Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 68 (2013) 299 – 304
Procedia Engineering
www.elsevier.com/locate/procedia
ELSEVIER

The Malaysian International Tribology Conference 2013, MITC2013

Pulmonary Adverse Effects of Weld Bonding Process by Malaysia's Automobile Assembly Welders

Azian Hariri[a]*, N. Azreen P.[a], A.M. Leman[b], M.Z.M. Yusof [a]

[a]*Faculty of Mechanical and Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia.*
[b]*Faculty of Technology Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia.*

Abstract

Spot welding adhesives were largely used in vehicle bodywork construction. Currently, spot welding adhesives process or also known as weld bonding process was the effective solution for improving mechanical properties of metal joining. However, it also created issues in occupational safety and health. Previous study confirmed notably higher airborne contaminants were detected prior to usage of welding adhesive. This study was conducted to investigate the personal welding fumes exposure and pulmonary function of welders involved in the weld bonding process. Welding fumes analysis revealed out of 15 investigated elements, none were exceeding the threshold limits for both spot and weld bonding processes. Pulmonary function tests (PFT) were conducted by using hand held spirometer to 15 control group, 11 spot welders and 19 weld bonding welders. Result of the study shows a significant mean difference of pulmonary functions values in investigated welder groups. Weld bonding welders had the lowest mean pulmonary functions values compare to other groups. Statistical analysis reveals that the pulmonary function of spot welders were affected significantly by number of smoking years but not significantly affected to duration of exposure. However, weld bonding welders pulmonary functions values were not significantly affected neither by smoking years nor working durations. It is suggested for future works to include the airborne contaminant monitoring of toxic gases for further understanding of weld bonding process on safety and health effects towards welders.

Selection and peer-review under responsibility of The Malaysian Tribology Society (MYTRIBOS), Department of Mechanical Engineering, Universiti Malaya, 50603 Kuala Lumpur, Malaysia

Keywords: Weld bonding process; pulmonary function effects; spot weld adhesive; Malaysian welder

Nomenclature

FEV	Forced expiratory volume
FVC	Forced vital capacity
ND	Not detected
PEF	Peak expiratory flow
PFT	Pulmonary function test

* Corresponding author. Tel.: +0-607-453-7880 ; fax: +0-607-453-6080.
E-mail address: azian@uthm.edu.my

1877-7058 © 2013 The Authors. Published by Elsevier Ltd.
Selection and peer-review under responsibility of The Malaysian Tribology Society (MYTRIBOS), Department of Mechanical Engineering, Universiti Malaya, 50603 Kuala Lumpur, Malaysia
doi:10.1016/j.proeng.2013.12.183

PM	Particulates matter
SD	Standard deviation
Subscripts	
1	in one second
10	up to 10 micrometer size

1. Introduction

The most common method for joining automobile components is spot welding. Spot welding cannot be used on the flat visible sides such as bonnet, boot, door and roof panels because this would result in unpleasant points and require time-consuming filling for repair works. The use of adhesive to solve this problem was introduced in order to join the components together and the number of welding points was reduced to a small number at the edges. Currently welding adhesives process or also known as weld bonding process was used on a large scale for vehicle bodywork construction. Previous researchers studied the fatigue behavior of steel single lap joints by adhesive bonding, conventional spot welding, and weld-bonding processes. They found that the weld-bonding joints prepared at optimum process parameters had superior mechanical properties than others especially under fatigue loading conditions [1-3]. The stress concentration, fatigue performance, corrosion problem and tearing strength of the joints was significantly improved by the application of adhesive [4].

In area of industrial tribology, fluid aerosol generated in metalworking operations had been the interesting subject of occupational safety and health studies [5, 6]. On the other hand, there were limited studies done in the investigation on effects of the usage of adhesive along with spot welding towards welders in automobile industries. Although weld bonding process improved mechanical properties of metal joining, unfortunately it also creates issues in occupational safety and health. In experimental study conducted by previous researchers, the level of benzene and 1,3 butadiene were notably higher in experimental study of weld bonding process compared to spot weld process [7]. According to National Institute of Safety and Health (NIOSH) (U.S) Programmed portfolio for lung effects of resistance spot welding using adhesives, some chemicals that are associated with adhesives used in resistance welding were detected in the air of the plant that have the potential to cause respiratory illness, including asthma and bronchitis. Little information exists about the composition and characterization of aerosols generated during resistance spot welding of metals treated with different adhesives and anti-slag agents [8]. Thus, this study was conducted to investigate fumes composition and the pulmonary function of welders involved in weld bonding process compare to the spot welding process in the same plant.

2. Methodology

The investigation was conducted in an automobile assembly plant with 30 welders. 11 of the welders worked on spot welding and 19 of the welders worked on weld bonding process. The plant operated 8 hours per day with 2 hours overtime work if applicable. There were 3 main assembly lines in the plant. Assembly line A and B consist of spot weld and weld bonding process while assembly line C only worked on weld bonding processes. Line A and B consist of 22 welders, while line C consist of 8 welders. Three type of adhesive were used SH-300-T, Z67-2 and S-340-1 for all assembly lines. For control subjects' purpose, male workers that did not exposed to welding processes were selected from similar workplace. Only 15 male workers were available as controls. They were primarily of technicians, engineers and administrators. The investigated plant had adequate workstation spacing and plenty of non-barrier free space. Welders worked without the benefit of fume ventilation or proper respiratory protective devices. Fans were located at each work station by means of controlling exposure.

Personal sampling of welding fumes were done by locating sampling head within the breathing zone (hemisphere (generally accepted to be 0.3 m in radius) extending in front of the human face, centred on a midpoint of a line joining the ears; the base of the hemisphere is a plane through this line, the top of the head and the larynx [9]. At least one employee in ten in a properly selected homogeneous group performing similar tasks [10]. The filters media (mixed cellulose ester 0.8 μm pore sizes) were analyzed by using ICP-MS with microwave digestion method for sample preparation according to the availability of these facilities in the certified laboratory. 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 [11] and BS-ISO 30011:2010 [12]. According to ASTM D7439-08 method, the microwave digestion method proved to be more effective on investigated elements compared to BS-ISO 30011:2010. Thus, ASTM D7439-08 method was chosen as the analysis method to identify the existence of 15 elements in the welding fumes sample. Samples were delivered to the accredited laboratory for analysis.

In Malaysia, Under the Occupational Safety and Health Act 1994, Use and Standards of Exposure of Chemical Hazardous to Health regulation (USECHH) were commenced on 4 April 2000 [13]. This regulation listed down the chemical classified hazardous to health with its permissible emission limits (PEL) that need to be comply by the employer. The concentrations were calculated in time weighted average 8 hours (TWA 8).

Pulmonary Function Test (PFT) were performed on handheld spirometer (Micro Medical DL, UK) connected to spirometer software (Care Fusion, San Diego) in notebook computer. Spirometer was calibrated daily with a 3L calibration syringe. The maneuver was explained with the help of short video clip demonstration. Maneuver was performed in sitting positions with nose clips. Tests were conducted according to forced vital capacity procedure of the American Thoracic Society recommends [14]. 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 [15].

Statistical analysis was conducted by SPPS software version 18 (SPSS Inc., Chicago). Analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) was used to compare mean pulmonary function values in spot welding welders, weld bonding welders and control. Pearson correlation analysis was done to get association between working duration and smoking status with pulmonary function values. Further analysis using linear regression was done to confirm the predictors of the pulmonary functions. The level of significance was taken as $p<0.05$.

3. Results and discussions

Table 1 showed the highest metal fumes concentration collected in the breathing zone of the welders. From 15 elements analyzed, none of the elements exceeded the TWA 8 PEL. Iron was the highest concentration detected with 0.849 mg/m^3. Nickel and tin elements were below the detection limit of analysis.

Table 1. Exposure concentration in spot weld and weld bonding processes

No.	Parameter	Symbol	Spot Weld	Weld Bond	USECHH PEL
			TWA 8 (mg/m3)	TWA 8 (mg/m3)	
1	Beryllium	Be	0.000	0.000	0.002, C 0.005
2	Aluminum	Al	0.018	0.020	5.0 (resp.), 15.0 (total)
3	Chromium	Cr	0.009	0.011	0.5
4	Manganese	Mn	0.006	0.000	0.2
5	Iron	Fe	0.633	0.027	5
6	Cobalt	Co	0.000	0.000	0.1
7	Nickel	Ni	ND*	ND*	1.5
8	Copper	Cu	0.003	0.002	0.2
9	Arsenic	As	0.002	0.003	0.01
10	Molybdenum	Mo	0.000	0.000	5 (soluble), 10(total insoluble)
11	Silver	Ag	0.001	0.000	0.1
12	Antimony	Sb	0.000	0.000	0.5

13	Cadmium	Cd	0.000	0.000	0.01, 0.002 (resp)
14	Lead	Pb	0.000	0.001	0.05
15	Tin	Sn	ND*	ND*	2

ND*: not detected

Table 2 shows the descriptive statistic for the investigated automobile assembly plant. The descriptive statistic showed frequencies and percentage of welder with normal and abnormal PFT results according to type of welding, duration of work and smoking status. Apparently weld bonding welders suffered higher percentage of abnormal PFT results (36.8%) compared to spot weld welders (27.3%). However, less than 10 years working weld bonding welders shows the highest percentage of abnormal PFT results (41.7%). This was due to the higher percentage of smoker in this group. Previous studies on welders also suggest a cumulative relation between the effects of smoking and welding, hence causing increase respiratory symptom and lung disease [16-18].

Table 2. Descriptive statistic of pulmonary function test (PFT) status results

PFT status	**Number of welder:30**											
normal	20 (67%)											
abnormal	10 (33%)											
Type of welding	**Spot weld**						**Weld bonding**					
normal	8 (72.7%)						12 (63.2%)					
abnormal	3 (27.3%)						7 (36.8%)					
Work duration	**Less than 10 years**			**More than 10 years**			**Less than 10 years**			**More than 10 years**		
normal	6 (75%)			2 (66.7%)			7 (58.3%)			5 (71.4%)		
abnormal	2 (25%)			1 (33.3%)			5 (41.7%)			2 (28.6%)		
Smoking status	**smoker**	**ex**	**non**	**smoker**	**ex**	**non**	**smoker**	**ex**	**non**	**smoker**	**ex**	**non**
normal	4 (66.7%)	1 (100%)	1 (100%)	2 (66.7%)	0 (0%)	0 (0%)	2 (33.3%)	1 (100%)	4 (80%)	2 (66.7%)	1 (50%)	2 (100%)
abnormal	2 (33.3%)	0 (0%)	0 (0%)	1 (33.3%)	0 (0%)	0 (0%)	4 66.7%)	0 (0%)	1 (20%)	1 (33.3%)	1 (50%)	0 (0%)

Pulmonary function data (mean ±standard deviation (SD)) of welders and control groups was shown in Table 3. Apparently pulmonary function results showed that the mean of all pulmonary function parameters of weld bonding welders were lower than control group and spot welder. The multivariate MANOVA analysis reveal there was a significant mean difference of pulmonary function values between welder groups $F(4,40)=4.95$, $p < .05$. Reduction of FEV_1, FEV_1/FVC and PEF relative to control indicates sign of airway narrowing or obstructive ventilator defect [19].

Table 3. Mean values for control, spot weld and weld bonding groups

Criteria	**Control n=15 (mean±SD)**	**Spot weld n=11 (mean±SD)**	**Weld bonding n=19 (mean±SD)**
FVC (% pred)	91.80±9.34	89.00±12.87	86.16±13.15
FEV_1 (% pred)	99.67±9.98	95.73±12.12	88.00±10.38
FEV_1/FVC	108.33±8.10	107.36±7.99	103.42±7.55
PEF (% pred)	82.33±8.41	81.00±14.16	78.68±16.75

Table 4 shows the correlation between pulmonary functions with working and smoking years in both welders groups. Pearson correlation reveals there was significant relationship between the increased of FEV1/FVC towards number of smoking years(r= .07, p (one tailed) < .001) and working duration(r= .78, p (one tailed) < .01) in spot welders. However, further analysis by multiple regressions confirmed number of smoking years contributes 74% of the variance in FEV1/FVC. Number of smoking years was also the significant predictor to the increase values of FEV1/FVC, (t (8) =3.03, p < .05). Meanwhile for weld bonding welders, Pearson correlation reveals there was no significant relationship between the pulmonary functions towards number of smoking years and working duration for weld bonding welders. Further analysis by multiple regressions revealed neither smoking years nor working duration were the significant predictors of the pulmonary functions.

Table 4: Pearson correlation between pulmonary functions with working and smoking years in welders

Spot welders				
	FVC	**FEV1**	**FEV1/FVC**	**PEF**
Number of working years	-.42 Ns	-.09 Ns	.78**	-.17 Ns
Number of smoking years	-.22 Ns	.24 Ns	.07***	.02 Ns
Weld bonding welders				
	FVC	**FEV1**	**FEV1/FVC**	**PEF**
Number of working years	-.07 Ns	.10 Ns	.24 Ns	-.17 Ns
Number of smoking years	-.37 Ns	-.34 Ns	.04 Ns	-.22 Ns

Ns=not significant (p>.05), *p<.05, **p<0.01, ***p<.001

4. Conclusion and future works

In this study, the welding fumes personal exposures were well below the threshold regulatory limits. The weld bonding fumes exposures were slightly higher than spot welding fumes exposure in aluminum, chromium, arsenic and lead elements. Thus, significant multivariate differences of mean pulmonary function values between all welder groups were obtained and weld bonding welders mean pulmonary function values were the lowest compared to other groups.

On the basis of our research finding, the pulmonary function values were not significantly affected by neither the number of smoking year nor working duration for weld bonding welder. However, for spot welder, the number of smoking years affected the pulmonary functions values significantly. Results of the study suggested that working duration (exposure duration) were not significantly affected the pulmonary functions values. These finding was in the same agreement with the lower personal sampling exposure of both spot and weld bonding welders groups.

Thus, several sources of bias could explain the results of this study such as the effect of harmful toxic gases associated with welding was not taken into consideration. On top of this, lifetime exposure of welding fumes and toxic gases among welders could not be measured accurately. Thus, it is suggested for future works to consider the personal sampling of harmful toxic gases to weld bonding welder groups.

Acknowledgements

This work was supported by the Exploratory Research Grant Scheme (ERGS) vote E003 under the Malaysian Ministry of Higher Education (MOHE). The authors gratefully acknowledge the cooperation given by the company management and all the welders that had took part in this study.

References

1. Ghosh, P.K., Vivek, 2003.Weldbonding of stainless steel, ISIJ International, 43(1): p. 85-94.
2. Ghosh, P.K., Balaram, M., 2005. Improvement in spot weld properties of steel sheet by weld bonding using particulate composite adhesive, Transactions of the Indian Institute of Metals, 58(1): p. 115-131.

3. Abdel Wahab, M.M., 2012. Fatigue in Adhesively Bonded Joints: A Review, ISRN Materials Science, p. 25.
4. Chang, B.H., 1999. A study on the Role of Adhesives in Weld-Bonded Joints, Welding Research Supplement, p. 275.
5. Sharma, B.C., Gandhi O.P, 2008. Safety assessment of lubricating oil using AHP and vector projection method, Industrial Lubrication and Tribology, 60(5): p. 259-265.
6. Park, D., 2012. The Occupational Exposure Limit for Fluid Aerosol Generated in Metalworking Operations: Limitations and Recommendations Safety and Health at Work, 3: p. 1-10.
7. TWI Limited, Fume Emissions from Resistance Welding Through Adhesives and Sealants, in Health and Safety Executive Contract Research Report, 2001.
8. NIOSH Program Portfolio: Lung Effects of Resistance Spot Welding Using Adhesives, 2010.
9. British Standard, BS EN ISO 10882-1:2001 Health and Safety in Welding and Allied Processes: Sampling of Airborne Particles and Gases in the Operator's Breathing Zone : Part 1: Sampling of Airborne Particles, 2001.
10. British Standard, BS EN 689:1996 Workplace Atmospheres Guidance for the Assessment of Exposure by Inhalation to Chemical Agents for Comparison with Limit Values and Measurement Strategy, 1996.
11. ASTM, Determination of Elements in Airborne Particulate Matter by Inductively Coupled Plasma-Mass Spectrometry, 2008.
12. British Standard, BS-ISO 30011:2010 Workplace Air-Determination of Metals and Metalloids in Airborne Particulate Matter by Inductively Coupled Plasma Mass Spectrometry, 2010.
13. Malaysia, Department of Occupational Safety and Health (Use and Standards of Exposure to Chemical Hazardous to Health) (USECHH) Regulation (P.U. (A) 131), 2000.
14. Miller, M., Hankinson, J., Brusasco, V., Burgos, F., Casaburi, R., Coates, A.., Crapo, R.., Enright, P., Van der Grinten, C., Gustafsson, P., Jensen, R., Johnson, D., MacIntyre, N., McKay, R., Navajas, D., Pedersen, O., Pellegrino, R., Viegi, G., Wanger, J., 2005. Standardisation of Spirometry, European Respiratory Journal, 26: p. 319-338.
15. Ingelheim Boehringer, Pneumobile Project, Indonesia, 1992.
16. Holm, M., Kim, J-L. Lilienberg L., Storaas, T., Jogi, R., Svanes, C. , Schlunssen, V., Forsberg, B., Gislason, T., Janson, C., Toren. K., 2012. Incidence and Prevelence of Chronic Bronchitis: Impact of Smoking and Welding. The RHINE Study, Int J of Tuberc Lung Dis, 16(4): p. 553-557.
17. Jafari, A.J., Assari, M.J. 2004. Respiratory Effects from Work Related Exposure to Welding Fumes in Hamadan, Iran, Arch Environ Health, 59(3): p. 116-120.
18. Bradshaw, L.M., Fishwick, D., Slater, T., Pearce, N., 1998. Chronic Bronchitis, Work Related Respiratory Symptom, and Pulmonary Function in Welders in New Zealand. Occup Environ Med, 55(3): p. 150-154.
19. Meo, S.A., Azeem, M.A., Subhan, M.M.,2003. Lung Function in Pakistani Welding Workers, J Occup Environ Med, 45(10): p. 1068-1073.