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D10LP

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1 Introduction

This research aims to reach a conclusion on the methodology of improving the thermal environment by the means of keeping the energy requirements to a minimum. Alongside thermal environment, this report will discuss the indoor air quality of well air-conditioned welding room located on the ground floor of Heriot Watt University Dubai Campus. As welding is defined by the fabrication process with forges two materials by melting them together by using extreme levels of heat which allows to materials to fuse together to become one. The welding process manufactures a number of various fumes which has an impact on the user's health as it affects the eyes, throat and nose. Due to this, the indoor air quality of a welding room can be classified as harmful and 'poor' because the fumes created from the process are toxic.

Thermal comfort relates to the satisfaction of a user in a space through the thermal environment of the area. According to Sciencedirect.com, the thermal environment plays a huge role in the productivity of an occupant. As a result, thermal comfort is directly linked to indoor air quality as poor indoor quality leads to thermal discomfort for occupants in the welding room. Alongside this, the energy efficiency of the area is analysed to ensure proper and suitable air flow circulation is provided. The importance of this leads to safeguard the health of the workers in the room while meeting the standards for thermal comfort (ASHRAE Standards). This will allow the users to have control of the fumes generated from the welding process which limit the circulation systems to minimize the toxic fumes from staying in the area causing any harm to the occupants.

The current progressive design of the welding room contains 3 diffusers with centralized air conditioning controlled to maintain a satisfactory thermal environment in the room. As the room is annotated to sustain welding for a substantial period of time, the room is equipped with an air extraction system which removes the toxic fumes from the room. Alongside the air extraction system, the room is appointed with fresh air supply as well.

All this considered, this report aims to analyse and evaluate the welding room in order to develop a more enhanced system to ensure health and safety of the users by limiting the fumes from the 'breathing' space of the occupants. This is done by modelling the room in a Computational Fluid Dynamics Simulation software in order to visualize the air distribution in the room. This is important due to the fact that the this will reduce the energy consumption of the room.

2 Literature Review

Basic means of welding indicate the process of using extreme heat to fuse two or more metals together. Using high levels of heat can lead to toxic and harmful fumes and gases which could lead to unwanted and lethal health issues for the user. As welding is mainly used in the manufacturing process of a project, the users are indefinitely exposed to the toxic fumes. This is a serious problem and early research indicates that by investing some time and strategy into the ventilation systems could help reduce the risk of such harm to a user.

In order to reach a conclusion on whether or not the welding room requires any improvements in the ventilation systems, a computational fluid dynamic (CFD) software is used to design the area with specific parameters to achieve the most reliable results. The software will indicate the air flows inside the area and can determine the CO_2 readings that are generated in the breathing zones of users while working in their welding projects. Studies show that natural ventilation can have a major impact on the air distribution whereas, just HVAC systems would require a lot of maintenance and could lead to a huge investment depending on the equipment and the area allocated.

Thermal comfort can be defined as the term in which a person's state of mind is corresponding with the thermal environment around them meaning that a person physically feels whether too hot or too cold. in detail, the thermal comfort is a very difficult aspect to describe as it has a lot of contributing factors which differentiates from person to person. Thermal comfort isn't necessarily measured by noting down the room temperature but by the number of complaints from users about the thermal discomfort level of the area, whether it's a workplace or a general place where a number of occupants stay in for longer periods of time. Room temperature is a feature which affects the thermal environment rather than the reason for being the measurement used to determine the thermal environment of the area. there are six major indications of examining the thermal environment of an area which include, air temperature, relative humidity, radiant temperature, air velocity, clothing insulation and metabolic rate. All these factors contribute to the analysis of the thermal comfort of a space. To ensure the area is thermally comfortable for users to stay in for longer periods of the time, the values obtained from the six factors contributing to the thermal comfort of the space, are compared with the ASHRAE Standards. The values can be compared to the ASHRAE Standards by first using a 7-point scale shown in Figure 2.1. the ASHRAE Standards allow the room to maintain a sustainable thermal environment and provides the building with a decent rating which has a mental satisfactory impact on the users. ASHRAE Standards also dictate that the point scale allows the thermal comfort to be guaranteed for a point scale of -5 (cold) to +5 (hot).

Cold	Cool	Slightly cool	Neutral	Slightly warm	Warm	Hot
-3	-2	-1	0	+1	+2	+3

GATHERED SAMPLE

Totals of 523 and 498 valid questionnaires were gathered during summer and winter respectively. A percentage of 42% of the respondents are native Australians distributed along the different states (Fig. 3).

Fig 2.1

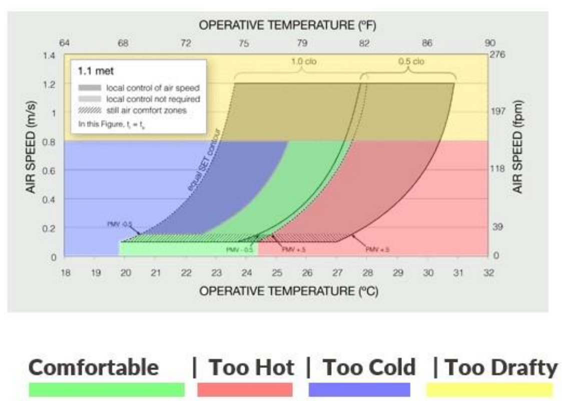


Fig 2.2

Indoor air quality, which will be analysed in this report alongside thermal comfort, is another important aspect when it comes to user satisfaction in a building or area. Indoor air quality (IAQ) refers to the health and comfort of the occupants of the area by the means of the air quality around them. Indoor air quality has a long-term effect on a user which can be shown after months or even years. Alongside long term affects, the immediate affects can include headache, dizziness and fatigue. This chains on to the productivity of the users regarding the indoor air quality.

Indoor air quality standards are also set by ASHRAE and OSHA which allows areas to maintain a healthy indoor environment. For this investigation, the indoor air quality relates to the toxic fumes created from the welding process in the room. As many reasons factor into place for user satisfaction relating back to indoor air quality, one of the main reasons is that people tend to spend more time indoors rather than a natural setting. This sheds light onto the fact that the importance of maintaining a healthy indoor air quality to allow the users to stay in these specified areas for a longer period of time. Poor indoor air quality can occur from poor circulation around the area.

The image on the left indicates the basic description and annotation of poor indoor air quality specified to each area.

As mentioned before, a computational fluid dynamic simulation software (CFD) is used to examine and analyse the air distribution of the room. A Computational Fluid Dynamics Simulation software allows a user to model a physical commodity which implicates fluid flow and numerically solving the process through computational means. As this simulation determines the fluid flow of an object, the various factors that are covered in this software help the user to gain the knowledge of the air flow of the selected area. These factors include, velocity, air temperature , density, viscosity, and pressure. This relates back to the points of thermal comfort and indoor air quality as it determines how comfortable the environment is and if the air quality inside the room is safe for users to be productive in. For this investigation, the CFFD Software used is ANSYS 2019.

3 Aims & Objectives

3.1 Aims

The aims of this investigation include:

1) Analyse the thermal comfort of the air flow of the air conditioning system of the welding room by using a computational fluid dynamic simulation software to model the area.
2) to determine whether or not there is room for improvement relating the thermal comfort of the room by presenting new ideas and designs
3) To study the factors that affect the air distribution in the welding room itself.

3.2 Objectives

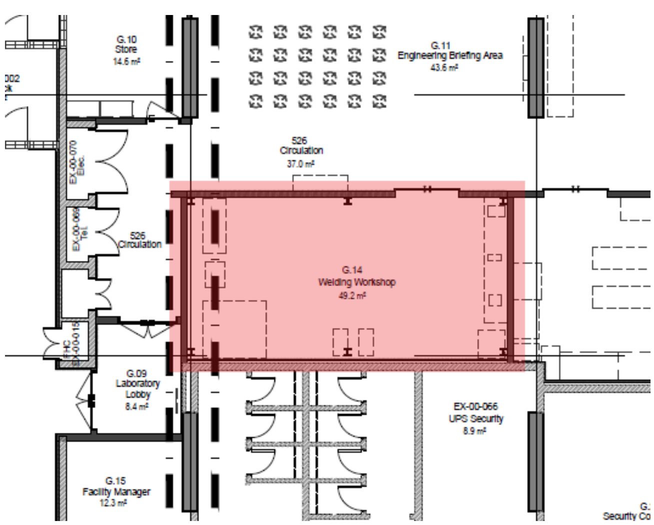
The main objectives of this project include:

1) Testing the sensitivity and effect of various air flow patterns and velocity on thermal comfort using the design aspect of the CFD software
2) Using Dubai Green Building Regulations, ASHRAE Standards and OSHA to examine new designs that improves the thermal comfort of the welding room

4 Methodology

4.1 Setting

The welding room is located on the ground floor of the Heriot Watt University Dubai Campus. The figure below shows the precise location of the room. It is stationed with the rest of the laboratories relating to engineering. The room is accessible to staff, and engineering students which have a course relating anything with welding.



Key

Welding room

The welding room is annotated as the 'Welding Workshop', as shown on the left. Its entrance is accessible first by navigating from the Laboratory Lobby (Left hand side of the image)

4.2 Apparatus

The following are the basic apparatus that was utilized in order to obtain reliable measurements for the various aspects of the room.

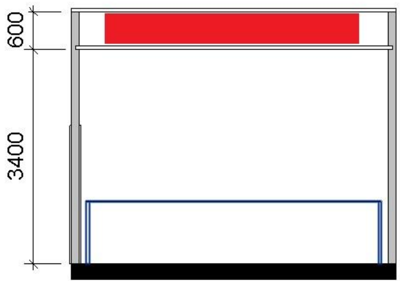
1) Measuring Tape
2) Heat Stress monitor - Wet Globe Thermometer
3) Thermo-Anemometer
4) Thermal Image Camera
5) ANSYS CFD Software (Design Modeler/Fluent)

4.3 Dimensions & Details

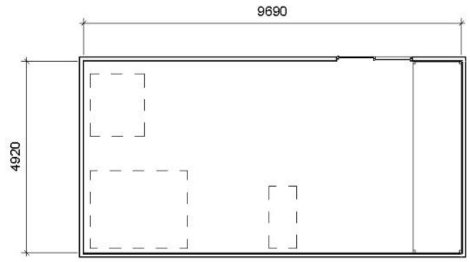
The method to collect and analyse the data was very straightforward in the sense of procedures. From attaining the measurements of the area to reaching a conclusion on where improvements could occur, everything was taken into consideration.

To start off with attaining the basic measurements needed to model the building in ANSYS. This includes the height, width, length of the room; the equipment in the room, for example, tables; the height and width of the door; and the duct placement dimensions (Table 4.3 shows all the dimensions mentioned). Moving on, the model replicated the actual design of the room to provide results of the thermal environment. This includes, air temperature, relative humidity, heat gains and dewpoint. The CFD software design is then adjusted with relevant changes in order to obtain a better thermal environment and can be tested through different measures such as different design parameters and some unique features which contribute to the air flow/distribution of the room. After multiple entries, the best achieved results can be proposed as the solution for air distribution. Furthermore, the entries inputted into the software can be set side by side to the locations building regulations as well as global thermal environment standards of a welding room. This would help the room to be free from any thermally comfortable flaws statistically. The CFD model will be explained more in detail further on in the report.

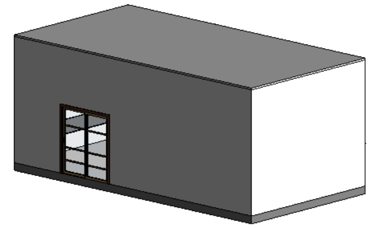
The images below visualize the welding room with the correct dimensions and placement of the equipment inside the room.



The above image is a section of the room indicating the duct work (RED PART) and the floor to ceiling height



Dimensions of the welding room

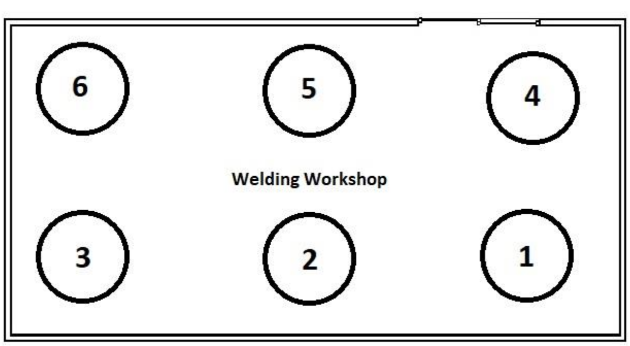


3D view of the entire room excluding its surroundings.

Room Dimensions	4.92 x 9.69 m
Ceiling Height	3.4 m
Height of Door	2.12 m
Width of Door	1.92 m
Height of Table	1.01m
Width of Table	1.23 m
Total Length of 2 Tables	4.9 m
Length of Duct	1 m
Width of Duct	0.2 m
Distance between 2 Ducts	1.75 m
Distance of Duct from Wall	2 m

Table 4.3 shows the dimensions of the main factors contributing to the ANSYS model.

To measure the thermal environment of welding room accurately, 6 different points were chosen inside the room to record the air temperature and relative humidity. This method was done in order to ensure accuracy of the readings and to determine the difference of the values when navigating through the room. this will allow the user to have the knowledge where there is room for improvement. The following table consists of the various different values obtained using the 'Heat Stress monitor - Wet Globe Thermometer' to record the temperature.



The key on the left clearly identifies the spaces where the measurements were taken from

No	Spot	Height from ground	Ta (°C)	Avg, Ta (ºC)	RH (%)	Avg, RH (%)
1	**One**	0m	20.3	**17.01**	65.2	**68.38**
2		0.4m	19.9		68	
3		0.8m	19.8		68.7	
4		1.2m	19.9		68.8	
5		1.6m	19.9		69.4	
6		2m	19.3		70.2	
7	**Two**	0m	19.6	**19.80**	71.2	**71.40**
8		0.4m	19.8		71	
9		0.8m	19.9		70.9	
10		1.2m	19.8		71.6	
11		1.6m	19.9		71.7	
12		2m	19.8		72	
13	**Three**	0m	20.3	**20.88**	71.4	**70.52**
14		0.4m	20.6		71.1	
15		0.8m	21		70.4	
16		1.2m	21.1		70.1	
17		1.6m	21.1		70.2	
18		2m	21.2		69.9	
19	**Four**	0m	22.7	**22.77**	60	**60.08**
20		0.4m	22.8		60.1	
21		0.8m	22.9		59.7	
22		1.2m	22.8		59.5	
23		1.6m	22.8		59.5	
24		2m	22.6		61.7	
25	**Five**	0m	22.4	**22.25**	61.3	**61.63**
26		0.4m	22.3		61.4	
27		0.8m	22.3		61.5	
28		1.2m	22.2		61.5	
29		1.6m	22.2		61.6	
30		2m	22.1		62.5	
31	**Six**	0m	22	**21.85**	62.7	**63.08**
32		0.4m	21.9		62.9	
33		0.8m	21.9		63	
34		1.2m	21.8		63.1	
35		1.6m	21.8		63.2	
36		2m	21.7		63.6	

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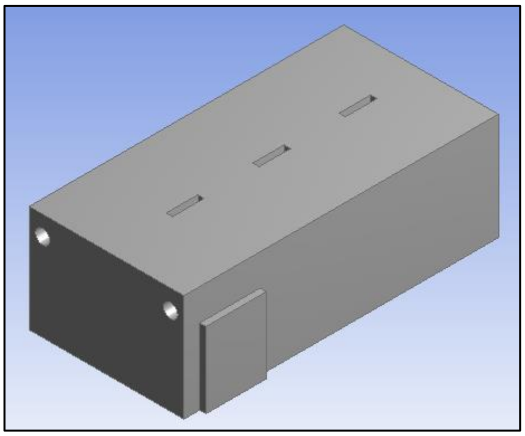
The table shows the different measurements obtained.

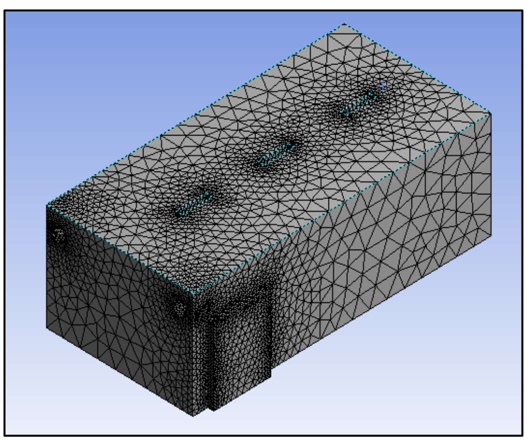
The values collected from the table are analysed by calculating the average temperature and relative humidity to evaluate each section of the room accurately as possible. An observation can be made, by examining the average temperature and average relative humidity , that the temperature fluctuates from each space ranging from 4.9^{O}C stating that the temperature isn't controlled throughout the room.

4.4 Summarized Results



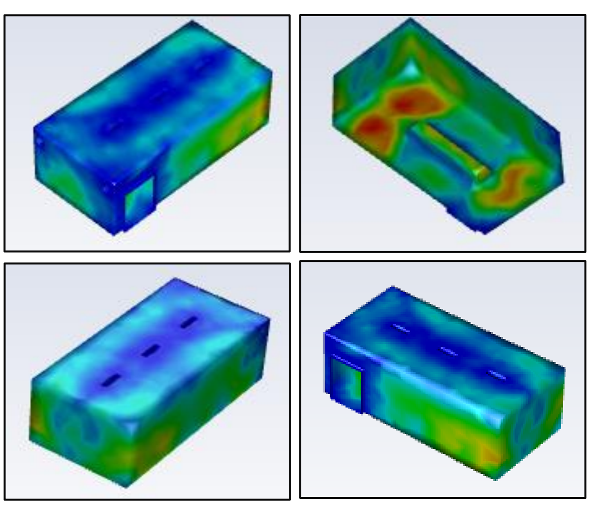
Geometry

Fig 4.4, The geometry model created via the dimensions mentioned above. This is created in ANSYS GEOM, to establish the most accurate model. There aren't any windows located in the room however fresh air is supplied to the room. 3 diffusers supply centralised air conditioning to the room. The geometry is created in ANSYS DesignModeler.



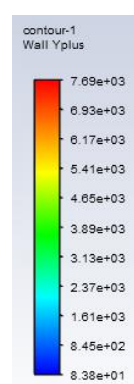
Mesh

Fig 4.5, The mesh created around the geometry file replicates the air flow/distribution around the room. the orthogonal quality of a maximum of 0.99516 with the minimum of 0.15036 proving the mesh is clearly in the acceptable range which is >0.05. The mesh is modelled with an exact amount of 99196 elements with 18865 nodes.



Fluent

Fig 4.6, The various views shown in the images on the left showing the air flow around the modelled room. The coldest part of the room is evidently around the diffusers and the warmest are of the room is shown on the floor part (this will further be explained in the 'Air Distribution Section)



4.5 Air Velocity

Air velocity of a room can be defined as the certification of the pressure that is originated by the movement of the air in an area. This is an aspect which correlates with the air distribution, possibly the most affective factor disturbing air distribution. The air velocity determines how fast the air enters the room whether it is from mechanical ventilation systems or natural ventilation.

For this investigation, the air velocity measurements were recorded manually by using a Hot Wire Anemometer, a thermal transducer which uses electric voltage measurements to calculate the transitory air flow of an area. the values were tabulated along with the temperature and relative humidity of the welding room. Measuring the air velocity in the welding room allows the occupant to gain the knowledge of whether or not the air velocity is one of the main reasons affect the air distribution of the room which chains on to affecting the thermal comfort. Air velocity also plays a huge role in maintaining the acoustic environment of the room. The following are the tabulated results for the air velocity measurements.

Position	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**Average**
Velocity (m/s)	2	2.58	0.37	2	1.86	0.56	1.78	1.72	0.96	0.8	0.2	0.55	2.6	3	2.9	**1.592**
Temperature (°C)	17.8	18	18.1	17.9	17.8	18.4	18	18.1	18.4	20.3	20.8	20.8	21.8	22	22.1	**19.35**
Relative Humidity	71.5			67			67.6			66.5			65.4			**67.6**

4.6 Air Distribution

The air distribution refers to the air circulation or sir dispersion in a well-conditioned space. Each conditioned space includes an air distribution system which allows an area to have a controlled thermal environment. This allows a user to feel, mentally and physically, more comfortable in the space they are in. Air distribution is a concept that needs to be inspected and maintained throughout a long period of time. the theory of air distribution should be analysed thoroughly before implementation due to the fact that it can greatly affect the thermal comfort of the room.

The air distribution used in the welding room is overhead air distribution, instead of underfloor air distribution, as buildings don't naturally require underfloor air distribution in UAE as it is mainly used for floor heating. Poor overhead air distribution could result in poor indoor air quality as the air distribution is designed to mix the air volume in the room, hence if the air distribution system is equipped with inadequate material or machinery, the air pollutants diffused in the air can linger longer in the air which can affect the health of the occupants. Especially in a welding room in which there are toxic fumes being created would affect the occupants, lungs, nose, throat etc. to a greater level than expected. The air distribution of the welding room is visualized through ANSYS Fluid Flow Fluent. It helps to gain the knowledge how the air is flowing through the room.

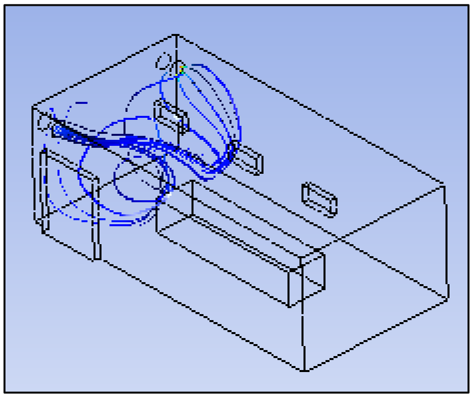


Fig 5.1, The image shows the air flow from the fresh air supplied to the room. It determines that the air distribution is a little disturbed however, the fresh air supply does cover the air of welding where the fumes are created. In basic terms, the distribution for the fresh air supply can be improved.

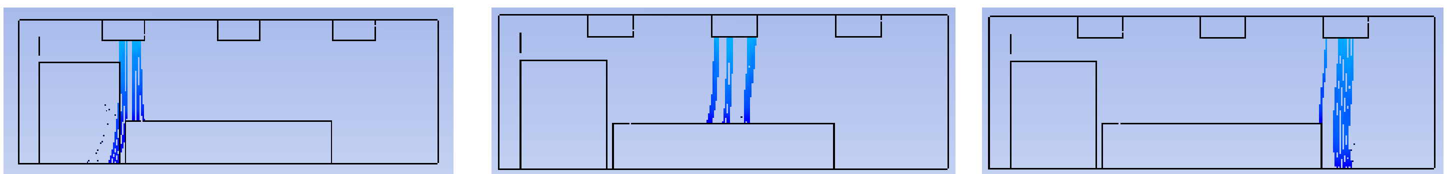


Fig 5.2, To understand and examine the air flow and distribution of presented from the diffusers is complicated even when modelling the room with accurate details. It is complicated in the sense of the unknown flow of the air which reflects form various objects in the room. Another factor that comes into play is if any equipment contains a cooling fan which is mainly used in computers, monitors, 3D printers etc. the air flow disturbed from those certain objects cannot be replicated in the CFD software for them to be examined. In this case, welding requires great forms of heat which essentially warms the air around the flame which causes the air to rise as it has the capability to expand when exposed to higher levels of heat. The images shown above show the basic air flow and distribution of provided by the diffusers. The real air dispersion of the welding room will be much more dispersed and distributed than shown in the images due to external factors affecting the distribution.

5 Improvements

After studying many various aspects regarding thermal comfort of the welding room on the ground floor of the Heriot Watt University, it can be stated that there is room for improvements. These improvements could help the building in reaching a better ASHRAE standard reading and would help the room in meeting a better 'green' classification from the Dubai Green Regulations. Improved thermal comfort of the welding room could propose better health for the occupants for over a longer period of time.

The first improvement that will help the thermal comfort of the welding room can be implemented be changing the position of the outlet. By transferring the outlet position from the wall to the ceiling could allow better air distribution of the room. this would help reduce the effect of quiescence. Applying a temperature of 21OC, according to Dubai Green Building Regulations, the outlet will have a controlled temperature with approximately 0.25 m/s of air velocity will have a major impact in the air flow of the welding room. from a user satisfaction point of view, this will neglect the effect of 'stuffiness' in the room.

Another improvement helping to control the thermal environment can be implementing a better air distribution system. This is a main aspect which if implemented correctly can help the room meet the energy requirements which chains on to cost saving measures. One factor is increasing the size of the diffusers and the inlet supply. This would affect the air distribution by using the surface air of air flow to its potential.

6 Conclusion

To conclude this report, the discussion about the thermal comfort of the welding room situated in Heriot Watt university can and should be improved with some alterations. This investigation thoroughly examined the thermal environment and indoor air quality of the welding room.

Taking the measurements for temperature, relative humidity, and air velocity from the welding room itself by using the correct apparatus. The measurements were taken multiple times at different spots in the room to ensure having accurate and reliable readings. That allowed investigators to visually oversee any changes that could help improve such air qualities. Noted down the potential readings that need to be altered in order to help the user satisfaction of the welding room.

The readings obtained from measuring every required aspect of the room were put to use in modelling the room in a computational fluid dynamic simulation software, ANSYS 2019. This software would help to visualize the air flow, air distribution and air velocity of the welding room. Using the potential of the software to create a mesh like form of the room to foresee the air distribution in the room. By implementing the mesh to another feature of the software, ANSYS Fluid Flow, which would help to determine, with details, the actual air flow and air distribution. The model was updated with the air velocity measurements and each factor of the room was assigned to its real feature which would allow the software to know the exact air distribution in the room. ANSYS Fluid Flow provides numbers and figures determining if the thermal comfort of the welding room is substantial.

Examining thermal comfort, especially for a welding room, is extremely important as it will help the health and safety of the users as indoor quality is directly related to thermal comfort and would help user satisfaction in the form of productivity. The thermal comfort values are compared to global standards such as ASHRAE Standards and OSHA along with Dubai Green Building Regulations. This is another aspect that will help in improving future areas that require a good thermal environment.

7 References

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