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The Effectiveness of Local Exhaust Ventilation (LEV) System in Welding Training Facilities using Validation Computational Fluid Dynamics (CFD) Simulation

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ABSTRACT

The Local Exhaust Ventilation (LEV) is the most common type of engineering control equipment used to control employees' exposure to chemicals that are hazardous to their health. Before a contaminant disperses into the workroom environment, LEV systems operate on the principle of capturing it at or near its source. The welding guideline stated that the suggested minimum hood velocity is 100 ft/min, the recommended velocity along ducts for vapors, gases, and smoke is 1000 ft/min, and 2000 ft/min. The research objective is to identify the effectiveness of the LEV system using validation computational fluid dynamics (CFD) simulation. The data collected by experimental design during the pre-testing phase of the LEV system is quantitative and obtained through a fieldwork survey and document analysis. Findings found that LEV systems are effective to be used and meet all the minimum requirements set by the guideline. In CFD simulation, upon validation, the average absolute error obtained from the case study is 8.4%. There is good agreement between actual experimental and CFD simulation results, and the acceptable validity of CFD simulation is less than 10%. Therefore, simple CFD modeling is a tool to simulate air velocity in the LEV system, saving labor costs and time consumption during the earliest stage of LEV design development before actual construction. This study's outcome can serve as a benchmark or guideline for training facilities equipped with the LEV system to prioritize safety and health.

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1. Introduction

The industry also focuses on speeding up the manufacturing process. Welding and metal fabrication are among the most popular industries in the industrial sector [1-3]. According to Troschitz *et al.,* [4], welding is joining two materials with a particular method, such as metal or thermoplastic. The welding process is critical in industrial manufacturing, such as automotive, aerospace, and shipbuilding [5-7]. The welding industry's technological breakthroughs have grown to match the industry's needs. Welding is a fabrication procedure that involves smelting the materials and then adding a filler material to make a solid welding connection [8]. Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (GMAW), Tungsten Arc Welding Gas (GTAW), Cored Arc Welding (FCAW), Submerged Arc Welding (SAW), and other welding processes are extensively employed in industries [9]. Each technique has its own set of benefits and procedures but has the same goal of connecting materials with high-pressure current.

Industries and training facilities often use Local Exhaust Ventilation (LEV), where occupants receive training on job responsibilities [10,11]. When there is no LEV, LEV drastically reduces fiber particle exposure [12]. Even though the reduction was a solid signal of LEV use, Flynn and Susi [13] stated that appropriate LEV design is the most crucial factor in LEV effectiveness. Another study found that when using LEV, the reduction of overall particle concentrations increased by 75% [14]. Enterprises and training facilities where occupants get training on job duties use LEV. According to the research background, facilities and the environment play a vital role in guaranteeing the safety and health of students. The Welding and Metal Fabrication Laboratory, FPTV in UTHM, are examples of areas that often use LEV. During the practical tasks at the laboratory, students will get a theoretical and practical understanding of the welding and metal fabrication process, which includes cutting and welding metals such as carbon steel, stainless steel, and aluminum throughout this course.

Research that leads to welding facilities is scarce, and there are hazards to users in the form of respiratory tract problems due to breathing toxic smoke when welding [15]. According to Budhathoki *et al.,* [16], LEV dramatically reduced fiber particle exposure compared to when no LEV was used. Iwasaki *et al.,* [17], and Pramadhony *et al.,* [18] explain that inadequate ventilation and lighting harm one's health and encourage illness due to prolonged work. Flynn and Susi [13] suggested that the correct LEV design is the most crucial factor in LEV efficacy. Another researcher Liu *et al.,* [19] claimed that LEV efficiently reduced welder exposure during welding activities if the exhaust cover was designed and used correctly. In a similar investigation, Riccelli *et al.,* [20] found that LEV design and condition influenced the efficacy of sanding carbon nanotubes to catch airborne particles (CNT). Furthermore, welding is a potentially risky operation that necessitates the installation of safe facilities to avoid sniffing gas, toxic smoke, and the revelation of ultraviolet radiation. Students who attend the workshop regularly to participate in practical activities may be at an increased risk of developing health concerns [21].

Welding fumes are a combination of tiny particles and gases produced by burning and liquid flux from welding electrodes and additional gases emitted by the main metal or principal metal covering. The health effects of welding activities are difficult to characterize because vapors can contain a variety of hazardous compounds. Welding fume particles can harm any body region, including the lungs, heart, kidneys, and Central Nervous System (CNS). Table 1 depicts the various types of contaminants produced by welding activities.

Table 1
Contaminant and source of fumes from welding activities

Contaminant	Source
Iron Fume	Vaporization of iron from metal and electrode coating.
Chromium	Stainless steel, electrode coating, plating.
Nickel	Stainless steel, nickel-clad steel.
Zinc Fume	Vaporization of zinc alloys, electrode coatings galvanized steel, zinc-primed steel.
Copper Fume	Vaporization of coating on electrode wires, sheaths on air carbon arc gouging electrodes, copper alloys.
Vanadium, Manganese, Molybdenum	Welding rods, alloying element in steels.
Tin	Tin-coated steel, some nonferrous alloys.
Cadmium	Plating.
Lead	Lead.
Carbon Monoxide	Combustible products of gas metal arc gouging oxy-fuel flames, exhaust from car engines.
Ozone	Gas metal arc welding air carbon arc gouging, titanium and aluminium welding in inert gas atmospheres.
Nitrogen Dioxide	Gas metal arc welding, oxy-fuel flame processes.
Phosgene	Welding of metal covered with chlorinated hydrocarbon solvents.

Low-skilled personnel who are unconcerned about the environment can cause accidents in the industrial sector [19]. Students use facilities and machines to carry out practical work at school. If students do not use the facilities and take proper safety precautions when completing the workshop activities, it can bring them danger. Students use various machine tools, and the workshop has considerable potential for accidents [17]. Safety issues that are not taken care of can be one of the causes of accidents. Therefore, teachers need to prioritize safety issues. Teachers must adequately and systematically maintain workshop equipment and machines to ensure students' comfort and safety. Each piece of equipment and work procedure should have a safety factor so that other workshop users are unharmed.

Although studies by Wurzelbacher and Jin [21], Zare *et al.,* [22], and Smargiassi *et al.,* [23] compared the effectiveness of LEV systems with and without using them to protect against occupants' exposure to contaminants, only one study conducted by Inthavong *et al.,* [24], involved LEV design simulation using CFD methods. Moreover, nearly every CFD simulation in previous studies has included a mechanical ventilation system, such as a ceiling fan, wall fan, and exhaust fan. Computational fluid dynamics (CFD) is a branch of fluid mechanics that analyses and solves problems using numerical analysis and data structures. The calculations necessary to simulate the free-stream flow and the interaction of the fluid (liquids and gases) with surfaces defined by boundary conditions using computers. Better answers can be achieved with high-speed supercomputers, frequently required to handle the most significant and complicated issues. Furthermore, nearly every CFD simulation in previous research has included a mechanical ventilation system, such as a ceiling fan, wall fan, and exhaust fan.

2. Methodology

The researchers used the experimental design in this study. This study aims to test and evaluate the efficiency and performance of the LEV system with a focus on fume extraction using real-world examples. This research has the following goals:

i. The experiment methods used DOSH Guidelines on Occupational Safety and Health for the Design, Inspection, Testing, and Examination of LEV systems.

ii. Velocity pressure (VP) was measured and obtained from actual experiments.
iii. Simulations of airflow distribution in LEV using the CFD tool.

The data collected during the LEV system's pre-testing phase is quantitative and obtained through a fieldwork survey and document analysis. The testing session is implemented during this period. A data comparison was carried out to determine the LEV system's performance during the installation phase. The acquired findings are then analyzed to build simulations of airflow distribution in LEVs using the CFD tool to identify the next step in this research. This research begins with a review of prior research on LEV system inspection, testing, and examination. It continues with the LEV system survey in the welding and metal fabrication laboratory, FPTV UTHM. Researchers used an anemometer to monitor the velocity pressure (VP). The noise exposure assessment is also included in the LEV system inspection to determine the comfort level when using the system. The study for LEV to assess the value of the system's index performance rank was performed following the Guidelines on Occupational Safety and Health for Design, Inspection, Testing and Examination of LEV system by DOSH.

Fume extraction of assessment and monitoring data system conducted at the welding and metal fabrication laboratory in FPTV UTHM. Implementation of the velocity flow measurement according to DOSH and ACGIH guidelines. The noise exposure was measured using the velocity flow measuring method. The Welding and Metal Fabrication Laboratory, FPTV UTHM, was chosen. The Laboratory provides welding training and metal fabrication work to faculty members. Students frequently use this Laboratory for educational reasons. It will be open 24 hours a day and have a complete LEV system. Students will use the LEV system during the welding process.

The LEV system is in place to absorb fumes produced by welding. A hood is attached to each welding workstation as part of this LEV system. The LEV system is accessible in the Welding and Metal Fabrication Laboratory, FPTV, as shown in Figure 1.

Fig. 1. Overview of LEV at Welding and Metal Fabrication Laboratory, FPTV

The researcher measured velocity pressure at six (6) locations along the duct and ten (10) locations calculated on the LEV system's hood. The sixteen (16) locations where actual trials were done are depicted in Figure 2. After the real experiments, a CFD simulation was run using SolidWorks.

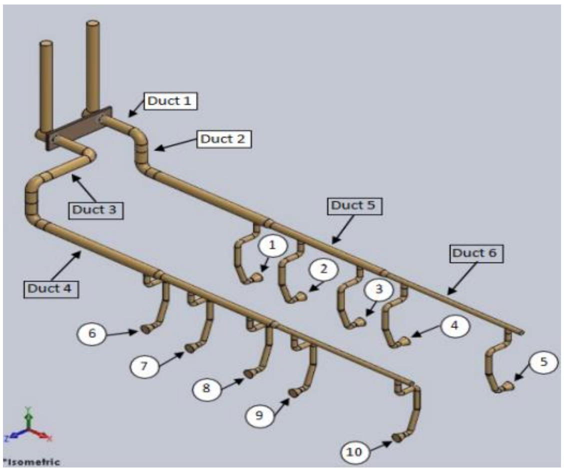

Fig. 2. The locations were chosen where actual experiments were conducted

Using an anemometer, the researcher measures velocity pressure (VP) and evaluates numerous aspects of the assessment criteria provided in the DOSH Guidelines on Occupational Safety and Health for Design, Inspection, Testing, and Examination of LEV Systems. Data from samples is converted into values using evaluation rubrics to determine the effectiveness of the LEV system. The anemometer has a statistical function and can measure and analyze maximum, minimum, and average values. The researcher might also use an anemometer to record all parameters simultaneously. Values can be read and seen on the anemometer's screen. The researcher can freely expand the anemometer's sensor probe. The data gathered and stored in the anemometer can be downloaded and transferred to a spreadsheet program on a personal computer for further analysis. The researcher used an anemometer to measure the velocity of the hood, as shown in Figure 3.

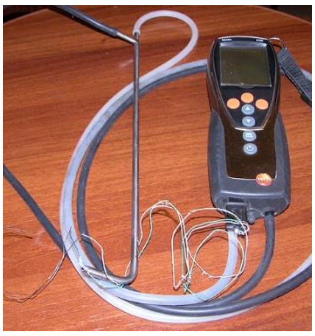
Fig. 3. Anemometer

A pitot tube is a tool used to measure fluid flow speed, especially air or liquid. Pitot tube measures the total pressure (stagnation pressure) and fluid static pressure to calculate the flow rate. L-type pitot tubes produce a velocity pressure signal and are used to determine the accurate measurement of airflow in a closed conduit system. Therefore, the velocity pressure along the ducts was measured using a pitot tube and an anemometer. The L-type pitot tube (Figure 4) is made of stainless steel to be robust and long-lasting.

Fig. 4. L-typepitot tube

The researcher used the CFD tool SolidWorks in mode flow simulation for simulation purposes as shown in Figure 5. SolidWorks in mode flow simulation is a CFD airflow simulation analysis tool designed to simulate airflow, heat transfer, and contamination control within rooms, buildings, vehicles, etc. Before actual construction, researchers use such simulations at the beginning of building development. SolidWorks assists in identifying, understanding, and resolving problems in existing facilities. SolidWorks focuses on the numerical simulation of fluid flow, heat transport, and related processes such as radiation. The SolidWorks goals are to provide engineers with a computer-based predictive tool to analyze the airflow processes within and around rooms, buildings, vehicles, and other structures to improve and optimize the design of new or existing heating or ventilation systems. In this study, incompressible fluid flow was employed for these case studies because the density of the fluid does not change about pressure.

In this case study, the researcher created an LEV system geometry model using SolidWorks to replicate the compartment of the LEV system. The researcher used the length, width, and cross-sectional area of each LEV element measured from actual trials to build the geometric model of the LEV system. The flow simulation was selected in SolidWorks, and drawing assembly files were imported. Then, to acquire accurate and precise findings, boundary conditions were set. The researcher must define the LEV structure in which the model is enclosed. The LEV hood inlet and discharge should be accurately defined because they are essential in determining simulation results.

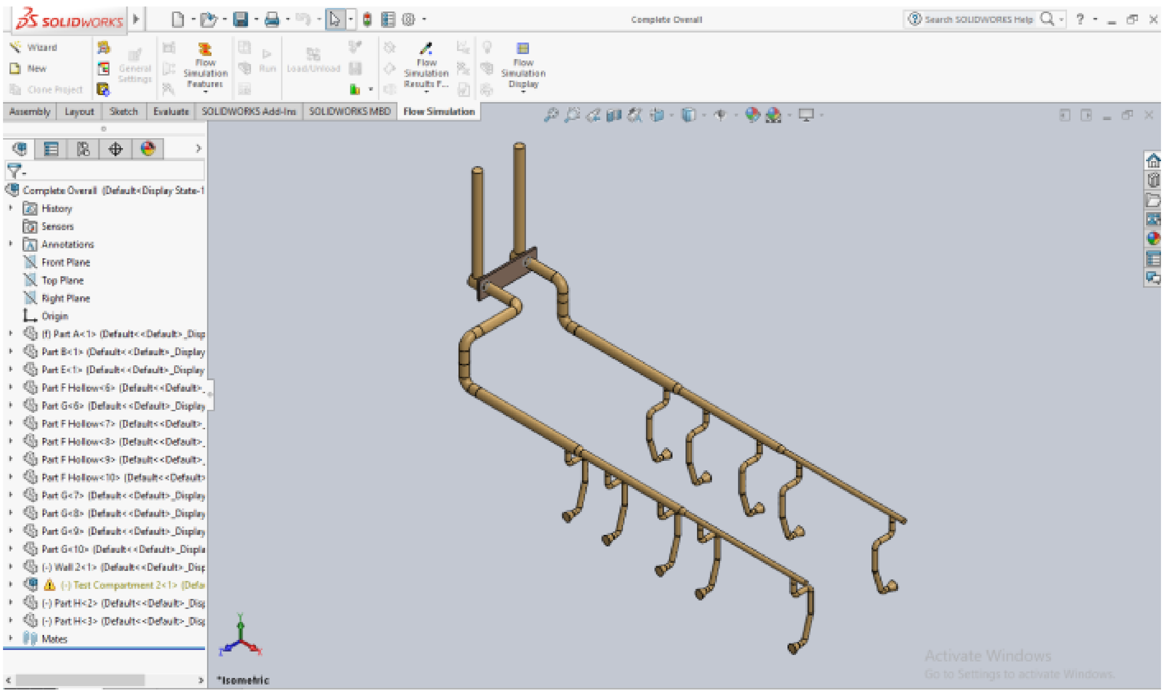

Fig. 5. SolidWorks flow simulation board

Solving the governing equations in the domain involves calculating pressure and temperature measured at each cell center and velocity at the cell boundary. Monitor points are often placed at critical locations for temperature or air velocity to solve the model. Fast and efficient solution implementation is required in stable conditions. It also helps us rapidly see if a significant error occurs throughout the simulation. For example, the monitor point shows an error or simulation error if it displays a temperature of 500°C instead of 270°C. As a result, the solver can pause, and the researcher can address the error.

The governing equations, on the other hand, are solved iteratively. The error is measured, and the findings are acceptable if the mistake is too minor. After the solver performs the task, the researcher can inspect the results and numerical data. At this point, they solve the model using a separate turbulence model to obtain solid and reliable results with minimal mistakes. Figure 6 shows iteration of CFD tools, SolidWorks.

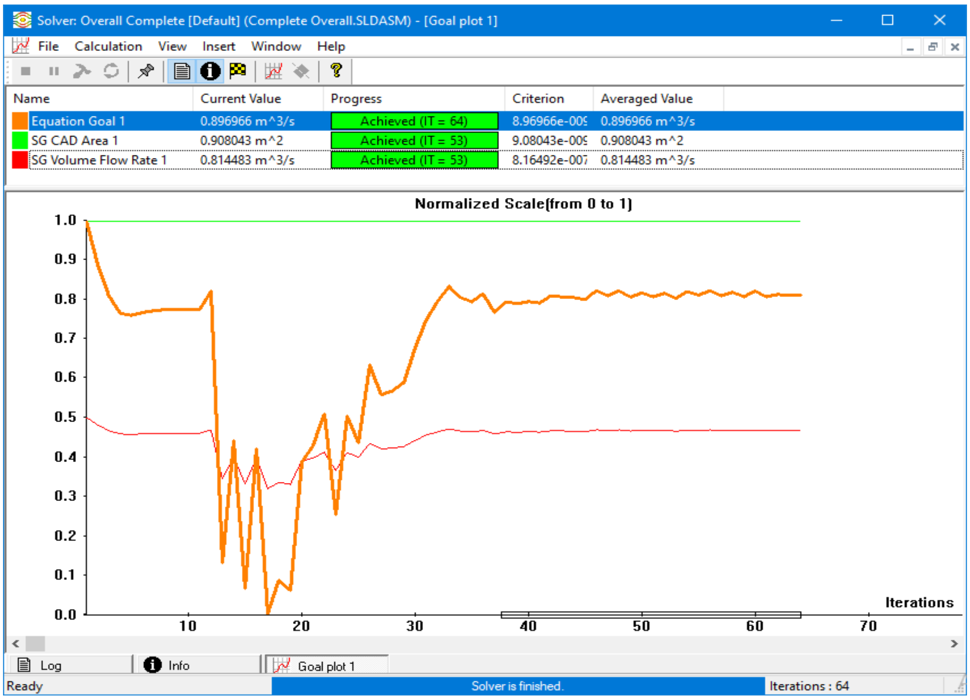

Fig. 6. Iteration of CFD tools, SolidWorks

CFD simulation results were then compared with actual experimental results using absolute error calculation as shown in the equation below:

$$E_{ABS} = |X_{CFD} - X_{exp}| \times 100\% \quad (1)$$

Where,
E_{ABS} is absolute error.
X is airflow parameter, which is air velocity.
$|X_{CFD} - X_{exp}|$ is the absolute difference between CFD simulation values and actual measurement values for variable X.

As a result, to analyze fluid flows, flow domains are subdivided into smaller subdomains (consisting of geometry primitives like hexahedra and tetrahedral in 3D and quadrilaterals and triangles in 2D). After that, the governing equations are discretized and solved inside each of these sub-domains. However, grid independence of the solution alone is insufficient to ensure that the solution obtained simulates what occurs in reality because other simulation assumptions, such as the accuracy of the boundary condition information supplied and the ability of the turbulence model, may be decisive factors in the simulation's agreement with physical reality. As a result, the results of CFD simulations must be thoroughly examined to assess the physical realism of the produced results. Figure 7 depicts creating a meshing process with refinement on an LEV geometry model.

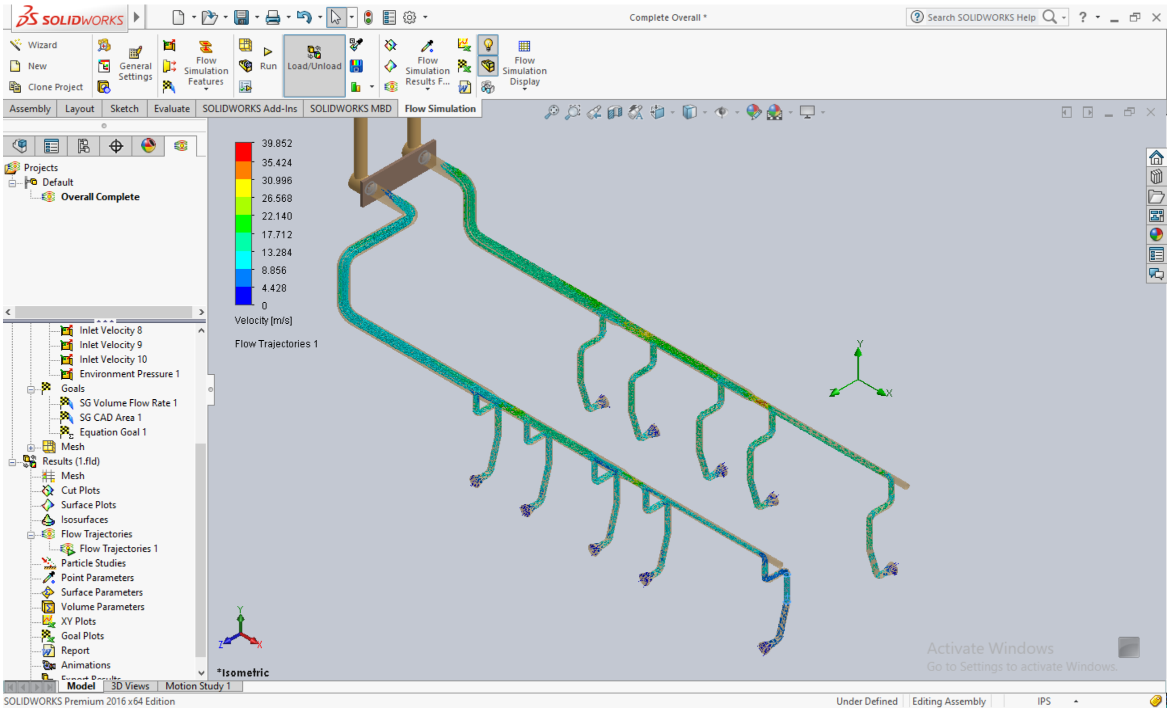

Fig. 7. Generate a mesh on the LEV geometric model

3. Results

3.1 Analysis Data of Actual Experiment on LEV System

The researcher did experiments and found the sixteen (16) locations. There are three (3) distinct sizes of round ducts in this laboratory, with diameters of 203mm, 154mm, and 102mm. A total of ten (10) LEV hoods are attached to the LEV system at UTHM's Welding and Metal Fabrication Laboratory, FPTV. The researcher measured velocity pressure at six (6) locations along the duct and ten (10) locations calculated on the LEV system's hood. Table 2 shows the research results of the experiment.

Table 2
The results of air velocity along ducts were actual experiment

Location	Velocity Pressure, VP (“wg)	Velocity, V (m/s) V=4005 X √VP	Static Pressure, SP (“wg)	Total Pressure, TP (“wg) TP=VP + SP
Duct 1	0.825	18.49	-2.850	-2.025
Duct 2	0.896	19.26	-2.040	-1.144
Duct 3	0.773	17.89	-1.123	-0.35
Duct 4	0.638	16.25	-3.500	-2.862
Duct 5	1.165	21.96	-3.320	-2.155
Duct 6	0.511	14.54	-1.458	-0.947

Table 2 shows that air velocity along ducts ranges 14.54 m/s to 21.96 m/s. The researcher used an anemometer to measure velocity along ducts. The anemometer had a statistical function and could measure and analyze maximum, minimum, and average values. The data gathered and stored in the anemometer can downloaded. The anemometer's screen shows the values of velocity pressure and static pressure.

Table 3 shows the results of measuring air velocity on the hood. During this data measurement, hood velocity ranged between 3.27 m/s and 1.94 m/s. The speed of the fan could not be obtained because the compartment covering the fan could not be opened.

Table 3
The results of air velocity were measured on the hood

Location	Velocity, V (m/s)	Location	Velocity, V (m/s)
Hood 1	3.27	Hood 6	2.92
Hood 2	3.25	Hood 7	2.56
Hood 3	3.22	Hood 8	2.56
Hood 4	3.19	Hood 9	2.33
Hood 5	3.12	Hood 10	1.94

The researcher has identified the selected location for the LEV system by referring to the procedures prescribed by DOSH. The actual experiment was conducted at sixteen (16) locations. The researcher measured velocity pressure at six (6) locations along the duct and ten (10) locations calculated on the LEV system's hood. The researcher drilled a hole at each location to allow the pitot tube to be inserted to measure the velocity and static pressure. The researcher will record the value obtained for further processing.

3.2 Analysis Data of Differentiate CFD Simulation with Actual Experimental Results

The results of CFD simulations for air velocity were validated with actual experimental results using Eq. (1) for absolute error calculations. The validation of air velocity results in Table 4 shows that absolute error ranges from 0.05% to 31.93%. However, the average absolute error is only 8.4%.

Table 4
The results of validation of air velocity

Location	Simulated Velocity, V_{CFD} (m/s)	Actual Velocity, V_{exp} (m/s)	Absolute Velocity Difference (V_{CFD}-V_{exp})	Absolute Error, E (%)
Duct 1	18.5	18.49	0.01	0.05
Duct 2	19.93	19.26	0.67	3.36
Duct 3	17.08	17.89	0.81	4.57
Duct 4	15.23	16.25	1.02	6.28
Duct 5	20.77	21.96	1.19	5.42
Duct 6	14.23	14.54	0.31	2.13
Hood 1	2.87	3.27	0.42	12.84
Hood 2	2.85	3.25	0.40	12.31
Hood 3	2.85	3.22	0.37	11.49
Hood 4	2.85	3.19	0.34	10.66
Hood 5	2.85	3.12	0.27	8.65
Hood 6	2.85	2.92	0.07	2.46
Hood 7	2.85	2.56	0.29	10.18
Hood 8	2.85	2.56	0.29	10.18
Hood 9	2.85	2.33	0.52	1.82
Hood 10	2.85	1.94	0.91	31.93

The disparity between the expected and actual values is referred to as absolute error. For example, the researcher has obtained a velocity measurement at Duct 1 which is 18.49m/s as a result of performing an actual experiment. While for CFD simulation, the researcher has obtained 18.5m/s at the same location, the absolute error is 18.5m/s minus 18.49m/s then the researcher will obtain 0.01m/s. The same calculation will be calculated at each location for the actual experiment and CFD simulation. The sum or difference of a number of numbers has an absolute error that is less than or equal to the sum of their absolute errors. The researcher has obtained absolute error ranges from 0.05% to 31.93%. However, the average absolute error is only 8.4%.

3.3 Identify Effectiveness LEV System in Using Validation Computational Fluid Dynamics (CFD) Simulation

Table 5 shows velocity obtained along ducts where the locations were chosen for the actual experiments. For this case study, velocity obtained along ducts ranges between 18.49 m/s to 14.54 m/s.

Table 5
Velocity along ducts where the locations were chosen for the actual experiments

Location	Duct 1	Duct 2	Duct 3	Duct 4	Duct 5	Duct 6
Velocity (m/s)	18.49	19.26	17.89	16.25	21.96	14.54

Table 6 shows hood velocity captured in this case study. For this case study, where ten (10) hoods are attached, hood velocity obtained ranges between 3.27 m/s to 1.94 m/s.

Table 6
Hood velocity obtained for every hood

No. of Hood	Hood 1	Hood 2	Hood 3	Hood 4	Hood 5	Hood 6	Hood 7	Hood 8	Hood 9	Hood 10
Velocity (m/s)	3.27	3.25	3.22	3.19	3.12	2.92	2.56	2.56	2.33	1.94

Table 7 shows the Guidelines on Occupational Safety and Health for Design, Inspection, Testing and Examination of LEV system by DOSH stated that the recommended minimum hood velocity is 100 ft/min (0.508m/s); while the recommended velocity along ducts for vapours, gases, smoke is 1000 ft/min (5.08m/s) and 2000 ft/min (10.16m/s) is required for welding.

Table 7
The inspection indicator for LEV system recommends by DOSH

Inspection Item	Inspection Indicator
Hood Velocity	Recommended minimum hood velocity is 100 ft/min (0.508m/s)
Velocity along Ducts	Recommended velocity along ducts for vapours, gases, smoke is 1000 ft/min (5.08m/s); and 2000 ft/min (10.16m/s) is required for welding

Figure 8 shows data collected from Computational Fluid Dynamics (CFD) Simulation, i.e.hood 10 velocity obtained is 1.94 m/s.

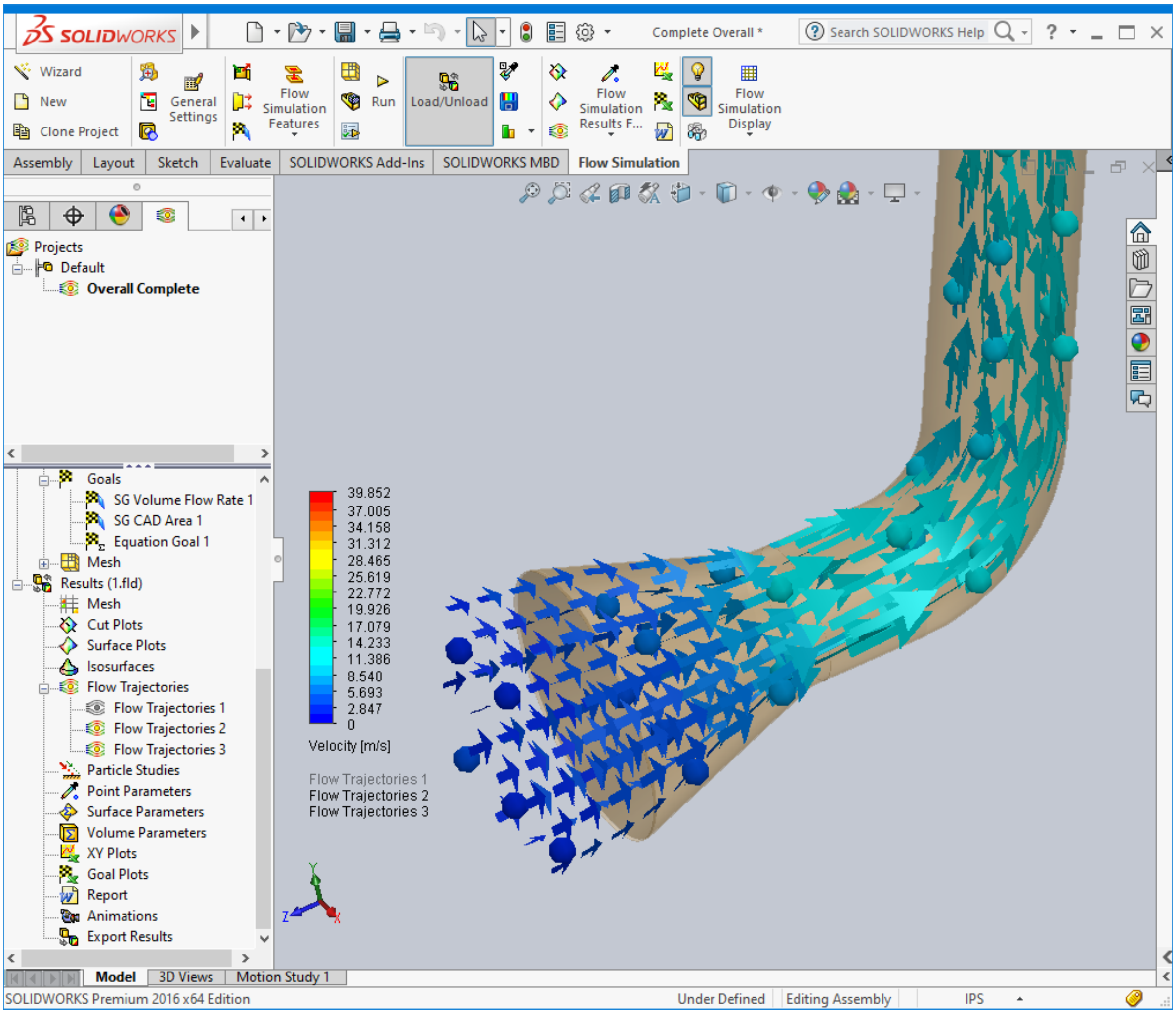

Fig. 8. Data collected from CFD Simulation (Hood 10)

This study, performed at the LEV system in the Welding and Metal Fabrication Laboratory, FPTV, found that ten hoods met the recommended minimum hood velocity requirement of 100 ft/min (0.508m/s). The particular hood obtains only 1.94m/s, which is caused by the design of the LEV system. This result can be shown in the CFD catering to the hood compartment space. However, the other nine hoods met the recommended minimum hood velocity and all the DOSH criteria, ranging from 3.27 m/s to 1.94 m/s. The LEV system of this laboratory also achieved the recommended velocity along ducts for welding, ranging from 18.49 m/s to 14.54 m/s. Therefore, in the Welding and Metal Fabrication Laboratory, FPTV is deemed adequate to be used for contaminants of welding as long as the particular hood barely reaches the recommended minimum hood velocity of 100 ft/min (0.508m/s), which is recommended by Guidelines on Occupational Safety and Health for Design, Inspection, Testing, and Examination of LEV system by DOSH stated.

Figure 9 shows a graph of the velocities of each location at the Welding and Metal Fabrication Laboratory, FPTV, in UTHM. The data are obtained in a descending pattern from velocity 21.96 m/s at location 1 to 1.94 m/s at location 16.

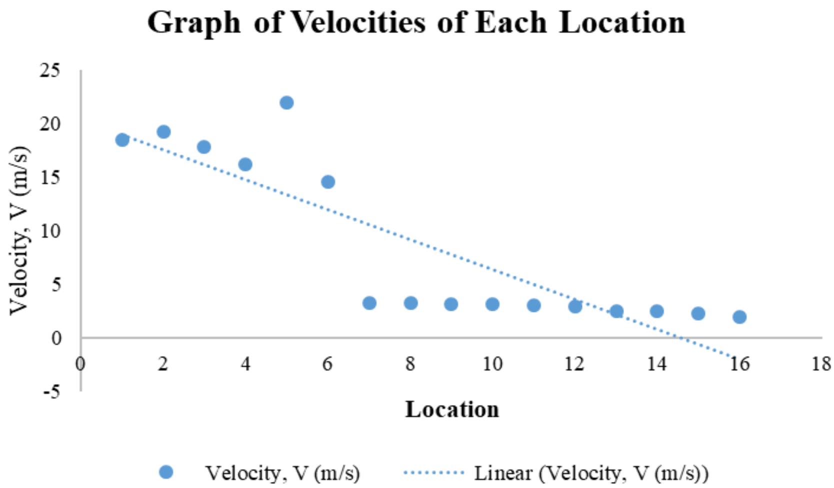

Fig. 9. Graph of velocities of each location at Welding and Metal Fabrication Laboratory

Table 8 summarizes this case study's overall LEV system effectiveness, where cross represents ineffective and thick represents ineffective. Therefore, the LEV system at Welding and Metal Fabrication Laboratory, FPTV, is deemed adequate to be used as long as it reaches the minimum velocity requirement recommended by the Guidelines on Occupational Safety and Health for Design, Inspection, Testing and Examination of LEV System by DOSH.

Table 8
Summary of overall LEV system effectiveness

	Effectives of Hood Velocity	Velocity along ducts where the locations were chosen	Overall LEV system effectiveness
LEV system in Welding and Metal Fabrication Laboratory, FPTV	✓	✓	✓

4. Conclusions

The research case is implemented at the Welding and Metal Fabrication Laboratory, FPTV, in UTHM. The main objectives of this study are to identify the effectiveness of the LEV system and to validate CFD simulation results with experimental results. According to actual experiment measurements, the airflow parameter measured in this case study is velocity. According to the DOSH Guidelines on Occupational Safety and Health for Design, Inspection, Testing, and Examination of LEV Systems, traverse insertion depths for round ducts must be measured using an anemometer and pitot tube. The DOSH guidelines also indicated that the acceptable minimum hood velocity is 100 ft/min (0.508 m/s), while the recommended velocity along ducts for vapors, gases, and smoke is 1000 ft/min (5.08 m/s). Welding requires a velocity of 2000 ft/min (10.16 m/s). In this research, the LEV system in the Welding and Metal Fabrication Laboratory, FPTV, satisfied all DOSH guidelines.

Regarding CFD simulations, the researcher drew the LEV geometry models of this case study using SolidWorks and imported them to flow simulation mode as an assembled file format to allow SolidWorks to run. The RNG k-Ɛ Turbulence Model was employed throughout the CFD simulations for this case study. Hood velocities were obtained from this case study using boundary conditions. The validity of the CFD simulation was determined by comparing the CFD simulation results to the actual experiment results in terms of the airflow parameter, which is air velocity. The average absolute error obtained from this case study is 8.4%. This percentage error range is shallow, at less than 10%. Therefore, it is possible to conclude that the validity of CFD simulation is satisfactory, and there is good agreement between actual experiment findings and CFD simulation results. Hence, it has been demonstrated that CFD may be utilized to model air velocity in an LEV system, reducing labor costs and time consumption. CFD can be used during the earliest stage of LEV development and through detailed design to observe the effects of design changes on the air behavior before actual construction is implemented.

Overall, this study was successful in meeting its objectives and scopes, which focused on determining the effectiveness of the LEV system and validating CFD simulation results with actual experiment data. This research will be valuable in future simulations involving airflow analysis. Nonetheless, future efforts may yield better outcomes.

According to the conclusions of this study, the effectiveness of an LEV system is determined by two measurements specified in the DOSH Guidelines on Occupational Safety and Health for Design, Inspection, Testing, and Examination of LEV Systems, which are measurements of hood velocity along ducts. These measurements are part of laws and regulations requiring LEVs to be in excellent condition to protect occupants from contaminants. It can also be utilized as part of LEV maintenance to determine whether or not the LEV system is still operational. Many occupants must know how crucial and dependable LEV maybe when its effectiveness is unknown.

There is no extensive analysis involving simulation before actual LEV construction to determine whether the LEV design drawn is practical to utilize. Once construction begins, it will take significant human resources and time to repair or create a new LEV design. CFD simulation can thus be conducted from the beginning or earliest stage of LEV design development to avoid this from happening again. CFD saves labor and time and delivers more specific and comprehensive information, such as airflow dispersion in an LEV system. The researcher determined the effectiveness of the LEV system by comparing minimum hood velocity and velocity along ducts using DOSH guidelines on occupational safety and health for design, inspection, testing, and examination. For future studies, the researchers suggest a detailed analysis can be conducted on a fan to determine the performance of the fan in the LEV system, for example, by comparing the design (before actual construction) and fabrication (after actual construction) of Fan Speed (rpm), Fan Static Pressure (FSP), Fan Total Pressure (FTP), Brake Horsepower (BHP) and Flow Rate (Q) to determine the percentage reduction.

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