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DESIGN AND PERFORMANCE ANALYSIS FOR WELDING FUMES EXTRACTION SYSTEM

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ABSTRACT

During Welding operation, the fumes and metallic gases are emitted from the work piece, which cause the pollution and hazard to workers, when gases were inhaled or ingested. This usually cause respiratory effects such as lung disease, bronchitis and possible of lung cancer. This paper deals with the designing of fume extraction system and evaluate the performance such as efficiency of the system, filtration capacity, and environmental friendly, during the welding process. Primarily, the purpose of the analysis of the welding fume extractor is to ensure that the system installed meet the minimum ventilation requirement of building regulation and the challenges pose by welding fumes to welders in the workshop. Investigation shows that extractor fan is characterized by high pressure, medium flow and continuous power increase, very suitable for handling dust-laden, moist air/gases and heavy contaminated airstreams. The machine is safe and easy to operate and does not require any technical training. Welding fume is hazardous to welding shop occupants therefore; there is the need to remove it so that health hazard will be reduced. Performance analysis shows that the flow rate is 0.5940 m^3/s, and the density of air is 1.225kg/s.

Keywords: Welding Fumes, Performance Analysis, Ventilation, CO, SO2, WFE.

I. INTRODUCTION

Joining of two similar metals dates back to several millennia which are called forge welding from Bronze Age. Welding was used in the construction of iron pillar in India, erected about 310AD and weighing 5.4 metric tons. The middle ages brought advances in forge welding in which blacksmiths pounded heated metals repeatedly until bounding occur. World War caused a major surge in welding processes, with various military powers attempting to determine which of the several new welding processes would be the best. During the 1920's major advances were made in welding technology. Shielding gas welding became a subject receiving much attention as Scientists and Engineers attempt to protect welds from the effect of oxygen and nitrogen in the atmosphere. In 1942, the Linde Company obtained a license to develop the Gas Tunsgsten-arc (GTAW or TIG), process used today (Rayond, 1984). The use of aluminum and magnesium by industries increased at a rapid rate as a result of the development of GTAW (TIG). Welding is a fabrication or sculptural process that joins materials, usually metals and thermoplastic, by causing fusion. Welding fumes are not good for health. Welding fumes and grinding dust are produced during welding and grinding in the workshop. While all fumes are bad, some fumes are recognized as more hazardous than others. One of such fumes is hexavalent chromium, which is produced when welding of stainless steel and other materials containing chromium. During welding process the chromium is heated, oxidation occur and it is converted into hexavalent chromium.

Hexavalent chromium is also designated by Chromium vi, Hexchromium, Cr (iv), Chromium +6 and Cr+6. It is classified as a carcinogen. There are other elements present in some welding fumes, such as manganese, that is very harmful to the welder, trainee welders (students), and others in the welding shop (Merger et al, 1994).

The Occupational Safety and Health Administration (OSHA) regulation requires that employers must assess their worker exposure to hexavalent chromium for a time weighted 8-hours average (8-hour TWA) for each work area and for welding activities is that space (OSHA, 1990). If the level is 50% greater than Permissible Exposure Level (PEL), the space must be 9monitored every six months. If the employee can demonstrate that the fumes for the space are less than 10% of the PEL, monitoring does not have to be performed.

Local exhaust ventilation is an engineering system to protect operators from hazardous substances (Yuth et al, 2017). To have an effective system it is important that all it is well designed and installed, used correctly and properly maintained. To ensure that the quality of welding fumes and grinding dust remain below legal limit, a high quality extracting system with effective stack exhaust is a necessity. Welding is the process of joining two similar or dissimilar metals by fusion, with or without the application of pressure and with or without the use of filler metals. The fusion that of metals that take place is by means of heat. The heat may be obtained from blacksmith five, electric, arc, electrical resistance or by chemical reactions. Welding is extensively used in fabrication as an alternative method for casting or forging and as a replacement bolted on oriented join. Welding can be traced to the historical development back in ancient times. The earliest examples of this come from Bronze and Iron Ages in Europe and the Middle East. The Middle Ages brought about advances in forge welding, in which blacksmiths, pounded heated metal repeatedly until bonding occur in 1800 Sir Humphry Davy discovered the "short-pulse" electrical arc and presented result in 1801. Resistance welding was developed during the final decades in 19th century, with the first patents going to Eliha Thomson in 1885. World War 1 caused a major surge in the use of welding processes, with the various military powers attempting to determine which of the several new welding processes would be the best. Recent developments is welding include 1958 breakthrough of electron beam welding, making deep and narrow welding possible through the concentrated heat source. Magnetic Pulse Welding (MPW) is industrially used since 1967. Friction stir welding was invented in 1991 by Wayne Thomas at the welding institute (UK), and found high – quality application all over the world. International health organization recognizes the importance of preventing health risk associated with welding fumes generated during welding processes. In many countries strict personal exposure regulations and standards such as Occupational Safety and Health Administration (OSHA) are heavily enforced to minimize workers exposure to hazardous metal particulate that can be present in welding fumes (WHO, 1987). Ventilation is the primary solution step to mitigate employee welding fume exposure. Because welding fumes is a thermal process, the particulate is suspended in the ambient air. When fumes plume cools, the particulate settles on the work place. It built up on the work station infiltrates machinery and electrical cabinets, which can cause additional housekeeping to clean up the dust. Control of the exposure to welding fumes can usually be achieved with the help of extraction and ventilation. The choice of technique depends on the circumstance. The aim is to capture the welding fumes as does as to the source as possible. This protects not only the work but also other workers stand machinery. Extraction at source is the most effective method of capturing and removing welding and similar fumes using this method the risk of a welder or operator being subject to hazardous fumes is minimized. Welding touch with integrated extraction allow the welder to work over large areas as well as inside partially enclosed space. It reduces heating and cooling cost by reducing the amount of heath/cooled air extracted from the premises letting the extraction system to run when not in use is a big waste of energy. Not only to the fan motor energy, but cost of heating or cooling make-up air, to replace the air exhausted outside. The major health risks with welding fumes are:

a. Cancer of the lungs
b. Brain damage
c. Neurological diseases
d. Decreased lung capacity
e. Pneumonia
f. Asthma
g. Allergies etc (Chandra et al, 1984).

Extreme care must be taken when welding or cutting some materials because of possible health hazards. Care must be taken when welding or cutting the materials listed below, along with their sources, can present possible health hazards it not controlled.

Table 1: Sources of Possible Health Hazards

Material	Source	Possible Health Hazard
Arsenic	Electrode coating, fluxes, base metal	Lung, lymphatic cancer, respiratory irritant
Beryllium	Base metal	Lung cancer
Cadmium oxide	Plating of steel	Lung cancer, and kidney disorder
Chromium	Electrode coating – stainless steel	Lung cancer, skin disorder
Copper fumes	Wire coating- non-ferrous metal	Fume fever

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Fluoride	Coating and flux core of electrode, flux	Kidney and bone disorder
Lead	Electrode coating, lead paint	System poisoning
Manganese	Welding rod, alloy steel	Nervous system disorder
Molybdenum	Welding rod, alloy steel	Respiratory disorder
Nickel	stainless steel, Nickel steel	Lung cancer, skin disorder
Tin oxide	Nonferrous alloys, tin coated steels	Irritating dust
Vanadium	Welding rod, alloy steel	Lungs, eye, skin disorder
Zinc oxide	Zinc – covered steels, electrode coating, nonferrous steel	Fume fever
Carbon monoxide	Oxygen flame, carbon – arc cutting, electric arc	Large amount can cause death.
Nitrogen dioxide	Electric arc and various flame welding processes.	Breathing disorder
Ozone	Titanium and aluminum welding	Lungs and breathing disorder
Phosgene	Base metal covered with chlorinated hydrocarbon solvent	Lungs and respiratory disorders

Source: Essentials of welding.

Statement Of The Problem/Justification

Welding fumes inhaled is a health hazard for welders, trainee welders and other people in the welding shop. Welding hazardous fumes are generated during welding processes at least 13 metals, including manganese (Mn), Beryllium (Be), Cadmium (Cd), Chromium (Cr), Cobalt (Co), Copper (Cu), Iron (Fe), Lead (Pb), Mercury (Hg), Antimony (Sb), and Vanadium(V) (OSHA, 1995). Welders are known to be at risk, particularly for chronic exposure to airborne manganese, which is one of the major coating materials in welding products. The performance analysis is to ensure that that the extractor meet the minimum ventilation requirement of building regulations.

Objectives of the Study

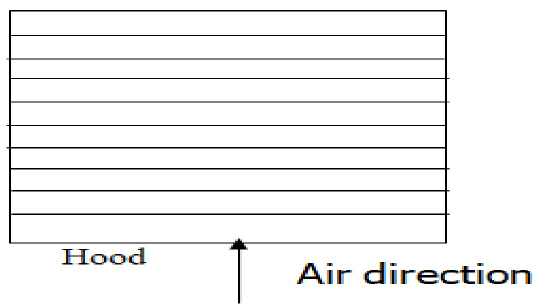
The objective of this study is based on the problem posed by the exposure of welder to welding fumes. The study has both the broad and specific objectives:

- Broadly, the study evaluated if the welding fume extractor as installed will meet the minimum requirement of building regulations
- Specifically, the study ascertained the extent to which welding fumes can be controlled to reduce the health hazard posed by the exposure of welders to the fumes during welding process.

II. MATERIALS AND METHODS

Direction of air movement:

The direction of air movement should carry air contaminant and fumes away from the breathing zone.



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Design Velocity

All ventilation system operate most effectively within a given air flow range usually measured by hood face velocity. For an enclosure capture velocity at enclosed opening, for theoretical unbounded suction source.

$Q = VA$

$= V4\pi r^2$

Q = Airflow into suction point (m^3/min)

V = Velocity art distance x (m/min)

A = $V4\pi r^2$ = area of a sphere

r = radius of the sphere

For unbounded line source

$Q = VA$

$= V\ 2\pi r xL$

= 6.28xL

Where

L = Length of line source (m)

In general equation used $Q = V(10x^2 + A)$

Where Q = Air flow (m^3/min)

X = distance from the hood (m)

V = Center line velocity at x distance from the hood (m/min)

A = Area of hood opening (m^2)

D= Diameter of hood or side of essentially square hoods. (m).

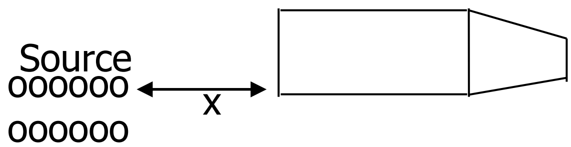
Air velocity (m/s)

$$\text{Air velocity} = 1096\,.\,5 \times \sqrt{\frac{\text{Velocity pressure}}{\text{Density of gas}}}$$

PROXIMITY AND EXHAUST VOLUME

To maintain the desired captive velocity the hood will be close to source as possible. The air volume requirement increases as square of the distance.

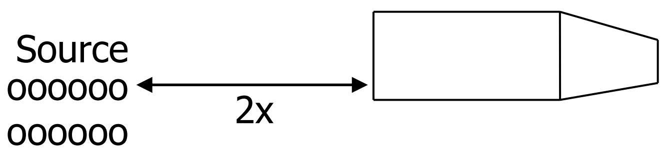
1



Smaller volume of hood is needed (m^3). Good location

Good proximity so source.

2



ie more volume of the hood is needed (m^3). Bad location

Bad proximity so source.

Data Obtained

Fan speed =2300rpm, blade diameter =342.8mm, air duct diameter = 914.4mm, effective pitch =13.5 degrees.

Impeller Analysis

Parameter	Unit	Values
Volume flow	M^3/s	0.594
Mass flow rate	Kg/s	0.6100
Air velocity	m/s	10.85
Density of air	Kg/m^3	1.225
Power	Hp	0.6880
Torgue	Nm	1.34

According to Henry J. McDermott (1985), the ventilation rate required to maintain a concentration of a fume in the occupied zone with Threshold Limit Value (TLV) can be calculated from the following equation.

$$Q_o = Q_{exh} + \frac{[G(10^6)(1-e) - Q_{exh}(C_{oz} - C_o)]}{K_c(C_{oz} - C_o)}$$

Where: Q_o is the air supply rate (m/hr), Q_{exh} is the local ventilation exhaust rate (m^3/hr), $G\ is\ the\ rate\ of\ fume\ generation\ \left(\frac{kg}{hr}\right)$, n is the local ventilation capacitor efficiency, C_{oz} is the desired concentration of fumes, gas particulate in the occupied zone (mg/m^3), C_o is the concentration of fumes, gas particulates supply in air (mg/m^3), C_{oz} is the desired concentration of fumes, gas particulates in occupied zone (mg/m^3), C_o is the concentration of fumes, gas particles supply in air (mg/m^3), K_c is the contaminants removal efficiency and e is the coefficient which represents the traction of time the welder spend at the workstation.

$$K_c = (C_{uz} - C_o)/C_{uz} - C_o$$

Where C_{uz} = concentration of fumes in the upper zone air (if the air is evaluated from t6he zone) or in the exhaust air (mg/m^3).

According to Francis (2016), the quality of fume or gas (kg/hr) generated in the space can be calculated by using the following equation.

$$G = R_1\ x\, T_m$$

Where:

R_1 is the fume (gas particles) generation rate $\left(\frac{kg}{min}\right)$, T_m is the average arc time per hour for the welding process used $\left(\frac{min}{hr}\right)$. The balance method defines the capture efficiency (n) of the extraction port (m) and the fume mass emitted during the welding process M_c Caster, H.R. (1995).

$$n = \left[\frac{M_c}{M_c}\right] x\ 100\%$$

n = capture efficiency

Minimum Ventilation Rates

Types of use	**CFM per ft^2 of conditioned floor area**
Auto repair shop	1.5
Barber shops	0.40
Bar, casinos	0.20
Beauty shop	0.40
Retail shop	0.26

Commercial dry cleaning	0.30

Source: 2013 building energy efficiency standard – reference ace.

III. RESULT AND DISCUSSION

Fume extractor system increases the visibility of the operator, thereby improving the efficiency and weld quality. Smoke swirls up away from the arc, and the rotating fan blade extract and channel it away through the pipe. The welding fume extractor comprise of units which was joined together by various joining operational, which include welding, soldering and bolted joint. These units include metal sheet, extractor fan, exhaust manifold, PVC suction flexible corrugated plastic etc.

The performance analysis of the welding fume extractor shows that the mass flow rate is 0.6100kg/s, Torque is 1.34Nm, Air density is 1.225kg/m^3, Air velocity is 10.85m/s etc. It was observed that during welding the fume produce was extracted by the extractor fans. The fumes were channeled through the manifold to the PVC suction plastic outside the welding workshop. The ventilation of the welding shop was greatly improved by the removal of the welding fumes.

IV. CONCLUSION

The analysis shows that the welding fumes extractor as installed meet the minimum ventilation requirements of building regulations and the challenges pose by welding fumes to occupants of welding shops. The fan impeller is suitable for high temperatures and can handle heavy contaminated airstream. This reduced the health hazard associated by exposure of welders and other workshop attendance to welding fume. The ventilation of welding shop must be greatly improved by the extraction of the welding fumes, and generally improve the effectiveness of the welder by reducing discomfort and health hazard associated with inhaling of fumes. The use of a welding gun equipped with exhaust fumes device to reduce the volume of exhaust fumes produced during welding is highly recommended.

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