen, B. Forsberg, T. Gislason, C. Janson, and K. Toren, "Incidence and prevelence of chronic bronchitis: impact of smoking and welding. The RHINE Study," *Int J of Tuberc Lu*ng, pp. 553-557, Dis. 2012.
[9] L. M. Bradshaw, D. Fishwick, T. Slater, and N. Pearce, "Chronic bronchitis, work related respiratory symptom, and pulmonary function in welders in New Zealand," *Occup Environ Med*, vol. 55, pp. 150-154, 1998.
[10] D. J. Chinn, I. C. Stevenson, and J. T. Cotes, "Longitudinal respiratory survey of shipyard workers: Effects of trade and atopic status," *Br J Ind Med*, vol. 47, pp. 83-90, 1990.
[11] A. J. Jafari and M. J. Assari, "Respiratory effects from work related exposure to welding fumes in Hamadan, Iran," *Arch Environ Health*, vol. 59, pp. 116-120, 2004.
[12] J. M. Antonini, A. A. Afshari, S. Stone, B. Chen, D. Schwegler-Berry, W. G. Fletcher, W. T. Goldsmith, K. H. Vandestouwe, W. McKinney, V. Castranova, and D. G. Frazer, "Design, construction, and characterization of a novel robotic welding fume generator and inhalation exposure system for laboratory animals," *Journal of Occupational and Environmental Hygiene*, vol. 3, pp. 194-203, 2006.
[13] M. Miller, J. Hankinson, V. Brusasco, F. Burgos, R. Casaburi, A. Coates, R. Crapo, P. Enright, C. Van der Grinten, P. Gustafsson, R. Jensen, D. Johnson, N. MacIntyre, R. McKay, D. Navajas, O. Pedersen, R. Pellegrino, G. Viegi, and J. Wanger, "Standardisation of spirometry," *European Respiratory Journal*, vol. 26, pp.319-338, 2005.
[14] I. Boehringer, Pneumobile Project, Indonesia, 1992.
[15] J. C. J. Luo, K. H. Hsu and W. S. Shen, "Pulmonary function abnormalities and airway irritation symptoms of metal fumes exposure on automobile spot welders," *American Journal of Industrial Medicine*, vol. 49, pp. 407-416, 2006.

Azian Hariri was born in Perak, Malaysia on 27 August 1978. Holds a B. Eng (Mechanical) from University of Fukui, Japan in 2002 and M.Eng (Mechanical) from Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor in 2009.

She had experience working in electronics company as a mechanical engineers for one years before appointed as an Instructor Engineer at Faculty of Engineering Technology, Kolej Universiti Tun Hussein Onn, Batu Pahat, Johor. She is now a lecturer in Department of Plant and Automotives, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor and on study leave for a PhD. at the same institution. Current research interests include Indoor Environment Quality, Industrial Hygiene and Occupational Safety and Health.