ISSN: 0975-766X
CODEN: IJPTFI
Research Article

Available Online through
www.ijptonline.com

INVESTIGATION OF FSW-ENVIRONMENTAL BENEFITS

D.Muruganandam, A.Abdul Rahman
Assistant Professor, Department of Production Engineering, Sri Sairam Engineering College, Chennai-44.
Professor, Department of Mechanical Engineering, Sri Sairam Engineering College, Chennai-44.
Email: murudurai@gmail.com

Received on 22-12-2015 *Accepted on 18-01-2016*

Abstract

Friction Stir Welding (FSW) was tested under certain environmental conditions in order to confirm the environmental advantages of the welder's health. The present study focuses on the demerits that are present in the arc and gas welding methods. The hazards caused due to arc and gas welding can be overcome by local exhaust ventilation and special respiratory equipments as a protective measure. But still this could only minimize the problems and could not eliminate the health hazards. This paper presents the various disorders caused from different welding processes and its characteristics features have been recorded. A methodology is developed for eco welding process based on over all energy consumption and possibility of the green house gas reduction.

Keywords: Friction stir welding, unconventional welding techniques, statistical data, eco - welding, green house gas reduction.

1. Introduction

The term fusion welding is a process when metals are heated to the temperature at which metal melt and are then joined without hammering or application of pressure and joints are formed without application of filler metal, usually in the form of wire or rod. Filler material has the same composition as the parent metal but may contain alloying metals to improve fluidity in the molten condition or to produce fine grain structure. Such coating perform more functions. As a flux removes oxides and then distributing the substances it improves weldability and protect welding against extra influences. It is known that welding has been identified as an high risking activity which results in the impact of health hazards on welders.

Several welders have been identified with health disorders in the community of welders. When the welders are exposed to ultraviolet radiations it affects the welders irrespective of age group ranges from 16 to 80 years. It is also reported that blind eyes of welders with pigmentary and maculopathy accounting for the single case of bilateral blindness. Hunnicutt *et al.,* (1964) precludes that pinguecula, pterygium, corneal opacity and pigmentary macular degeneration were the common eye disorders among welders and also determined spirometric measurements which was helpful to identify the symptoms of the lungs.

Although eye disorders were the early detection from the welders health point, yet the hazards gaseous materials in the form of oxides cost respiratory symptoms and pulmonary function among welders (Fogh A et al, 1969). Pulmonary test were conducted in shipyard welders report provids earlier finding of diseases is due to pulmonary disorders among the welders (Peter J M *et al.,* 1973).

It is perceived that the environmental condition of the welder working in the shipyard is different when compared to the welder working in the accessible land. It may be suggested that the composition of air, wind and its velocity are known to be responsible a role in the health aspect of the welder, durning welding direction. Welding workers suffer from non-pulmonary health problems such as eye irritation, photokeratitis, cataract, skin irritation, erythema, pterygium, non-melanocytic skin cancer, malignant melanoma, reduced sperm count, motility and infertility [Sultan A M and Thamir A K, 2003].Many such pulmonary problems are usually attributed to these toxic fumes and gases. Lung cancer, occupational asthma, rhinitis, cough, dyspnea, obstructive and restrictive lung disease, pneumoconiosis, lung function impairment and pneumonia are among the most frequent respiratory problems due to welding process have also been documented [Antonini J M and Taylor M D, 2004].

However, controversy remains about whether manganese as a raw material when exposed to workers have increased risk of developing idiopathic parkinson disease (PD) and whether the associated neurobehavioral and neurological signs and symptoms constitute early manifestations of manganese needs to be ascertained [Levy B S *et al.,* 2003]. Antonini J M *et al.,* (2006) developed an animal model and studied the welding fume inhalation while reviewing the causes it raises exposure of potential neurotoxic effects. Santamaria A B *et al.,* (2007) investigated whether exposure to manganese posed any neurological risk and raised unsolved problems in the welding. As per Gallagher R P *et al.,* (2006) artificial ultraviolet radiation from welding increases the risk of cortical cataract, conjunctival neoplasms, and ocular melanoma. The impact of ultraviolet radiation caused adverse effects on the vision.

However according to a study by Xu Y *et al.,* (2012) ultraviolet radiation produced during welding operations also affects the auxiliary workers involved in other operations. Like manganese, it is suggested that nickel metal compounds during welding and electroplating can also cause skin irritation, lung fibrosis, and the metal fumes produces lung cancer and associated diseases [Zhao J *et al.,* 2009]. As per the study of Wittczak T *et al.,* (2009) the metal fumes responsible for metal fume fever, bronchial asthma, chronic obstructive airway disease, pneumoconiosis, and lung cancer.

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 [NIOSH Program Portfolio, 2010].

Wise S S *et al.,* (2008) studied hexavalent chromium-induced DNA damage and repair mechanisms leading eventually to neoplastic deformation. Chronic occupational exposure to hexavalent chromium causes DNA damage in electroplating workers [Zhang X H *et al.,* 2011].

A comparison between the weld bonding fumes exposures were found to be 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 [Azian Hariri N *et al.,* 2013].

A retrospective database was collected from 1985 to 2008 with 4155 male shipwrecking employees on Kaohsiung Ship breaking Workers Union. This cohort was linked to the Taiwan Cancer Registry from 1985 to 2008 and determined cancer incidence was due to asbestos exposure. Mesothelioma cases were found due to inhalations asbestos containing smoke from welding processes [Wu W T *et al.,* 2014].

Although several authors worked on the various aspects of physical, chemical, ergonomic and psychological, organizational factors and providing evidence cost due to welding fumes affecting the eyes, nervous system, pulmonary system and even skin irritation in various age group of welders, yet the technology is wanted to remove such health hazards among welders. The present paper describes the methodology adopted to overcome the health hazards of welders.

In the present study, it is found that FSW resulted in approximately 31% less green house emission gas results Co_2 due to the solid state nature of the FSW process when compared to the welding (Oxhoj H *et al.,* 1979).

The study further supports to the overall energy consumed in joining and pre and post processing for FSW is less than when compared to the other welding (Sevcik M et.al., 1960).

2. Materials And Methods

Friction stir welding (FSW) is capable of fabricating either butt or lap joints, in a wide range of materials thickness and lengths. During FSW, heat is generated by rubbing a non-consumable tool on the substrate intended for joining and by the deformation produced by passing a tool through the material being joined. The rotating tool creates volumetric heating, so as the tool is progressed, a continuous joint is created. FSW, like other types of friction welds, is largely solid state in nature. As a result, friction stir welds are not susceptible to solidification related defects that may hinder other fusion welding processes. The FSW process is diagrammed in Fig 1. The parts intended for joining are usually arranged in a butt configuration. The rotating tool is then brought into contact with the work pieces. The tool has two basic components: the probe, which protrudes from the lower surface of the tool, and the shoulder, which is relatively large diameter.

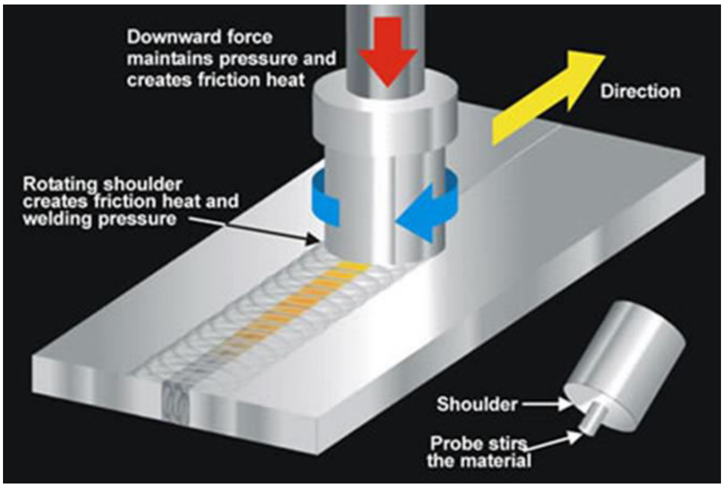


Fig-1: Diagrammatic representations of the friction stir welding.

The length of the probe is typically designed to match closely the thickness of the work pieces. Welding is initiated by first plunging the rotating probe into the work pieces until the shoulder is in close contact with the component top surface. Friction heat is generated as the rotating shoulder rubs on the top surface under an applied force. When sufficient heat is generated and conducted into the work piece, the rotating tool is propelled forward. Material is softened by the heating action one limitation of the FSW process is mechanical stability of the tool at operating temperature. During FSW, the tool is responsible for not only heating the substrate material to forging temperatures, but also providing the mechanical action of forging. Therefore, tool material is said to be capable of sustaining high forging loads and temperatures in contact with the deforming substrate material without either excessive wear or deformation of the shoulder, and transported by the probe across the bond line, facilitating the joint. The base material composition is listed in the Table 1.

Table.1 Chemical composition for the Aluminium and Magnesium alloys (Base metals).

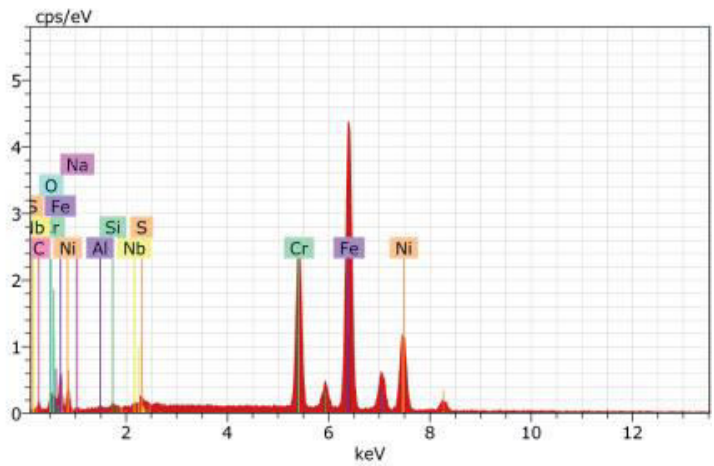
Element	Si (%)	Fe (%)	Cu (%)	Mn (%)	Ni (%)	Cr (%)	Mg (%)	Al (%)	Others (%)
AA 6061	0.6	0.5	0.3	0.1	0.04	0.3	1.0	96.2	0.96
AZ 61	0.1	0.005	0.05	0.15	0.005	-	92.29	6.2	1.2

3. Results:

The EDX analysis of the collected MAG and TIG particles showed that the most dominant elements by mass in particles from MAG were Fe (40-60% w/w), O (about 30 % w/w), C (5-20% w/w) and Mn (5-10% w/w). Most of the carbonaceous particles were found in the smallest particles, and the decrease in C with increasing particle diameter explains the observed increase in Fe and Mn content, and also O_2. Oxygen is present due to the formation of oxides of Fe and Mn. The results for TIG were quite different in composition, as the most abundant elements found from TIG welding were Mn (15-35% w/w), C (15-50% w/w), O (20- 30% w/w), K (3-7% w/w), and W (1-3% w/w) [Fuglsang K *et al.,* 2011]

The Gas Tungsten Arc welding of Inconel 625 subjected to SEM/EDAX analysis is shown in Fig. 2. In Fig 2(a), the dominating Fe and Ni elements forms islands on the as welded zones. The weld zone and the HAZ of Inconel 625 have been enriched with Ni, Cr, Mo and Nb and the presence of the elements such as Fe, Al, and Ti was also being noticed as per Fig 2(b). The domination of Ni leads to irritating respiratory track, renal dysfunction, dermatitis, pneumoconiosis, central nervous system and lung damage, cancer. The equivalent dominations of the hexavalent chromium insoluble compounds also causes intoxication, , liver, kidney, and respiratory cancer [Mithilesh P *et al.,* 2014]

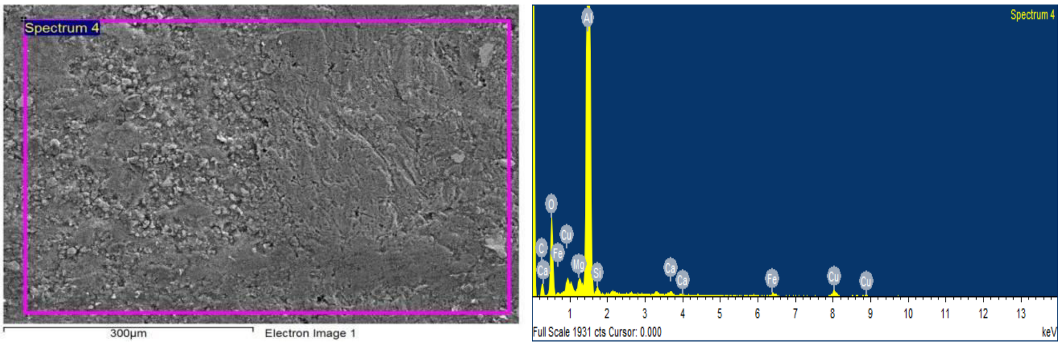
(a)



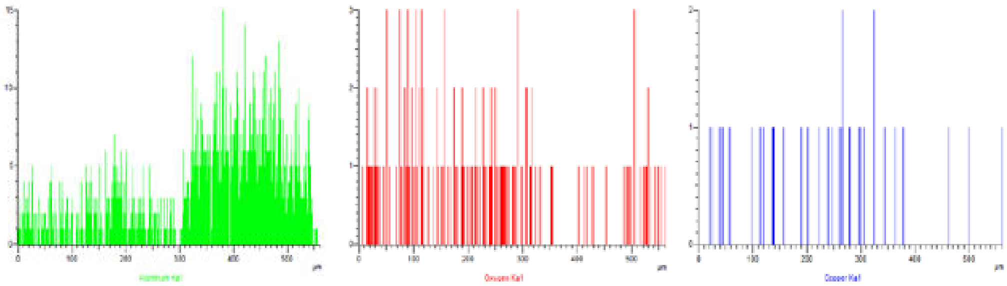
(b)

Fig.2. (a) SEM analysis on the composite region of the weldment in the as-welded conditions and (b) EDAX analysis on the composite region of the weldment in the as-welded conditions [Mithilesh P *et al.,* 2014].

From Fig. 3 (a), the SEM image represents fine grains which is a indication of uniformity of all elements. The element contribution is further analysed with EDAX on Fig 3(b) that the aluminium element is dominant one and there is no presence of hazardous manganese which leads to neurological risk and only the oxygen is the second dominant. As respiratory symptoms are caused by oxides on formation of fumes, it is required further to investigate the oxygen has any chemical reaction to form hazardous oxides. Fig 3(c) to 3(e) aluminium, oxygen and copper. The energy dispersion of oxygen reveals that it is having unifrom energy flucutuation and hence less chance of forming the oxides.



(a) (b)



(c) (d) (e)

Fig.3. (a) SEM analysis (b) EDAX analysis (c) energy dispersions of aluminium (d) energy dispersions of oxygen (e) energy dispersions of copper for the FSW butt joint of AA6061-AZ61.

Table-2: Life cycle impact assessment.

Impact category	**Category indicator**	**Product system**	
		Present study result	**Result referred**
Acidification	Moles of H	2.7	3.9 (Oxhoj. H
Ecotoxicity	Kg 2.4-Deg	2.1	2.8 (*ibid*)
Eutrophication	Kg N	8 x 10^4	11 x 10^{-4} (*ibid*)
Global warming	Kg co2 – Eq	6.8	9.8 (*ibid*)

Ozone depletion	Kg cfc-11 Eq	1.7×10^{-7}	2.4×10^{-2} (*ibid*)
Photo chemical ozone formulation	Kg No Eq	1.7×10^{-2}	2.5×10^{-2} (*ibid*)

Table-3: Comparison of green house gas such as Co_2 between FSW and GMAW.

Product System	FSW (kg Co_2 eq)	GMAW (kg Co_2 eq)
Aluminium	6.72	9.51
Electricity	0.05	0.09
Electrode Wire	-	0.22
Shielding Gas	-	0.002
Total	6.78	9.82

4. Conclusions

During the process of welding (FSW), seven parameters were taken into consideration and the impact assessment was also reported for (GMAW) (Oxhoj *et al.,* 1979). The results indicate that when compared to (GMAW), the impact is significantly low in FSW [Table 2]. It is due to the less green house emission and the overall less energy consumption during the process. It is inferred from the study that the product system between (FSW) and (GMAW) are consistently lower suggesting that the emission of green house gases such as carbon dioxide is low 6.72 kg Co_2 eq for Aluminimum in FSW compared to 9.51 kg Co_2 eq in GMAW (Oxhoj *loc.cil*). The result strengthens the findings on the conceptualization of the eco welding process as FSW and is more advantages in terms of its energy consumption and GHG emission.

References

1. Antonini J M, Taylor M D, Zimmer AT (2004), Pulmonary responses to welding fumes: Role of metal Contituents. J Toxicol Environ Health; 67(3):233-249.
2. Antonini J M, Callaghan J P, Miller D B (2006), Development of an animal model to study the potential neurotoxic effects associated with welding fume inhalation. Neurotoxicol; 27:745-751.
3. Azian Hariri N. Azreen P, Leman A M, Yusuf M Z M (2013), Pulmonary adverse effects of weld bonding process by malaysia's automobile assembly welders, procedia Engineering 68 299 – 304.
4. Fogh A, Frost J, and Georg J (1969), Respiratory symptoms and pulmonary function in welders. Ann Occupy Hyg; 12:213-218.

5. Fuglsang K, Gram L K, Markussen J B and Kristensen J K (2011), Measurement of ultrafine particles in emissions from welding processes, 16th International Conference on Joining of Materials, Elsinore, Denmark, 1-11.
6. Gallagher R P, and Lee T K (2006), Adverse effects of ultraviolet radiation: A brief review. Prog Bio physics Molecular Biology 92:119-131.
7. Hunnicutt J R, Cracovaner D J, Myles J T (1964), Spiro metric measurements in welders. Arch Environ Health ; 8:661-669.
8. Levy B S, and Nassetta W J (2003), Neurologic effects of manganese in humans: a review.Int J Occup Environ Health; 9:153-163.
9. Mithilesh P, Varun D, Ajay Reddy Gopi Reddy, Devendranath Ramkumar K, Arivazhagan N, Narayanan S (2014), Investigations on Dissimilar Weldments of Inconel 625 and AISI 304, Procedia Engineering 75, 66 – 70.
10. Muruganandam D (2014), Studies on Mechanical Properties of Friction stir welded dissimilar joints over AA7075 and AA 2024 Age Hardenable Aluminium Alloys.PhD thesis. University of Sathyabama, Chennai, India.
11. Muruganandam D (2014), Health Hazards due to various welding techniques and its remedy by friction stir welding(FSW).IJRAME 2,3:96-101.
12. NIOSH Program Portfolio (2010), Lung Effects of Resistance Spot Welding Using Adhesives.
13. Oxhoj H, Bake B, Wedel H, and Wilhelmsen L (1979), Effects of electric arc welding on ventilatory lung function. Arch Environ Health; 34:211-217.
14. Peters J M, Murphy R L H, Ferris B G, Burgess W A, Ranadive M V, and Perdegrass H P (1973), Pulmonary function in shipyard welders. Arch Environ Health 1973; 26:28-31.
15. Sevcik M, Chalupa B, Klhufkova E, and Hrazdira C L (1960), Injuries to health in electric welders, Zentralbl Arbeitsmed 10: 77–82.
16. Sultan A M, and Thamir A K (2003), Health hazards of welding fumes. Saudi Med J ; 24(11):1176-1182.
17. Santamaria A B, Cushing C A, Antonini J M, Finley B L, and Mowat F S (2007), State-of-the-Science Review: does manganese exposure during welding pose a neurological risk? J Tox Environ Health Part B 2007; 10:417-465.

18. Wise S S, Holmes A L, and Wise J P (2008), Hexavalent chromium-induced DNA damage and repair mechanisms. Rev Environ. Health; 23:39-57.
19. Wu W T, Lin Y J, and Shiue H S (2014), Cancer incidence of Taiwanese ship breaking workers who have been potentially exposed to asbestos. Environ Res; 132:370-378.
20. Wittczak T, Walusiak J, and Paczyñski C (2009), Welding-related respiratory diseases. Med Pr ; 60: 201-208.
21. Xu Y, Gong M M, Wang J, and He L H, Wang S and Du W W (2012), Investigation of occupational hazards of ultraviolet radiation and protective measures for workers in electric welding. Beijing Da Xue Xue Bao; 44:448-453.
22. Zhang X H, Zhang X, Wang X C, Jin L F, Yang Z P, and Jiang C X (2011), Chronic occupational exposure to hexavalent chromium causes DNA damage in electroplating workers. BMC Public Health; 11:224.
23. Zhao J, Shi X, Castranova V, and Ding M (2009), Occupational toxicology of nickel and nickel compounds. J Environ Pathol Toxicol Oncol ; 28:177-208.

Corresponding Author:

D. Muruganandam,

Email: *murudurai@gmail.com*