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OCCUPATIONAL HEALTH AND SAFETY ASSESSMENT OF EMISSIONS OF CUTTING AND GOUGING ELECTRODES USED IN TURKISH SHIPYARDS

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Abstract: *Welding is the most widely used joining process in shipyards to join shipbuilding sheet metals and stiffener members. SAW, GMAW and SMAW processes are highly utilized in shipyards. Covered electrodes are employed not only in welding but sometimes also in gouging and cutting. Arc welding and cutting processes form fume emissions and as a consequence, welders are exposed to an assorted mixture of toxic particulates and noxious gases and these are believed to put a large number of workers at increased risk of adverse health effects. Welding has been associated with many respiratory problems, which vary from acute or chronic respiratory symptoms, such as malaise, cough, chronic bronchitis, asthma to lung cancer. Many epidemiologic studies demonstrate that welding workers have high risk of cancer. In this study, some experiments with regard to fume formation rate have been realized and results have been assessed in terms of occupational health and safety.*
Key-words: *cutting, gouging, electrode, emission, shipyard, FFR, welding fume*

1. INTRODUCTION

Most of the “World Sea Trade” is held by sea transportation. Therefore shipyard and shipbuilding industry is quite crucial throughout the world. Shipbuilding industry is named as a heavy industry due to complexity, the big size or the size and weight of the used hardware and the equipment within the ships built[1]. In shipbuilding and repair industry, welding is the most common and highly employed joining technique and is of utmost importance to sector.

Welding is considered a dangerous occupation because: (1) there are multiplicity of factors that can endanger the health of a welder, such as heat, burns, radiation, noise, fumes, gases, and electrocution; and (2) the high variability in chemical composition of welding fumes which differs according to the work piece, method employed, and surrounding environment. The particulates and gases generated during welding are considered to be the most harmful in comparison with the other byproducts of welding [2].

There are many risks associated with welding. Radiation from the arc may cause eye and skin damage. In addition, gases and respirable particles in the welding environment contain chemicals that can create adverse side effects after inhalation, if delivered in the appropriate dose and chemical state. A major source of respirable particles is welding fume [3]. Several irritant gases, such as carbon dioxide (CO_2), carbon monoxide (CO), ozone (O_3), and oxides of nitrogen (NxO), may be generated in significant quantities during common arc welding processes due to different shielding gases and fluxes used [1].

Hazardous metals listed in the 1990 Clean Air Act Amendments that have been detected in welding fume include manganese, nickel, chromium, cobalt and lead[4]**.** These fumes and gases containing cobalt (Co), silica (Si), manganese (Mn), chromium (Cr), nickel (Ni), magnesium (Mg), zinc (Zn), and copper (Cu) are capable of causing several pulmonary diseases and neurological damage[1].

Over the past 40 years, numerous studies have evaluated the health effects of welding. Most studies have focused on the pulmonary effects associated with welding fume exposure. Bronchitis, metal fume fever, lung function changes, siderosis, immunosuppression, and a possible increase in the incidence of lung cancer have all been reported in welders [5]. Both chromium and nickel have been classified as human carcinogens. Exposure to high levels of manganese has caused neurological disorders in workers involved in the mining and processing of manganese ores. Hexavalent chromium has been designated as a priority pollutant due to its ability to cause genetic mutations and cancer [1].

Welding fume particles are less than 1 µm, that is, 0.001 mm in diameter, when formed, but they appear to grow in size with time due to particles sticking together, i.e.agglomeration. Cadmium oxide fume on inhalation may cause acute irritation of the respiratory passages, bronchitis, chemical pneumonia or excessive fluid in the lung tissues (pulmonary oedema). A single exposure to a very high concentration of cadmium oxide fume may be fatal. Chronic cadmium poisoning results in damage to lungs and kidneys.Exposure to fume from welding on manganese steel may give rise to acute inflammation of the lungs. Metal fume fever is also a possibility after exposure to manganese fume. Chronic manganese poisoning, characterized by a severe disorder of the nervous system, has been reported in welders working in confined spaces on high-manganese steels [6].

Most welding involves ferrous materials.Welding fume particles less than 1 mm in diameter constitute the greatest health hazard because of their ability to penetrate deep into the lungs, and because they are not readily cleared by the cilia lining the respiratory tract[7]. Particulate matter and particulate-phase hazardous air pollutants are the major concerns in the welding processes. Only electric arc welding generates these pollutants in substantial quantities. The lower operating temperatures of other welding processes cause less fume to be released. Most of the particulate matter produced by welding is submicron in size and, as such, is considered to be all PM-10. The elemental composition of the fume varies with the electrode type and chemical composition of the work piece[8]. The three major subdivisions of the respiratory tract include the nasal/head airways, the tracheo-bronchial region, and the alveolar or pulmonary region. Manganism is a neurological syndrome that resembles Parkinson’s disease, but there is considerable evidence that manganese preferentially damages different areas of the brain from those that are affected in Parkinson’s disease. Fate of manganese associated with the inhalation of welding fumes: Potential neurological effects [9].

In addition to welding fumes, metal cutting operations, which are commonly used in ship scrapping, generate air emissions that contain particulate matter, heavy metals, metal ions, oxides of nitrogen, carbon monoxide, and ozone. Metal cutting is a sort of process that melts the metal down, like welding. Although the effect of metal cutting on human health is not as serious as the effect of welding fumes, it should not be neglected [1]**.**

2. EXPERIMENTAL STUDY

Air arc cutting and gouging of St 52 (thickness 20 mm) carbon steel base metal (chemical composition in table 1) were realized for copper coated cutting and gouging electrodes, which are widely used in shipyards, in order to define fume formation rate (FFR). Glass fiber filters from Staplex, U.S.A. (type TFAGF810) were utilized to capture cutting and gouging fume. A rectifier power supply from GekaMac with output range up to 650A and rated output 500A with %60 duty cycle was used. Electrodes were polarized DCEN (direct current electrode negative) andcopper coated cutting electrodes and gouging electrodes were 10 mm and 5 mm in diameters, respectively.

Table 1. Chemical composition of St 52 carbon steel

Material	% C (max)	% Mn (max)	% Si (max)	% P (max)	% S (max)
St 52	0.2	1.7	0.50	0.03	0.03

In experiments AWS F1.2:1999 standard [10] was followed and first, filters were conditioned at 100°C in a drying oven for 1 hour and then weighed using MettlerAE200 balance with a capacity of 200 g and readability of $1x10^{-4}$ g. Filters before fume formation rate experiments are shown in figure 1. After weighing filters, cutting and gouging electrodes were weighed as well (figure 2).

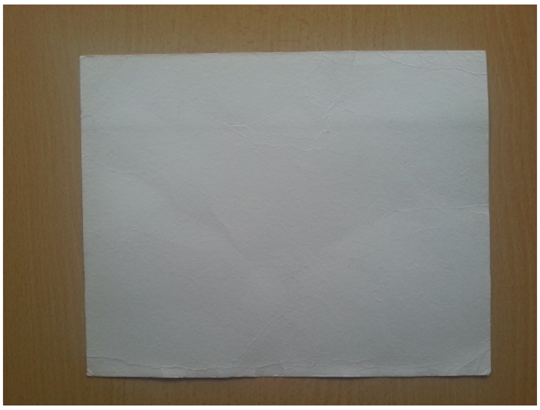

Figure 1. Glass fiber filters before experiments

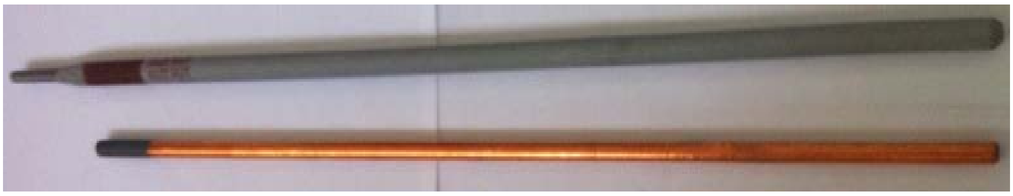

Figure 2. Cutting (lower) and gouging (upper) electrodes before experiments

Two different current settings were set for the experiments, one representing a relatively low and other representing a relatively high heat input. Current settings stayed within the recommended current range given by the manufacturer and mean current and voltage values seen in rectifier’s digital indicators, were recorded. Before starting each experiment, filter was placed in a fume chamber (figure 3) and ventilation system was initiated and then stopwatch was started when the arc stroke. Schematic procedures for cutting and gouging electrodes are given in figure 4 and figure 5.Cutting or gouging was conducted for 30 seconds and then fume chamber was left for another 30 seconds to be cleaned up by exhaust system.

Figure 3. Fume chamber

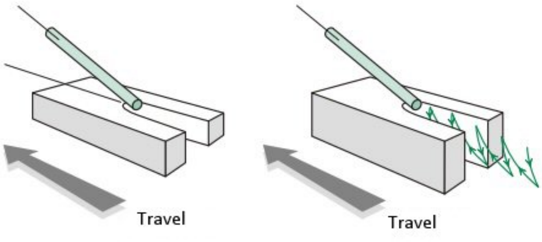

Figure 4. Schematic representation for cutting procedure [11]

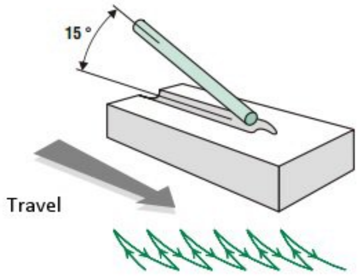

Figure 5. Schematic representation for gouging procedure [12]

Each experiment was repeated three times and when all the experiments were done, filters were conditioned again in the same conditions and reweighed.Filters after cutting or gouging is shown in figure 6. After cooling down the electrodes, they were weighed for a final weight (figure 7). After the measurements, fume formation rate and % fume for electrodes were calculated using AWS F1.2:1999 standard.

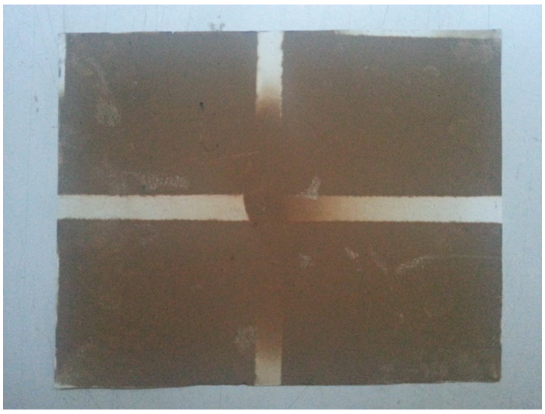

Figure 6. Filters after experiments

Figure 7. Cutting (left) and gouging (right) electrodes after experiments

3. RESULTS AND DISCUSSION

Fume formation rate was expressed as the weight of the fume that accumulated on the glass fiber filter per minute; whilst % fume was expressed as the ratio of the weight difference of final and initial filter weights to weight difference of initial and final consumable weights and is given as the mean value of three tests [10]. Results for FFR and % fume results of cutting and gouging electrodes for relatively high energy input are summarized in table 2. As it is derived from table 2, even with the considerably lower energy input (around 19% less), gouging electrodes exhale more fume (around 83% more). Unlike this, % fume is greater with cutting electrodes.

Table 2.FFR and % fume results of cutting and gouging electrodes for relatively high energy input

Electrode	FFR (g/min)	% Fume	Mean Current Intensity (A)	Mean Arc Voltage (V)
Cutting	0,121	0,95	452	51
Gouging	0,222	0,215	340	55

Comparison of the influence of energy inputs on FFR and % fume for gouging electrodes is given in table 3. It can be stated that relatively higher energy results in higher fume formation and this is parallel to % fume amount. Increase in energy input around 19% led to an increase in FFR around 68%.

Table 3. Comparison of the influence of energy inputs on FFR and % fume for gouging electrodes

Electrode	FFR (g/min)	% Fume	Mean Current Intensity (A)	Mean Arc Voltage (V)
Gouging (low energy input)	0,132	0,133	303	52
Gouging (high energy input)	0,222	0,215	340	55

4. CONCLUSION

Welding is a major joining technique for ships and it highly utilized in shipyards. Cutting and gouging with electrodes is one of the most used thermal cutting processes in heavy industry, i.e. shipyards. Welding is highly associated with fume formation, which is not only harmful to worker's health but the environment. Many welders experience bronchitis, metal fume fever, lung function changes, and an increase in the incidence of lung infection. It has been suggested that welding fume exposure increases lung cancer risk in welders.

Experiments showed that cutting and gouging electrodes exhaled less fume (maximum of 0.222 g/min) compared to welding with covered electrodes. Sowardset. al [13] pursued FFR test with E6010 electrodes and they obtained FFR around 0.6 g/min for high heat input. Especially during welding, cutting and gouging, blasting and painting processes, personal protective equipment (PPE) usage is required for shipyard workers. Surface preparation operations present a significant risk for skin, eye, and respiratory exposure to toxic and corrosive chemicals, as well as risk of burns, cuts, and lacerations. Each welding or cutting operation, depending on the materials welded or cut and the type of welding method has specific safety and health hazards from which workers must be avoided. Hot work performed on surfaces containing lead, cadmium, or mercury requires an air-line respirator to be used if local exhaust ventilation is not provided or effective.Although cutting and gouging operations do not exhale as much fume as welding with covered electrodes, necessary safety precautions must be met since these operations are still detrimental to human health.

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