Design and Computational Fluid Dynamics Analysis of aFume Extraction Systemfor a Welding Company in Guyana

Authors' contributions

This research and design work was carried out in collaboration among all authors. Author BK, SE and AY designed the study, ran simulations for draft two of the study, developed the first draft of this paper. Author SF, SN, CQ and SL worked on the introduction, references and design of the of the extraction system. Authors SJ and AJ managed the discussion and conclusion of this paper.
All authors read and reviewed the first draft and approved this final draft of this paper

ABSTRACT

The arc welding operation results in harmful fumes being emitted where welders are exposed to dangerous metallic gases and fumes for 6 to 8 hours daily at INFAB welding company in Guyana.This paper presents a design of a fume extraction system, the design incorporates workspace dimensions, volume calculations, duct materials required, framework materials, airflow requirements, and fan selection, guided by a target of 6 air changes per hour (ACH). In addition, the calculated required airflow rate of 58,500 ft³/h ensures the selection of appropriate fans. The design aims to create a safe and healthy welding area for the employees by removing harmful fumes. Computational fluid dynamics (CFD) simulations were employed to analyse velocity and pressure distribution, offering valuable insights into airflow patterns and pressure variations.

Keywords: Welding fumes, CFD, ACH, Transition duct

1. INTRODUCTION

Employees' exposure to welding fumes can lead to severe health problems and affect organs in the body such as the kidney, liver, and brain. The welder's health will be dependent on the concentration, composition, and length of time being exposed to the fumes. [1,2,3,4,5]. Epidemiological findings show that respiratory illness is common in many welders. The observed respiratory effects include irritation of air passage, chronic and acute bronchitis, occupational asthma, and the potential increase of cancer in the lungs. [6, 7, 8, 9].

Manual metal arc welding (MMAW) is one of the most common welding technologiesthatuses a coated flux electrode. Using this type of welding process, the electric arc produces an extremely high temperature used to melt the metal and fuse the two parts which results in fumes caused by the electrode flux components and core metal vaporization. The air reacts with the vaporized metals forming metal oxides which condenseto form fumes [10, 11]. The fumes emitted from welding are complex because it is made up of different metals, the configuration and the rate at which the welding fumes are generated depend on the type of electrode and coating, the metal components to be welded, the temperature and current of the welding unit, the technique used in the welding process and the skill level of the welder. The welding fumes generally consist of metals such as copper, cadmium oxides, chromium, beryllium, iron oxide, manganese, lead, aluminum, fluorides, zinc oxides, nickel, molybdenum and vanadium. Further, mild steel welding generates fumes thatcontain mainly iron; however, it has small amounts of copper, manganese, and molybdenum. [11,12]. The welding fumes are inhaled by the welder which enters the nerve cells in the brain, bloodstream, spinal cord, and lungs resulting in serious short and long-term health effects. In addition, the fumes can cause throat, nose, and eye irritation, nausea, chills, fever, and muscle pain [13,14, 15]. Researchers indicated that implementing an exhaust ventilation system can result in reduced exposure to welding fumes and can be used in an effective way to control the fumes [16,17, 18, 19]. CFD software is a valuable tool that can used for simulating how the fumes will be extracted by the fans in the fume ventilation system [20].Performing a CFD simulation to study the performance of the fume extraction system can be a better option compared to the experimental method [21].

This paper outlined the design and implementation of a fume extraction system specifically engineered for a welding workshop operation in Guyana. The main objective was to optimise air quality, with a particular emphasis on the efficient removal of welding fumes, which was fundamental to the safety and well-being of workers functioning in this challenging environment.

2. MATERIAL AND METHODS

The INFAB welding shop was selected to carry out the research and design of the ventilation system. The arc welding processes were observed, the various arc welding done was recorded and the length of time welders were exposed to welding fumes was documented.

2.1 Welders' Worktime, types of welding, and materials welded.

The company has six (6) full-time welders. These welders work an 8-hour shift each day, during which they take a half-hour lunch and for the rest of the 7 ½ hours, they will take 5 minutes break every hour.

Therefore, each welder will be welding for = $(7.5 \times 60) - (7.5 \times 5) = 412.5$ min or 6.875 hr.

That is, each welder will be exposed to the harmful fume for 6.875 hr. each day.

Types of welding operation done by INFAB:

- Tungsten Inert Gas (TIG)
- Metal arc welding (MMA)
- Metal Inert Gas (MIG)

Types of material welded

- Mild steel

- Stainless steel
- Aluminum

3. LOCATION OF THE VENTILATION SYSTEM

In the selection of an appropriate location for the system, several factors were considered. Thesource, availability of space, and easy access to the system.

Fig. 1.Outside view where the extraction system will be mounted

Fig. 2.Inside view of the extraction system and its easy access to the welding station

4. DESIGN APPROACH

Galvanized and mild steel are the two types of materials used for the design of the fume extraction system. Mild steel material was considered for the frameworks while galvanized was used for the ducting. Galvanized has many advantages when used as a ducting material, hence this type of material was chosen.

Part 1 (Ducting Body)

The ducting body is the central part of the system, to receive the inlet fume and release it into the atmosphere. This part is designed to be positioned outside of the building to help with the limited space available within the workshop, it will be bolted onto the wall along with additional supports. This part was designed with three openings on the front and two on the top. A framework design was first done via solid works along with the material estimation. Additionally, a design was done to cover the framework with galvanized sheet metal, the design was done using the solid works software.

Part 2 (Fume outlet ducting)

The fume outlet ducting is that part of the system where the fume exists. There are three inlets, therefore, the system was designed with two fume outlets to allow the fumes to exist in the ducting body more easily. These outlets are positioned perfectly between the three inlets to achieve maximum disposal of the fume and will be fitted directly to the ducting body. A framework design was done via Solid Works software along with the material estimation. Subsequently, a design was done to cover the framework with galvanized sheet metal, also via solid works along with the material estimation.

Part 3 (Fume Inlet Framework)

The fume inlet ducting is that part of the system where the fume is captured. Because INFAB has six welders, the system was designed with three inlets, where each inlet has two capturing hoods. These inlets are positioned inside the workshop and bolted directly to the wall. Each inlet has a 12’’ axial fan, filter, and a one-way flow control attached to it. The fume inlets are also designed with a maintenance access door, which is positioned by the fan and filter. A framework design was done using Solid Works software along with the material estimation. Subsequently, a design was done to cover the framework with galvanized sheet metal, also via solid works along with the material estimation and a cost analysis. A 12-inch axial flow fan was selected based on certain criteria; the measure of fumes needed to be extracted, the distancebetween the hood and the welding operation, and the duct velocity. Once the fan was selected the CFM (cubic feet per minute) was determined. Finally, the power consumption was calculated at 6.875 hr. for a 20 working days’ month. The appropriate filter for the extraction system was selected. The filter was chosen based on the welding fume particle size for the three welding operations. The H14 High-efficiency particulate air (HEPA) Air Filter was the best match for the design criteria and was chosen for this design.

In the one-way fume flow control design, this component will be attached directly to the fume inlet frame. It will be positioned just after the filter, which will move upwards by the fan force. The one-way movement will ensure that the fume doesn’t feedback to the other inlets. For the fume inlet hoods, several factors had to be considered; mainly hood shape and capture velocity. For the fume hood, a spherical design was selected, this allows for a greater capture velocity. The theory of the frustum of a cone was used to determine the surface area. The capture velocity was computed at various distances to determine how efficientlythe system would work with the selected fan, it was determined that if the hood is moved two feet away from a source to four feet away (twice the distance), the airflow required to provide the same degree of capture will be four times greater. For the fume inlet ducting, a combination of smoke pipe and semi-rigid flexible ducting was used in the design. The design of this type of ducting allows for easy maintenance, in that it can be disassembled and assembled easily. The galvanized smoke pipe has a snap-lock mechanism and crimp ends, these pipes are very light in weight and will work well with semi-rigid ducts. The aluminum flexible duct is semi-rigid, this semi-rigid feature will help position the hood in a different location and hold it in place because of the rigidity. The smoke pipe and the flexible duct are joined together utilizing a duct connector, which is also crimped at the ends. Once they are assembled, they are clampedutilizing duct connector clamps.

4.1 CFD Simulation

The workshop floor area is length=50ft, width=13ft, and height=15ft, providing a total volume of 9750 ft^3. This volume forms the basis for calculating the required airflow and fan sizes. To maintain adequate air quality, it was essential to determine the required airflow rate in terms of air changes per hour (ACH). The ACH is calculated as follows:

Required ACH = (Total Air Volume per Hour) / (Workspace Volume)

The required ACH depends on local regulations and safety standards. For industrial applications, a range of 4 to 10 ACH is typical. We considered a target of 6 ACH for our design:

Required Airflow (m^3/h) = Required ACH * Workspace Volume
Required Airflow = 6 x 9750 ft^3
Required Airflow = 58,500 ft^3/h

After calculating the required airflow for the welding workshop, totaling 58,500 ft^3/h to achieve the essential 6 ACH, we focused on the efficiency of welding fume extraction through the transition duct using simulation. This critical component will be directly connected to the extractor fans and plays a pivotal role in managing airflow velocities, pressure distributions, and vibration while the workshop is in continual operation. Within this context, our primary focus shifted to understanding airflow velocity, pressure distributions, and wall shear stresses in the transition duct.

To ensure the success of the fume extraction system, it was imperative to acquire precise data on these key parameters. The velocity and pressure distributions provided crucial insights into the efficiency and effectiveness of the system design. This allowed us to optimize the placement and characteristics of the extractor fans. In parallel with this simulation focus, we also acknowledged the significance of selecting the right extractor fans for our setup. The fans needed to possess the capacity to deliver the required airflow. Therefore, key factors guiding the fan selection process included considerations of fan type, size, and capacity through simulations and placement.

4.1.1 Simulation and Placement

The Computational Fluid Dynamics (CFD) in ANSYS Fluent was used to study the extracted airflow patterns and pressure behaviour within the workshop since we are aware clean incoming air volume must equal extracted volume for the system to be in a steady state. This will ensure welding fumes are efficiently extracted based on calculated ACH. This includes setting up the geometry, defining the boundary conditions, specifying the airflow rate, and appropriate selection of extractor fans based on the calculated requirements.

4.1.2 Geometry, Physics and Materials

The initial phase of the CFD study involved the development of the transition duct model geometry. SpaceClaim Modeler was used to modify a transition duct for the research and adhered to inch units to align with the project's requirements. Since we were interested in the internal airflow physics we extracted the internal volume of the model, created a flow description then excluded by suppression, all solid body components from the applied physics. Within this fluid flow volume, we created inlet, outlet, and wall boundary conditions to represent welding fume extraction and gauge pressure distribution of fumes to the atmosphere. To ensure the accuracy of the simulation results, significant attention was paid to mesh quality and generation. ANSYS meshing tools were utilised and opted for a normal unstructured mesh approach to streamline computational efficiency. In defining the material properties, the fluid as air was specified, and the solid duct as aluminum using values in Table 1.

Table 1. Material values used for simulation

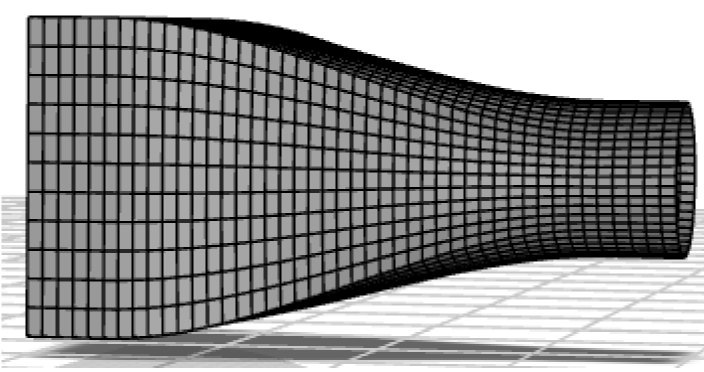
Material	Air	Aluminum
Density (kg/m3)	0.946	
Thermal conductivity (W/mK)	0.0314	
Specific Heat (J/kgK)	1009	

Flow = 33 ft^3/m^3 = xx in^3/s, thus, equation (x)
u = xx in^3/s / (4.72/2) ^2 * pi = xx in^3/s equation (y)

To define the boundary conditions, we let the airflow velocity at the duct inlet mimic incoming air at vents, as a reasonable assumption for steady-state conditions, while the outlet end of the duct was set to the outlet (zero-gauge pressure) using calculations obtained from equation x and y. The default setting for the applied physics was obtained using: a pressure-velocity coupling scheme, second order upwind for momentum, turbulent kinetic energy of 0.38 m^2/s^2, and specific dissipation rate of 2580 in Ansys solver.

4.1.3 Meshing

A non-conformal mesh with element size 1.e-002m and max sizing of 2.e-002m with a minimum edge length of 5.08e-0002m as shown in Figures (3a, 3b) for wall and inlet to outlet was applied. A mesh sensitivity analysis to ensure that the mesh was sufficient for reliable and accurate results with cheap computational costs was performed. Adjustments to the mesh were made as needed to achieve convergence and refinement of the solution.



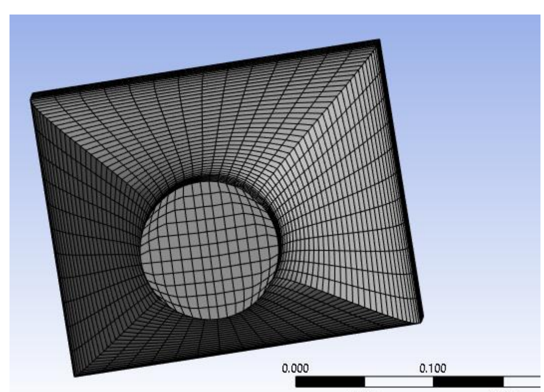


Fig. 3.(a) Wall surface mesh(b) Duct inlet to outlet mesh quality

Finally, we created name selection boundary conditions (bcs) for the inlet, outlet, and wall as shown in Figures (4 a, 4 b) launched the Fluent solver, initiated the simulation, set monitors, and defined residuals (acceptable errors for convergence). Further, plot criteria wereset, and 50 iterations were defined at a residual level of 1e-6. Convergence was obtained after 30 iterations in 5 seconds. The simulation was done on an i5 3.2ghz Intel processor with 8 GB of RAM.

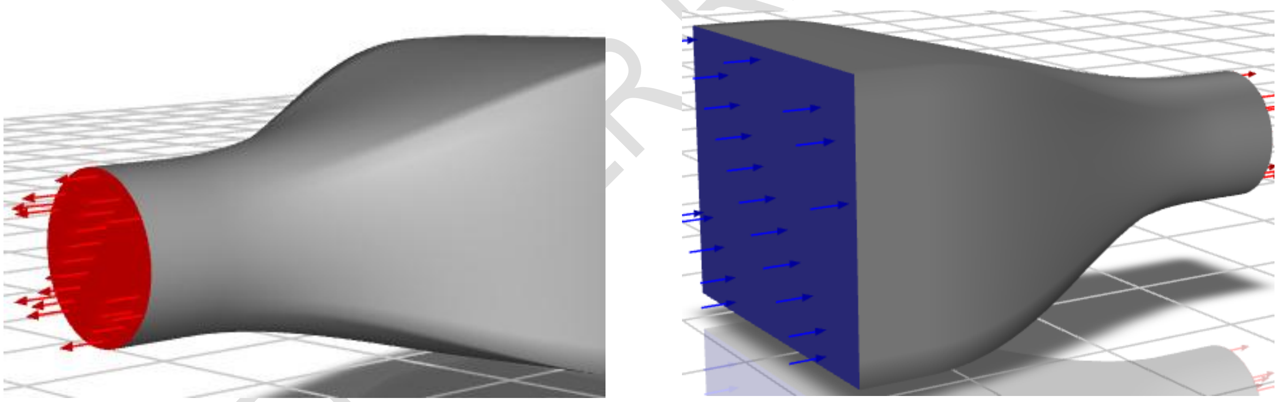


Fig. 4.(a) Duct inlet bc (b) Duct outlet bc

5. RESULTS AND DISCUSSION

5.1 Part 1 (Ducting Body)

Figure 5 shows the framework design of the ducting body; this was created using SolidWorks. This body is 22 ft. long by 3 ft. wide and 3 ft. high. It is constructed using 1 ½ and 1-inch square sections, all the square sections are welded together using 6013 electrodes. The rectangular cuboid is welded together using 1 ½ square sections. On the front side, it has three openings for the fume inlet, the framework for those inlets is constructed with 1-inch sq. sections. On the top of the body, it has two openings for the fume to exit, the framework for those exits is constructed with 1-inch sq. sections. All the other supports are to accommodate the sheet metal constructed of ½ inch sq. sections.

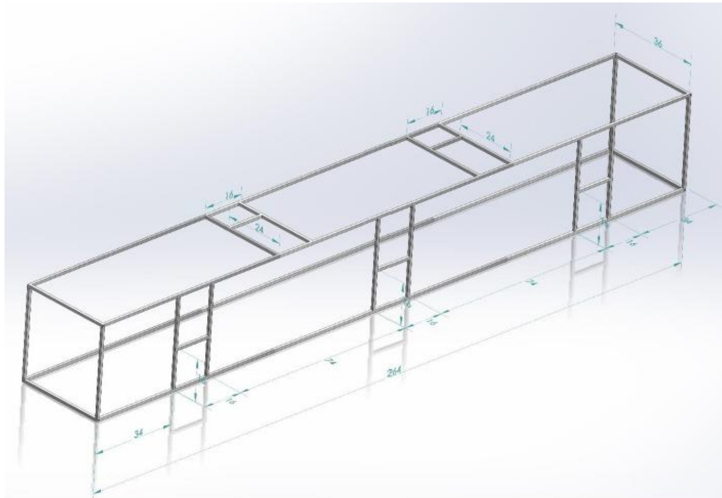


Fig. 5.Framework design of the body

Table 2. The rectangle cuboid

No.	Description (Inch)	Length (ft.)	Quantity	**(Length x Quantity)**
1	1 ½ sq. section	22	4	88 ft.
2	1 ½ sq. section	3	8	24 ft.
Total				112 ft.

Table 3. The three-fume inlet

No.	Description (Inch)	Length (ft.)	Quantity	**(Length x Quantity)**
1	1 sq. section	2 ft. 10 inches	6	17 ft.
2	1 sq. section	1 ft. 2 inches	3	3 ft. 6 inches
Total				20 ft. 6 inches

Table 4. The two-fume outlet

No.	Description (Inch)	Length (ft.)	Quantity	**(Length x Quantity)**
1	1 sq. section	2 ft. 10 inches	4	11 ft. 4 inches
2	1 sq. section	1 ft. 2 inches	2	2 ft. 4 inches
Total				13 ft. 8 inches

Table 5. Sheet metal supports (front)

No.	Description (Inch)	Length (ft.)	Quantity	(Length x Quantity)
1	1 ½ sq. section	2 ft. 8 inches	4	10 ft. 8 inches
2	1 ½ sq. section	6 ft.	4	24 ft.
3	½ sq. section	10.7 inches	16	14 ft. 3 inches
Total				48 ft. 11 inches

Table 6. Sheet metal supports (top)

No.	Description (Inch)	Length (ft.)	Quantity	(Length x Quantity)
1	1 ½ sq. section	6 ft. 5 inches	4	25 ft. 8 inches
2	1 ½ sq. section	6 ft.	2	12 ft.
3	½ sq. section	10.7 inches	34	30 ft. 4 inches
Total				68 ft.

Table 7. Sheet metal supports (back and bottom)

No.	Description (Inch)	Length (ft.)	Quantity	(Length x Quantity)
1	1 sq. section	21 ft. 10 inches	4	87 ft. 4 inches
2	½ sq. section	10.7 inches	66	58 ft. 10 inches
Total				146 ft.

Table 8. Sheet metal supports (ends)

No.	Description (Inch)	Length (ft.)	Quantity	(Length x Quantity)
1	½ sq. section	2 ft. 10 inches	4	11 ft. 4 inches
Total				11 ft. 4 inches

Table 9. Total square sections needed for the ducting body

Square section size (Inch)	Amount	Total
1 ½ sq. section	112 ft.	112 ft.
1 sq. section	(20 ft. 6 inches + 13 ft. 8 inches + 87 ft., 4 inches)	121 ft. 6 inches
½ sq. section	(48 ft. 11 inches + 68 ft. + 58 ft. 10 inches +11 ft. 4 inches)	187 ft. 1 inch

5.1.1 Ducting Body covered with sheet metal

The sheet metal covering design for the ducting body was created using SolidWorks software. This body is 22 ft. long by 3 ft. wide and 3 ft. high. It is constructed using 30-gauge galvanized sheet metal. The sheet metal is held in place by 1⁄8 rivets.

5.1.2 Materialsfor the Covered Body

The 30-gauge sheet galvanized sheet metal (Available in 4 ft. width) was used for the analysisSince the Galvanized sheet metal thickness for 30 gauge is only 0.0157 inch, then the benddeduction is negligible for this type of sheet metal.

To cover the front, back, and ends with a ¾ inch lap.

Total length = [(22×2) + (3×2) + (0.0625×2)]

Approx. = 51 ft.

Cover the top and bottom with a ¾ inch lap.

Total length = [(22×2) + (0.0625×2)]

Approx. = 45 ft.

Total amount of sheet metal needed to cover the ducting body

= 51 ft. + 45 ft.

= 96 ft. of sheet metal is needed at 4 ft. width

5.2 Part 2(Fume outlet ducting)

The framework design of the fume outlet ducting was created using SolidWorks software. This L-shaped fume outlet is 3 ft. long by 16 inches wide and 3 ft. high. It is constructed using 1 inch and ½ and mild steel square section, all of the square sections are welded together using 6013 electrodes. The L-shaped is welded together using 1-inch square sections. All the other supports to accommodate the sheet metal are constructed of ½ inch sq. sections.

Table 10. The L-shape box

No.	Description (inches)	Length (ft.)	Quantity	(Length x Quantity)
1	1 sq. section	1 ft. 4 inches	6	8 ft.
2	1 sq. section	3 ft.	4	12 ft.
3	1 sq. section	2 ft.	4	8 ft.
4	1 sq. section	1 ft.	4	4 ft.
Total				32 ft.
Total for 2 parts				64 ft.

Table 11. Sheet metal supports

No.	Description (inches)	Length (ft.)	Quantity	(Length x Quantity)
1	½ sq. section	2 ft. 10 inches	2	6 ft. 8 inches
2	½ sq. section	3 ft.	2	6 ft.
3	½ sq. section	10 inches	2	1 ft. 8 inches
4	½ sq. section	2 ft.	4	8 ft.
Total				22 ft. 4 inches
Total for 2 parts				44 ft. 8 inches

Table 12. Total square sections needed for the outlet ducting

Square section size (Inches)	Amount	Total
1 sq. section	64 ft.	64 ft.
½ sq. section	44 ft. 8 inches	44 ft. 8 inches

5.2.1 Fume outlet covered with sheet metal.

The sheet metal covering design for the fume outlet ducting was created using SolidWorks software. This L-shaped box fume outlet is 3 ft. long by 16-inch-wide and 3 ft. It is constructed using 30-gauge galvanized sheet metal. The sheet metal is held in place by 1/8 rivets.

5.2.2 Materials for the Covered Fume Outlet

Using 30-gauge sheet galvanized sheet metal (Available in 4 ft. width) Since the Galvanized sheet metal thickness for 30 gauge is only 0.0157 inch, then the bend deduction is negligible for this type of sheet metal.

To cover the top, one side, and the two ends with a ¾ inch lap.

Total length = [(3×2) + (2×2) + (0.0625×2)]

Approx. = 11 ft.

Cover the bottom and one side with an ¾ inch lap.

Total length = [(3×2) + (0.0625×2)]

Approx. = 7 ft.

Total amount of sheet metal needed to cover the ducting body

= 11 ft. + 7 ft.

= 18 ft. of sheet metal is needed for one outlet at 4 ft. width

= 36 ft. of sheet metal is needed for the two outlets at 4 ft. width

5.3Part 3 (Fume inlet framework)

The framework design of the fume inlet ducting was created using SolidWorks software. This L-shaped fume inlet is 3 ft. 4-inch-high by 1 ft. 4-inch-wide and 1 ft. 5 inches long. It is constructed using 1 inch and ½ and mild steel square section, all the square sections are welded together using 6013 electrodes. The L-shaped is welded together using 1-inch square sections. All the other supports to accommodate the sheet metal are constructed of ½ inch sq. sections.

Table 13. The L-shape box

No.	Description (inches)	Length (ft.)	Quantity	(Length x Quantity)
1	1 sq. section	3 ft. 4 inches	2	6 ft. 8 inches
2	1 sq. section	2 ft.	2	4 ft.
3	1 sq. section	1 ft. 4 inches	12	16 ft.
4	1 sq. section	1 inch	2	2 inches
Total				26 ft. 10 inches
Total for 3 parts				80 ft. 5 inches

Table 14. The filter box.

No.	Description (inches)	Length (ft.)	Quantity	(Length x Quantity)
1	½ sq. section	1 ft. 4 inches	6	8 ft.
Total				8 ft.
Total for 3 parts				24 ft.

Table 15. The maintenance door

No.	Description (inches)	Length (ft.)	Quantity	(Length x Quantity)
1	½ sq. section	1 ft. 8 inches	2	3 ft. 4 inches
2	½ sq. section	1 ft. 4 inches	2	2 ft. 8 inches
Total				6 ft.
Total for 3 parts				18 ft.

Table 16a. Sheet metal supports

No.	Description (inches)	Length (ft.)	Quantity	(Length x Quantity)
1	½ sq. section	3 ft. 4 inches	2	6 ft. 8 inches
2	½ sq. section	2 ft.	1	2 ft.

3	½ sq. section	16 inches	3	4 ft.
4	½ sq. section	2 ft.	1	2 ft.
5	½ sq. section	1 ft. 8 inches	1	1 ft. 8 inches
Total				16 ft. 4 inches
Total for 3 parts				49 ft.

Table 16b. Total square section for the outlet ducting

Square section size (inches)	Amount	Total
1 sq. section	80 ft. 6 inches	80 ft. 6 inches
½ sq. section	24 ft. + 18 ft. + 49 ft.	91 ft.

5.3.1 Fume inlet covered with sheet metal.

The sheet metal covering design for the fume inlet ducting was created using SolidWorks software. This L-shaped fume inlet is 3 ft. 4-inch-high by 1 ft. 4-inch-wide and 1ft. 5 inches long. It is constructed using 30-gauge galvanized sheet metal. The sheet metal is held in place by 1/8 rivets.

5.3.2 Fume inlet covered with sheet metal.

Materials for the covered fume inlet

The 30-gauge sheet galvanized sheet metal (Available in 4 ft. width) was used in the analysis. Since the Galvanized sheet metal thickness for 30 gauge is only 0.0157 inch, then the bend deduction is negligible for this type of sheet metal.

To cover the top, one side, and the two ends with a ¾ inch lap.

Total length = [(3 ft. 4 inch×1) + (1 ft. 4 inch ×3) + (0.0625×2)]

Approx. = 8 ft.

Cover the bottom and one side with an ¾ inch lap.

Total length = [(3 ft. 4 inch×1) + (0.0625×2)]

Approx. = 3 ft. 6 inch

Total amount of sheet metal needed to cover the ducting body

= 8 ft. + 3 ft. 6 inch

= 11 ft. 6 inches of sheet metal is needed for one inlet at 4 ft. width

= 34 ft. 6 inches of sheet metal is needed for the three inlets at 4 ft. width

5.5Fan

The axial flow fans are especially suited for handling air at relatively low pressures and when in large volumes. Contributing factors forairflow are the speed at which the blades turn, the overall fan design, the diameter and blade shape, and the horsepower (hp). The cubic feet are used to measure the fan capacity. Cubic feet per minute (CFM) is determined below.

5.5.1-12-inch-high velocity utility blower fan multi-function axial fan 3300 rpmspecifications:

Color: Orange
Diameter of the fan: 300mm (12 inches)
Power supply: AC: 110v / 50-60 Hz
Input power: axial motor 520 w/ 0.7 hp
Speed (rpm): 3300r/min
Material: steel
Airflow: 65m^3/ min 2295CFM
Noise: 71db
Body pressure: 373 pa
Protection grills protection grade: ip54

The efficiency is typically 75 to 90 %.

5.5.2Performance specification

Airflow: 65m^3/min 2295 CFM

Velocity = CFM / Duct area (in sq. ft.)

Duct area = $\pi D^2 / 4$

Duct diameter = 5” = 5/12 = 0.4167 ft.

Duct area = $\pi\ (0.4167)^2 / 4$

= 0.1364 ft^2

Velocity = 2295 / 0.1364

= 16825.5 ft./min or 280.42 ft./sec

Table 17. Power consumption of the three fans at 520 watts

Equipment type	Quantity	Rating (watts)	Running hours/semester (hrs.)	Energy consumption (kWh)	GYD @ $56.38
12” axial fan	3	520	6.875	10.725	$604.67

5.6Filter selection

5.6.1 H14 HIGH-EFFICIENCY particulate air (HEPA) air filter

Outer frame: Galvanized steel
Filter material: Water resistance fiberglass
Filter material separate: Hot melt glue
Filter efficiency: H14 (EN 1822)

Protecting Net: White steel mesh coating (according to request)
Sealing gasket: Jointless Polyurethane
Sealing gum: Polyurethane
Operating temperature: ≤70℃；
Operating humidity: ≤ 95% RH；
Suggestion finally resistance: ≤ 600 Pa
HEPA air filters needed:
Each hood ducting needs = 1 filter
For six hood ducting = 1 × 6
= 6 HEPA filters are needed

5.7 One-way fume flow control

The one-way fume flow control design will be attached directly to the fume inlet frame itself. It will be positioned just after the filter, which will move upwards by the fan force. The one-way movement will ensure that the fume doesn't feed to the other inlets. The hinges are shown in the drawing, but three hinges will be placed on the end without the notches. These hinges will allow for the up and down movement.

Table 18. Materials for the flow control

No.	Description (inches)	Length (ft.)	Quantity	(Length x Quantity)
1	1 sq. section	1 ft. 4 inches	1	1 ft. 4 inches
2	28 Gauge sheet metal	1 ft. 4 inches	1	1 ft. 4 inches

5.7.1 Materials needed for the hood.

Using 30-gauge galvanized sheet metal

$A = \pi (R + r) L$

$= \pi (4.5 + 2.5) 5.66$

= 124.5 sq. inches of sheet metal is needed

5.8 Duct Connector

5.8.1 DAC_C-Duct connector – Aluminum with bead and clamp

General Information

Part Number DAC5C

Item Weight 6.8 pounds

Product Dimensions 5 x 3 inches

Item model number DAC5C

Color Aluminum

Material Aluminum

Thickness 30 gauge

5.8.2 Connectors needed.

Each hood ducting needs = 5 connectors

= 5

For six hood ducting = 5 × 6

= 30 connectors are needed

5.9Dust connector clamps

MC525 5" metal worm drive clamp
General Information
Part Number MC525
Item Weight 0.11 pounds
Product Dimensions 7/16"(11mm) wide x .030(.7mm) thick

5.9.1 Connector clamps needed.

Each connector needs 4 clamps.

Each hood ducting need = 5 connectors × 4 clamps

= 20 clamps

For six hood ducting = 20 × 6

= 120 connectors clamp are needed

5.10Electrical controls

The entire operation of the Fume Extraction System will be controlled from a Control Panel utilizing a circuit breaker, motor circuit protector, fuse, electrical copper wires, and a start and a stop bottom.

5.11 CFD Simulation

The velocity vectors plot was done to obtain an overview of velocity magnitude as shown in Figure 6a. The static pressure distribution was also computed and shown in Figure 6b. Further, we compared the vector distribution of wall shear stress and static pressure occurring from the inlet of the duct to the outlet and observed good fluid behaviour.

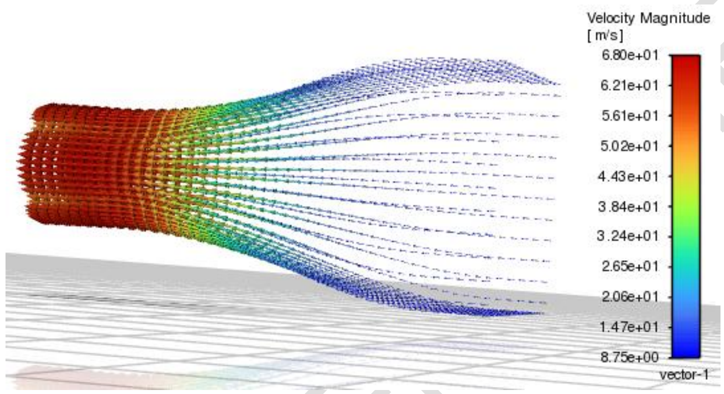


Fig. 6.(a) Velocity vector distribution

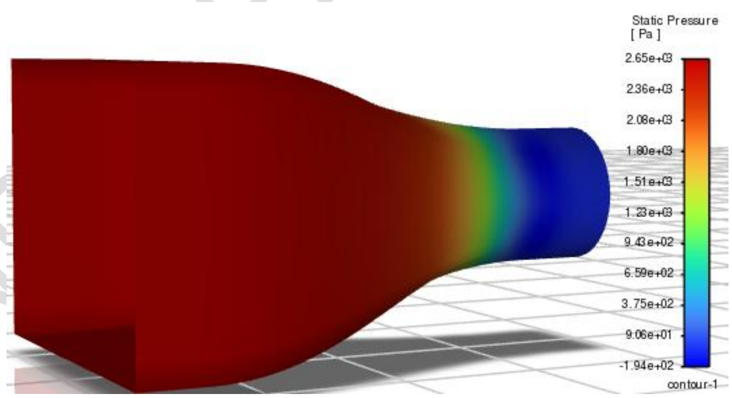
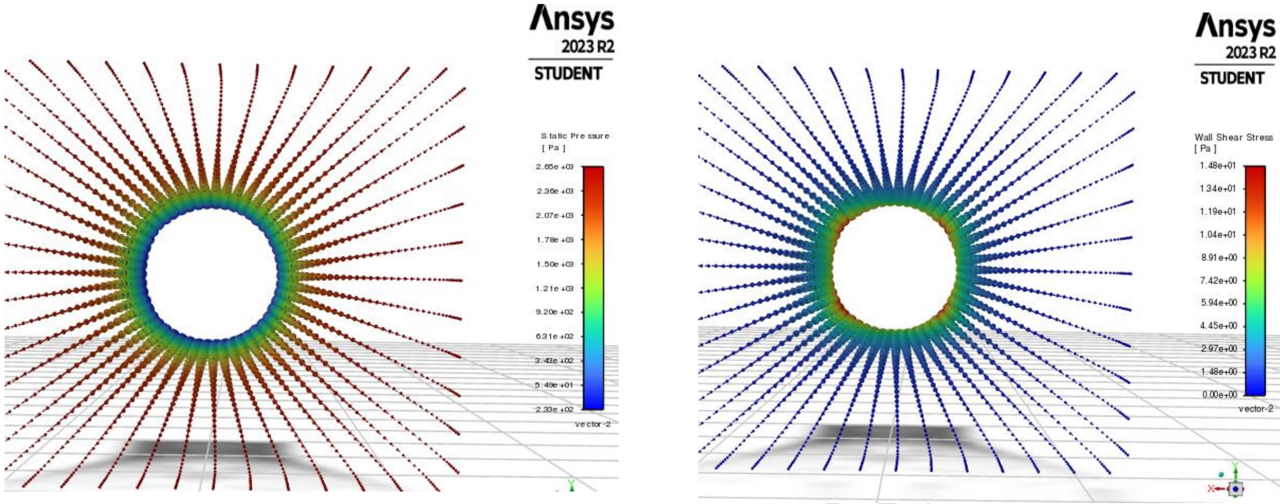


Fig. 6.(b) Pressure distribution



Figures 7: (*l*) Static pressure vs (*r*) wall shear stress vectors

In this study, the aim was to enhance the design with CFD simulations. The results obtained from the simulations have provided valuable insights into the airflow patterns, velocity magnitudes, pressure distributions, and wall shear stresses within the welding workshop. These insights are essential for optimising the ventilation system's performance to ensure the safety and well-being of workers in the workspace.

One of the fundamental aspects of this study involved the visualisation of velocity vectors. Figure 6a illustrates velocity vectors, which offer a good overview of velocity magnitude and direction. These visualisations help us understand how the welding fumes disperse from the workspace into the transition duct. The proper management of airflow is crucial in ensuring fumes are effectively captured and extracted to minimise the risk of exposure to hazardous welding by-products. Furthermore, the static pressure distribution, shown in Figure 6b, plays a pivotal role in understanding the pressure differentials within the workspace as extracted fumes enter and exit the duct. These variations in pressure influence the flow and welding fumes. Thus, analysing pressure distribution, allowed us to identify areas of high and low pressure for informed decisions regarding the optimal placement of exhaust hoods and fans. This ensures that fumes are effectively directed towards the extraction system.

To evaluate the effectiveness of our fume extraction system, we compared the vector distribution of wall shear stress and static pressure along the entire duct, from the inlet to the outlet. The observation of well-behaved fluid behavior and consistent pressure distributions indicates that the design effectively controls the flow of welding fumes. This contributes to improved air quality and the removal of harmful contaminants from the workspace.

In future work, we can consider extending our simulations to include thermal equations. Thermal effects are significant in welding processes, and their inclusion in the simulations would provide a more in-depth understanding of fume dispersion and temperature control. It is worth noting that our experiments with finer mesh sizes did not yield substantial improvements. This suggests that the mesh resolution used in our simulations is adequate for capturing the relevant flow characteristics.

The simulation results also play a crucial role in fan sizing and determining the required airflow rate. The workshop's dimensions—length of 50 feet, width of 13 feet, and height of 15 feet—provide a total volume of 9750 cubic feet. This volume formed the basis for calculating the required airflow and fan sizes.

6.CONCLUSION

This paper presents a practical and robust design for a fume extraction system at awelding company in Guyana. The design process accounted for essential parameters, including workspace dimensions, duct and frameworkmaterial required, volume calculations, airflow requirements, and fan selection, with the aid of CFD simulations to analyse velocity and pressure distribution. The core objective was to create a safe and efficient working environment by addressing the challenges associated with welding fume extraction.One of the main takeaways from this design is the recognition of the pivotal role of workspace dimensions. By considering the length, width, and height of the workspace, we calculated the required airflow rate, aiming for a target of 6 air changes per hour (ACH). The calculated required airflow rate, based on a workspace volume of 9750 ft^3, was found to be 58,500 ft^3/h. This value guided the selection of extractor fans to ensure the extraction system's efficiency criteria were met. The use of CFD simulations to visualise and analyse velocity and pressure distributions within the workspace emerged as another key takeaway. The simulations provided valuable insights into airflow patterns and pressure variations, contributing to the optimisation of the fumes extraction system's performance. Importantly, the holistic approach outlined in this paper sets a foundation for enhancing occupational health and safety in welding workshops.

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