SIMULATION MODEL OF AN AIR FRESHENER FLOWS IN A ROOM BY AN AUTOMATIC SPRAY

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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Date……28/06/2021…….

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated.

Other sources are acknowledged by giving explicit references.

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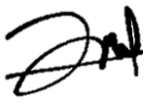
Signed……  ……. (NURUL RIFHANI BINTI ROZANI)

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ABSTRAK

Pasaran penyegar udara di seluruh dunia bernilai $ 10,124.4 juta pada tahun 2017 dan dijangka bernilai $ 13,279.1 juta pada tahun 2025, meningkat pada CAGR (Kadar pertumbuhan tahunan majmuk) 3.5 peratus antara 2018 dan 2025. Pasaran penyegar udara telah dibahagikan kepada empat segmen: jenis, penggunaan akhir, saluran pengedaran, dan wilayah. Produk pasaran telah dibahagikan kepada beberapa jenis, termasuk elektrik, semburan, gel, dan lain-lain. Penyegar udara adalah produk yang mengeluarkan aroma untuk menghilangkan bau yang tidak diingini dari dalam bilik. Untuk kepuasan pelanggan, memaksimumkan aroma penyegar udara di ruang adalah sangat penting. Dalam projek ini, peredaran aliran penyegar udara di ruang tertentu dikaji untuk meningkatkan aroma yang dihasilkan oleh semburan penyegar udara automatik. Model simulasi semburan penyegar udara automatik dengan jumlah yang berbeza di ruang tamu telah diperhatikan untuk mengenalpasti kesan jumlah semburan automatik di dalam bilik terhadap peredaran aroma. Hasil analisis menunjukkan bahawa ruang tamu dengan jumlah penyegar udara automatik tertinggi mempunyai peratusan isipadu tertinggi dengan nilai 0.95%. Hasil projek ini dapat menyumbang kepada industri pembuatan penyegar udara automatik dengan cara meningkatkan pembelian pelanggan untuk meningkatkan kepuasan mereka terhadap produk penyegar. Maka akan menguntungkan pengeluar.

ABSTRACT

The worldwide air freshener market was worth $10,124.4 million in 2017 and is anticipated to be worth $13,279.1 million by 2025, growing at a CAGR (compound annual growth rate) of 3.5 percent between 2018 and 2025. The air freshener market has been divided into four segments: type, end-use, distribution channel, and region. The market has been divided into several types, including electric, spray, gel, and others. An air freshener is a product that releases a scent to remove unwanted odours from a space. For customer satisfaction, maximizing the scent of an air freseher in a space is of paramount importance. In this project, the circulation of an air-freshener flows in a particular space were studied to enhance the scent produced by an automatic spray. A simulation model of an automatic air freshener spray with a different number of it in the living room were presented to investigate the effect of the number of automatic spray in a room on scent circulation. The analysis results shows that the living room with the highest number of automatic air freshener has the highest percentage of the volume occupied with value of 0.95%. This project findings may contribute to guide customer purchases to enhance their satisfaction of the freshener product. Then will benefit the manufacturer.

CHAPTER 1 INTRODUCTION

1.1 Overview

Airflow happens when there are existences of air. The principle of airflow is the flow of air due to pressure difference at two different points. This pressure difference can result in the air flowing from the area with higher pressure to an area with lower pressure. The quantity of air that flows through a duct and the speed at which it flows depends on the degree of pressure differential produced (and the resistance of the device or friction). The greater the pressure differential, the greater the volume of air that can flow for a given period[1]. The distribution of various parameters like temperature and velocity has been studied to determine the best placement location for the air conditioner blower and the area suitable for the occupant[2]. Then, the CFD simulations are validated based on wind-tunnel measurements of mean surface static pressures and mean indoor airspeed for a one-sided wind-catcher to determine the airflow of wind and air conditioner [3]. In this project, the propagation of an air freshener from the automatic spray will be studied based on the affected area after the air freshener sprays the liquid that contains odour in the bottle to space.

Nobody like a room with an unpleasant smell, but unfortunately, odours can regularly happen, especially in a room with no window. All the fragrances will stick in that room. The scent can be disgusting if someone is sweat or there is food in the room. Therefore, many people frequently use an automatic air freshener in their households and workplaces to keep the room fresh and fragrant. Air fresheners are available in various formats, including sprays, gels, oils, liquids, solids, plug-ins, hanging discs, beads, potpourri, wick diffusers, and scented candles. They can be active or passive, and they can emit aroma instantly, intermittently, or continuously to disguise or minimise unwanted room smells is an air freshener. Usually, these products inject scent into the air and other odour counteractants. It comprises odour-neutralising chemicals such as aerosol propellants, perfumes, and solvents such as 2-butoxyethanol, mineral oil, and glycol ethers.[4]

The room smells and air fresheners are particularly popular right now, thanks to the growing "wellness business." Certain odours are claimed to be linked to feelings of

well-being and an increase in personal efficiency, among other things. The bulk of explanations for these phenomena rely on the ancient notion of essential oil aromatherapy–the physiological and psychological effects of essential oils have long been recognised in aromatherapy. The olfactory advantage seems to be influenced differently by gender, with women having more incredible olfactory performance. The olfactory system is defined by its close ties to memory and emotion-related brain areas such as the hippocampus, thalamus, and frontal cortex. The olfactory tract transports axons from the olfactory bulb to the primary olfactory cortex, made up of several components.[5]

The endurance of its scent, however, relies on room space. Therefore, to help customer satisfaction of the commodity, the distribution of air-freshener flows in a specific space needed for the investigation. The area covered by the air freshener when the spray bottle was pressed will be determined using an ANSYS CFD Software simulation. This project results may help the air freshener's product customer satisfaction regarding how many spray bottles needed in a particular space. The air freshener that will be used in this project is an automatic air freshener dispenser wall mounted.

1.2 Problem Statement

In the pasts, related works were concentrated on the simulation of airflow in lecture rooms[6] and analysis on improving lettuce canopy airflow distribution in a plant factory by using the CFD method.[7] Recent works considered a different location of air condition and how it will affect the airflow in that room. Existing results were limited to simulation and modelling the airflow in a space. No studies had analysed the airflow of air freshener when the spray was press in a closed space living room. As the airflow is determined by several factors, the propagation of air freshener flow in space needed to study.

1.3 Objectives of Project

The objectives of this project are:

i. To develop the simulation model to investigate the propagation of air-freshener flow in a room.
ii. To identify the spread volume of the air freshener when the bottle is pressed.

1.4 Scope of Work

The scope of work for the Final Year Project of Simulation model of an air freshener flows in a room by an automatic spray includes all the planning, researching and simulation. His project aims to help air freshener manufacturing's company improve their customers or client's satisfaction. The first stage of the project is to start with a proper research study to get an overview and some idea on what to do by studying the method used. The next stage is a progress report of what going to do in the simulation method and procedure. Then, preparing a thesis and presentation. Each stage needs to be submitted to the respective supervisor to get their approval.

CHAPTER 2 LITERATURE REVIEW

2.1 Air Flow

The movement of air is referred to as airflow. The presence of philosophy is the primary cause of airflow. Particles naturally move from a location of tremendous pressure to places of lower pressure because air functions in a fluid manner. Altitude, temperature, and composition all have an impact on atmospheric air pressure. When the air freshener sprayed the particle inside it to spread the fragrance, the space that affected can be determined by finding the airflow of the air freshener. Airflow is the movement of air between two points, and the movement can be caused by two factors: a square root of the pressure drop between the two points and the efficiency of the component being tested.[8] There are a few ways to calculate the airflow using the air balancing hood measurement, traverse the airflow in the exhaust duct, plot the fan airflow, or combine one or more test methods to get a more accurate airflow decision result. [9] The calculation of airflow is usually done to increase customers' satisfaction and comfort level and provide a better service, especially in the manufacturing of air conditioning or fan since this is an essential thing that everyone will have in their house or company.

Most of the paper reviewed talks about the simulation of airflow in air conditioning like in[2]. In this paper, the airflow was calculated using a different air conditioner position in the same type of room. The airflow was calculated by finding the turbulent kinetic energy, k, and dissipation rate ɛusing this formula.

$$\rho \frac{D_\varepsilon}{D_t} = \frac{\partial}{\partial x_j}\left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial xj}\right] + C_{\varepsilon 1}\frac{1}{2}[P_{ii} + C_{\varepsilon 3}G_{ii}]\frac{\varepsilon}{k} - C_{\varepsilon 2}\rho\frac{\varepsilon^2}{k}$$

In [7], the paper talked about the simulation of airflow in the different ventilation system to achieve the most suitable design at the crop canopy surface. The airflow was calculated using the numerical modelling of airflow distribution in the CFD solver (Ansys Fluent). In the paper [10], a study of airflow and temperature

distribution was done in an air-conditioned car. The simulation was conducted in a vehicle with different locations by considering the level of the human's part body and the seat location using the numerical simulation in Fluent software. In [11], the paper was talked about developing the airflow meter by improving the blower design in a multiple configuration nozzle using the CFD simulation software. To evaluate the air distribution performance in lecture rooms, a simulation was conducted by considering the different air conditioning locations with the same arrangement to see which one can have a better airflow by using the CFD modelling.[12].

Numerical modelling of the air conditioning unit was done in an article [13] to observed reduction by the interaction of the flow-through air conditioning unit with the flow boundary layer of the train roof. The source term consists of two parts to simplify the air conditioning unit model: the viscous term associated with Darcy's law and the inertial term, proportional to the square of velocity.

$$\Delta p = \frac{1}{2} C_2 \rho \beta v^2 + \frac{\mu}{\alpha} \beta v$$

Then, there is a paper that modelling the airflow rate is significantly flattened rounded rectangular ventilation ducts. [14]. The measurement in this paper was considering the geometry similarity and modelling the volume flow rate. In [15], the evaluation of airflow and thermal comfort was simulated in buildings ventilated with windcatcher using the CBE tool to know the airflow with the influence of windcatcher geometry. In mine tunnels, my ventilation is the process of continually inputting fresh air and outputting polluted air. Therefore, a simulation of airflow distribution was conducted using the numerical simulation by analysing the airflow pattern and average velocity distribution. [16]. In [17], to validate the developed numerical model, three air properties(temperature, relative humidity and velocity) were measured simultaneously over a significant part of the indoor swimming pool with instruments installed in a mobile forklift. This parameter is used to simulate the airflow with heat and mass transfer in an indoor swimming pool. Next, a simulation showing the meshing and excellent computing performance to show the superb scalability in a substantial scaling test at a complex terrain surface was simulated. [18]. By doing the airflow simulation, micro-particle deposition in human nasal airway pre- and post-virtual sphenoidotomy surgery can be known [19]. A better surrounding can also be achieved

if a simulation of airflow was simulated conducted at that place to see the pollutant dispersion. [20]. In [21], demonstration of the seamless integration of geometry modelling, meshing and analysis tools using linear, quadratic and cubic spline elements and the achievable accuracy to simulate flow around a two-dimensional NACA0015 airfoil was conducted.

2.2 Spray Parameters

Three separate factors can be used to characterise a spray (droplet Sauter-meandiameter,d_{32}, droplet velocity,V, and droplet flux,N). [22] In research study written by Ruey-Hung Chen, the study was done a research about "Optimal spray characteristics in water spray cooling". In this investigation, each of these characteristics was changed while the other two were held constant by utilising a mixture of spray nozzles, operating pressures, and distance between the nozzle exit and the heating surface.

In order to describe a spray under certain conditions, a number of parameters are established. The following are some examples of widely used parameters:

i. Penetration length is the distance from the nozzle to the end of the spray.

ii. Spray angle: The spray angle determines the size of the spray. It is defined as the quasi-steady angle achieved after the spray head has passed.

iii. Sauter Mean Diameter (SMD): The SMD of a droplet in a spray is often used to define its size. SMD is proportional to the surface to volume ratio and has the benefit that even if the droplets are not spheres, their surface to volume percentage is comparable to a sphere, so they heat up and evaporate in the same manner. [23]

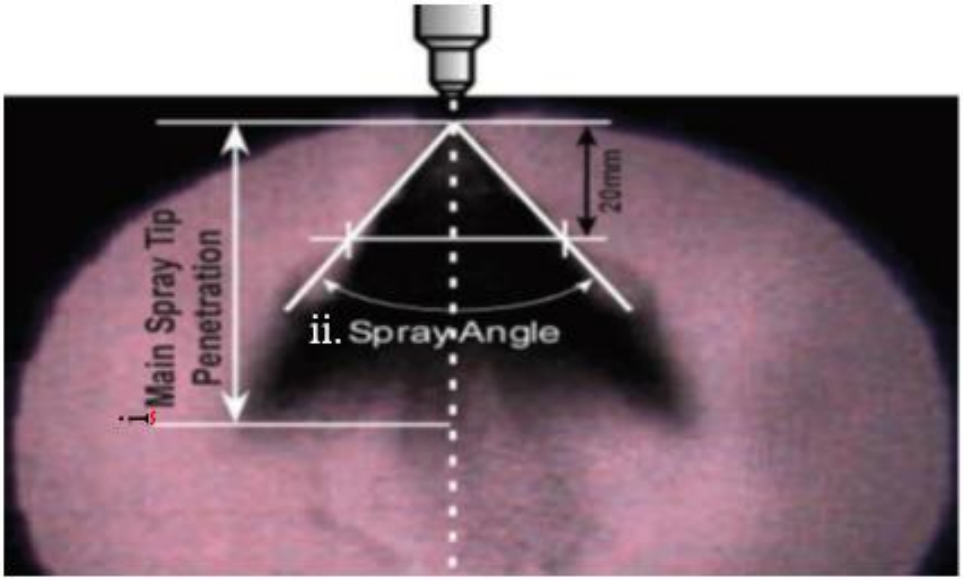


Figure 2-1 : Spray tip penetration and spray angle[23]

2.3 Air Freshener

Air fresheners are consumer goods that emit a scent to provide a room with a fragrance, to mask an odour, or both. There are various versions of air fresheners, including sprays, gels, oils, liquids, solids, plug-ins, hanging disks, beads, potpourri, wick diffusers, and scented candles; inactive or passive forms; and with immediate, occasional, or continuous-release. [24] The air freshener can be connecting to the ventilation or air conditioning that can emit a fragrance through the flow from that ventilation and air conditioning. In the air freshener, there might be various volatile organic compounds classified as toxic or hazardous under U.S. federal laws, including fragrant chemicals, and each product emitted at least one of these compounds.[25] The article written by S. Perera about “Measurement and Analysis of Indoor Air Pollutants in a Room Sprayed With a Locally” talks about the investigation that he has done to measure the concentration of a few gases due to spray of air freshener onto the air.[26] As a result, air freshener contains many total volatile organic compounds that can cause lung irritants and asthma attacks with a long term usage of air freshener in a room. In an experiment conducted to identify the risk of air freshener, almost the whole target fragrance ingredients in air fresheners were detected, showing a high detection level.[27]

2.4 Composition of Air Freshener

VOCs, which are principal emission chemicals, are emitted by air freshener products. Terpene, ethyl alcohol, benzene, toluene and xylenes are significant VOCs released by air fresheners. [28] These compounds are commonly referred to as "perfume" or "fragrance" on product labels. Table 2-1 shows some compound that had been found in the air freshener bottle.

Compound	Max. (mg/kg)[b]	Mini. (mg/kg)[c]
Benzene	0.7	0.005
Formaldehyde	96	4.9
Benzyl alcohol	46.4	7.8
d-limonene	1.507	0.15
Linalool	228	93
α-pinene	596.3	0.06
Toluene	11.9	0.04
Xylene	0.7	0.003

[a] Nazaroff and Weschler, 2004; Carslaw, 2007; Wolkoff, 2013a.
[b] Max. Con.: The maximum detected concentration in air fresheners.
[c] Mini. Con.: The minimum detected concentration in air fresheners.

Table 2-1 : The contents and the detected chemical compounds found in the air freshener.

2.4.1 Terpene

Terpenes are aromatic chemicals present in many plants, but they are most usually associated with cannabis because of the large amounts of cannabis plants. The molecular formula for terpene hydrocarbons is (C5H8)n, where n is the number of units involved. Isolated terpenes are used to generate the tastes and fragrances of various common items, including perfumes, body goods, and even meals. When these chemicals are present in a living plant, they are known as terpenes. Terpenes, for example, oxidise and produce terpenoids as a plant dries and cures in the creation of cannabis.

2.4.2 Ethyl alcohol

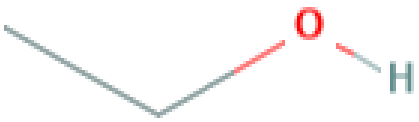


Figure 2-2 : Chemical structure of ethyl alcohol[29]

Ethyl alcohol, commonly known as alcohol, ethanol, or grain alcohol, is a colourless, transparent liquid used to make alcoholic drinks such as beer, wine, and brandy. Ethyl alcohol is used in various items, from personal care and cosmetic items to paints and varnishes to gasoline, since it dissolves easily in water and other organic molecules.[29] Essential oils are solubilised (‘dissolved') in ethanol to allow them to be mixed or diluted without separating. Ethanol "marries" essential oils and water together at the right concentration, resulting in a single homogenous material that can no longer be divided into two different compounds.

2.4.3 Benzene

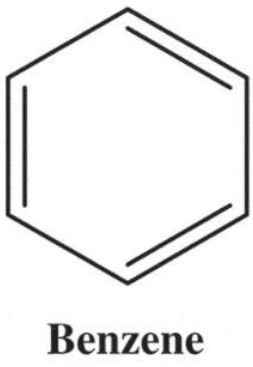


Figure 2-3 : Chemical structure of benzene[30]

At room temperature, benzene appears as a colourless or light yellow liquid. It smells delicious and is quite combustible. Benzene evaporates fast into the air, and its vapour is heavier than air; thus, it may settle in low-lying places. Benzene, on the other hand, dissolves just minimally in water and floats on top of it. Its interaction with other contaminants has the potential to harm several biosphere components. Benzene is used to make plastics, resins, synthetic fibres, rubbers, dyes, detergents, medicines, insecticides, and other products, as well as a lubricant. The lungs, gastrointestinal tract, and skin are all routes for benzene to enter the human body. Half of the benzene breathed enters the circulation after passing through the lungs.[31] A definite link exists between benzene exposure and acute nonlymphocytic leukaemia, chronic nonlymphocytic leukaemia, and chronic lymphocytic leukaemia.

2.4.4 Toluene and Xylenes

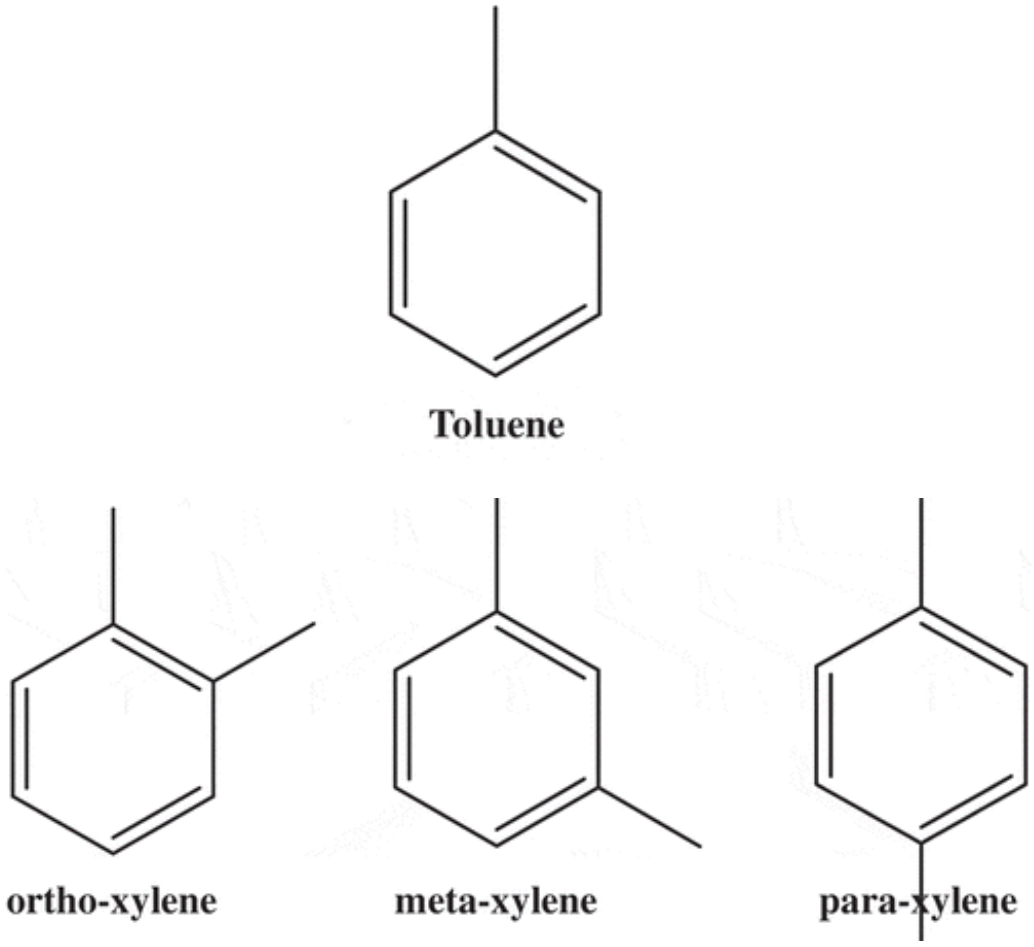


Figure 2-4 : Chemical structure of toluene and xylenes.[30]

Toluene and xylene are potent chemicals used in a variety of home and commercial items. Poisoning from toluene and xylene can occur when these chemicals are swallowed, inhaled as fumes, or come into contact with the skin. [32] C7H8 is the chemical formula for toluene, an organic molecule. Methylbenzene is the IUPAC designation for toluene. It has a benzene ring with a methyl group connected to it. This chemical has a molar mass of 92.14 g/mol. It appears as a colourless liquid with a distinct benzene-like odour at normal temperature and pressure. While (CH3)2C6H4 is the chemical formula for xylene, an organic molecule. Because it contains benzene with two linked methyl groups, it is classified as dimethylbenzene. It might come in the form of colourless, combustible liquids.[29]

2.5 Impact of Room Fragrances

2.5.1 Impact of Room Fragrances on Emotion

Several fragrances emerge in our everyday lives, and our sense of smell is vital in the physiological consequences of mood, tension, and functioning capability. The olfactory system detects fragrance, which is a volatile chemical component with a molecular weight of more than 300 Daltons or 300 g/mol.[33] Ambient scents, rather than emotions, are more likely to alter users' cognitive levels (awareness of the world), according to Michon et al.[34] A study was conducted to review the research on the effects of scents on human psychophysiological activity, with a focus on EEG alterations in an article written by K.Sowndhararajan and S.Kim. The result that they found was It may be inferred that perfumes have a direct and/or indirect effect on human psychological and physiological states. Furthermore, electroencephalographic investigations clearly indicated that scents considerably alter the activities of various brain waves and are responsible for a variety of brain states. A significant difference was detected solely in the levels of comfort, warmth, and pleasantness, suggesting that the most important distinctions between scented and unscented settings are psychological rather than physical in nature. For the most part, the properties with the

greatest assessment ratings were identified in Lavender. The greatest scores in the instance of orange relate to the room's brightness and height levels.[35] Odours, like music, may have a greater emotional impact on consumers than they do on feelings. It was discovered, for example, that stores with music playing in the background have a significant cognitive impact on both cognitive reaction and information processing. They explain that having music playing in the background can either enhance (or inhibit) powerful cognitive activities. Odours, we believe, may have comparable impacts.[36]

2.5.2 Impact of Room Fragrance on Health

Air fresheners release a variety of volatile organic chemicals, some of which are dangerous to the environment. Air freshener exposure has been linked to health issues such as migraine headaches, respiratory problems, and asthma episodes. An experiment was conducted to evaluating the air quality with and without air fresheners written by Nigel Goodman. The result shows that D-limonene concentrations in toilets using air fresheners was drastically increase while the D-limonene concentration in toilets without using air freshener was slightly increased. [37] It demonstrates the wide range of chemicals emitted by room fragrance products and during the research, it was also discovered that the following goods can be significant contributors to air pollution. Some solvents, in addition to producing smell compounds in high concentrations, can also be detected in even greater quantities.[38] According to the findings from the article “Fragranced consumer products: exposures and effects from emissions” written by Steinemann, Anne, over a third of Americans experience negative health impacts from fragranced items, such as respiratory problems and migraine headaches. Half of those surveyed said the consequences can be debilitating. Nonetheless, at least once a week, over 99 percent of Americans are exposed to fragranced items, whether via their own or others' use. However, different brand of air freshener gives a different amount of chemical that can make the effect differ from each other and the effect of environment also need to be considered.

2.6 Final Word

As can be observed from the paper that has been cited, there is a lot of simulation of airflow that has been done in previous research either in a numerical, graphical, or computational simulation. A lot of it using a simulation in a certain software to get the final result for example in [39], they use a few software to get a clearer result such as CT-scan, Catia, Ansys and CFD Post & Tecplot. The paper that shown a similar subject as in my project is [40] the simulation on airflow and aerosols deposition in human airways that determining the size particle of the aerosol. However, in the project, the airflow that needs to be determined is from the air freshener, and it distributes in a room.

CHAPTER 3 METHODOLOGY

3.1 Overview

This project will use SolidWorks, ANSYS Workbench, and ANSYS Fluent CFD simulation software to analyse the flow performance of the automatic air freshener in a living room under various design conditions. SolidWorks is a computer-aided design and engineering application for solid modelling. Next, Computational Fluid Dynamics (CFD) is the study of numerically solving the set of governing mathematical equations to forecast fluid flow, heat and mass transport, chemical processes, and related phenomena. The process for modelling and simulating the flow performance of the automatic air freshener spray involved three basic steps. The first step is to create the geometry using SolidWorks according to the dimensions provided, as shown in Table 3.1. The geometry sample drawn for the automatic air freshener and the living room can be illustrated in Figure 3.1. For instances, three different models with a different number of automatic air freshener will be simulated (APPENDIX A). During the measurements, the actual physical circumstances in the living room are not changed. In the simulation procedure part, a detailed figure can be found in APPENDIX B.

3.2 Create Geometry

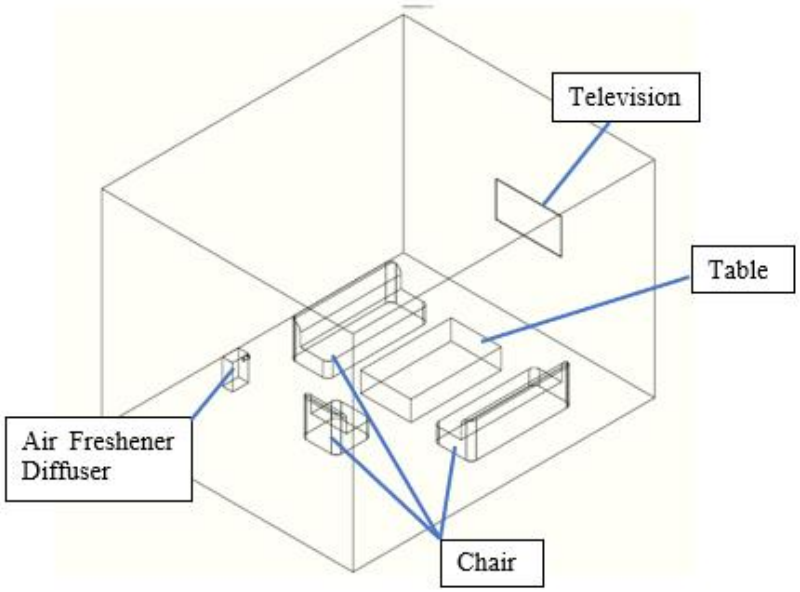


Figure 3-1 : Geometry part inside the close room.

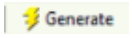
Part	Dimension (m)
Height of the living room	4.1
Width of the living room	6
Length of the living room	5
Dimension of the television	1.3*0.01*0.7
Dimension of the single-seater sofa	0.7*0.7*0.7
Dimension of the triple seater sofa	2*0.7*0.7
Dimension of the table	1*1.8*0.4
Dimension of the automatic air freshener dispenser	0.2*0.32*0.5
The hole diameter of the air freshener spray	0.05

Table 3-1 : Dimension of the geometry

After creating the geometry, the geometry was saved as a STEP file to make sure the file can be imported into Ansys Software.

3.3 Simulation Procedure

3.3.1 Import Geometry

The workbench was started by click on the Start menu, and Fluid Flow (Fluent) module was dragged Toolbox into the Project Schematic as shown in Figure 3-2. Then, the Design Modeler was clicked to launch the Design Modeler. To import the model, click on file> Import External Geometry File as shown in Figure 3-3. The STEP file was select, and to complete the importation, generate button 

was clicked. The figure shown in Figure 3-4 will be shown after generate button was clicked.

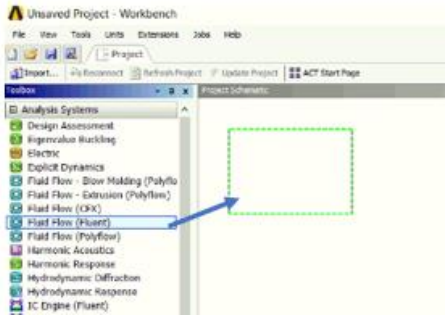


Figure 3-2 : Drag the Fluid Flow (Fluent) module

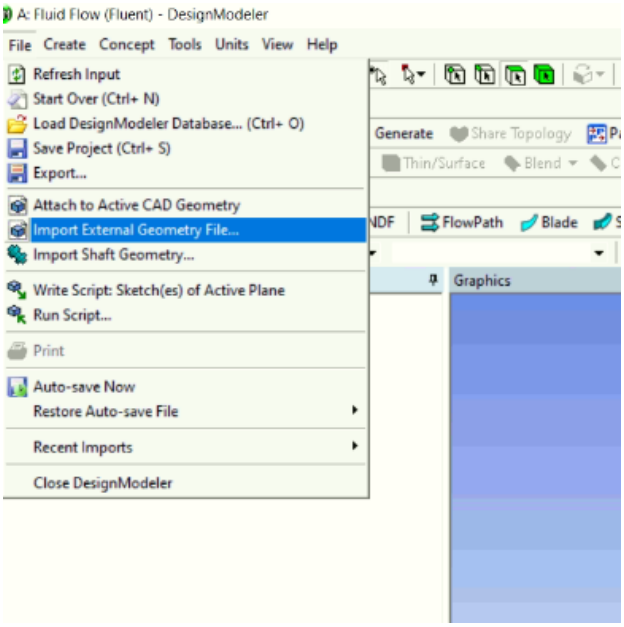


Figure 3-3 : Click import external geometry file

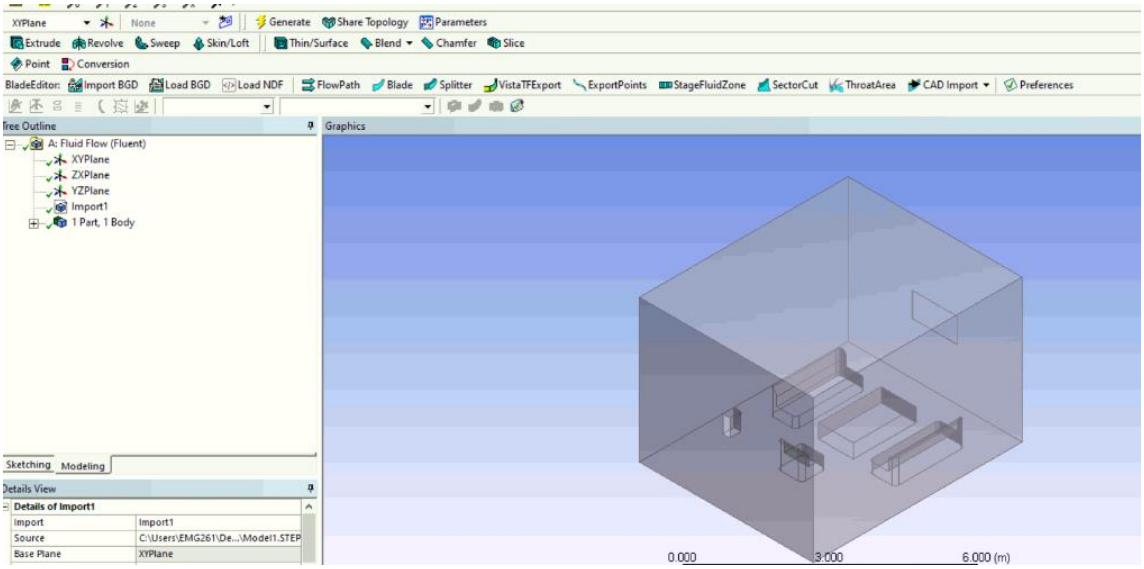


Figure 3-4 : Imported Geometry in Design Modeller

3.3.2 Meshing

A mesh is a tool that divides a shape into several parts. The CFD solver uses them to create control volumes. Before generating the mesh, name selection is defined on the inlet, pressure outlet, and walls as shown in Table 3-2 and a detail view can be shown in Figure 3-5. This is used to define the boundary conditions required in this model.

Named Selections	Locations
Inlet	The surface of the spray
Outlet	Top of the living room
Walls	Walls

Table 3-2 : Names Selections defined for boundary condition

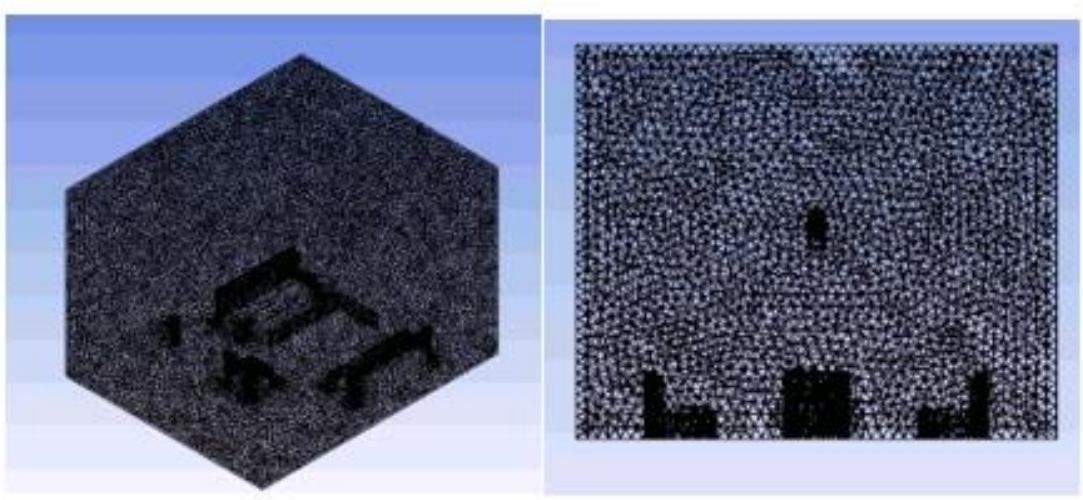


Figure 3-5 : Isometric and side view of mesh geometry.

3.3.3 Model Setup

K-epsilon was enabled by clicking viscous in Tree and tick k-epsilon, standard and standard wall function in the dense model box as shown in Fig 3-6. Since the simulation involves spray, therefore discrete phase was enabled to define the injection, as shown in Figure 3-7. The liquid for the air freshener spray was defined as ethyl alcohol because in the air freshener composition, ethyl alcohol was found in the air freshener as VOC. The boundary condition was set as in Table 3-3.

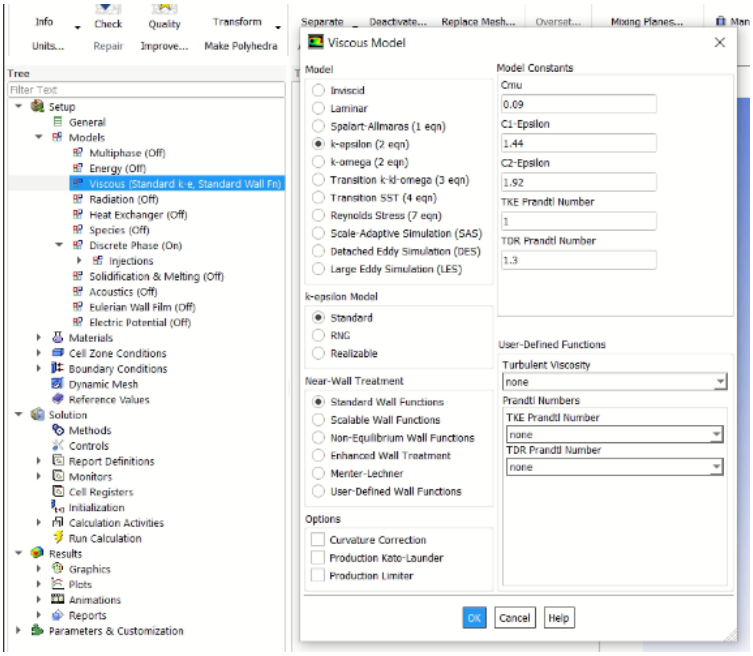


Figure 3-6 : Viscous Model Box

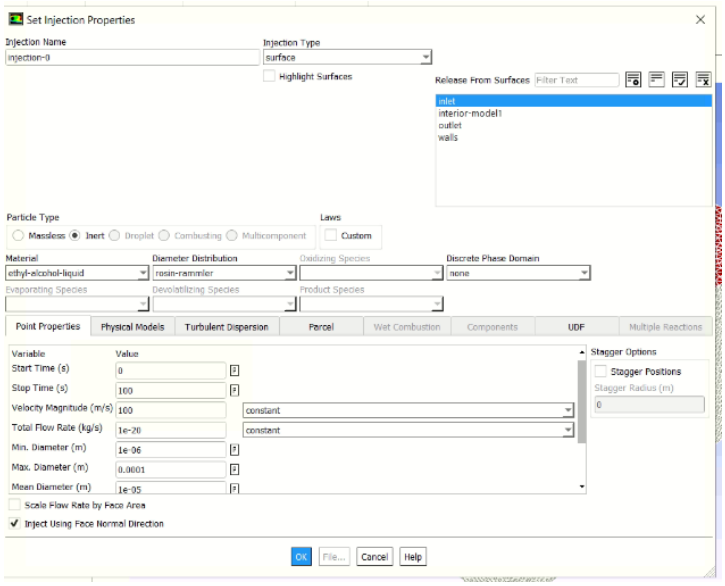


Figure 3-7 : Set Injection Parameter

Type of Boundary Condition	**Parameters**	**Units**
Inlet	Velocity Inlet	15m/s
Outlet	Pressure Outlet	1 Pa

Table 3-3 : Boundary Condition

3.4 Calculation of volume occupied

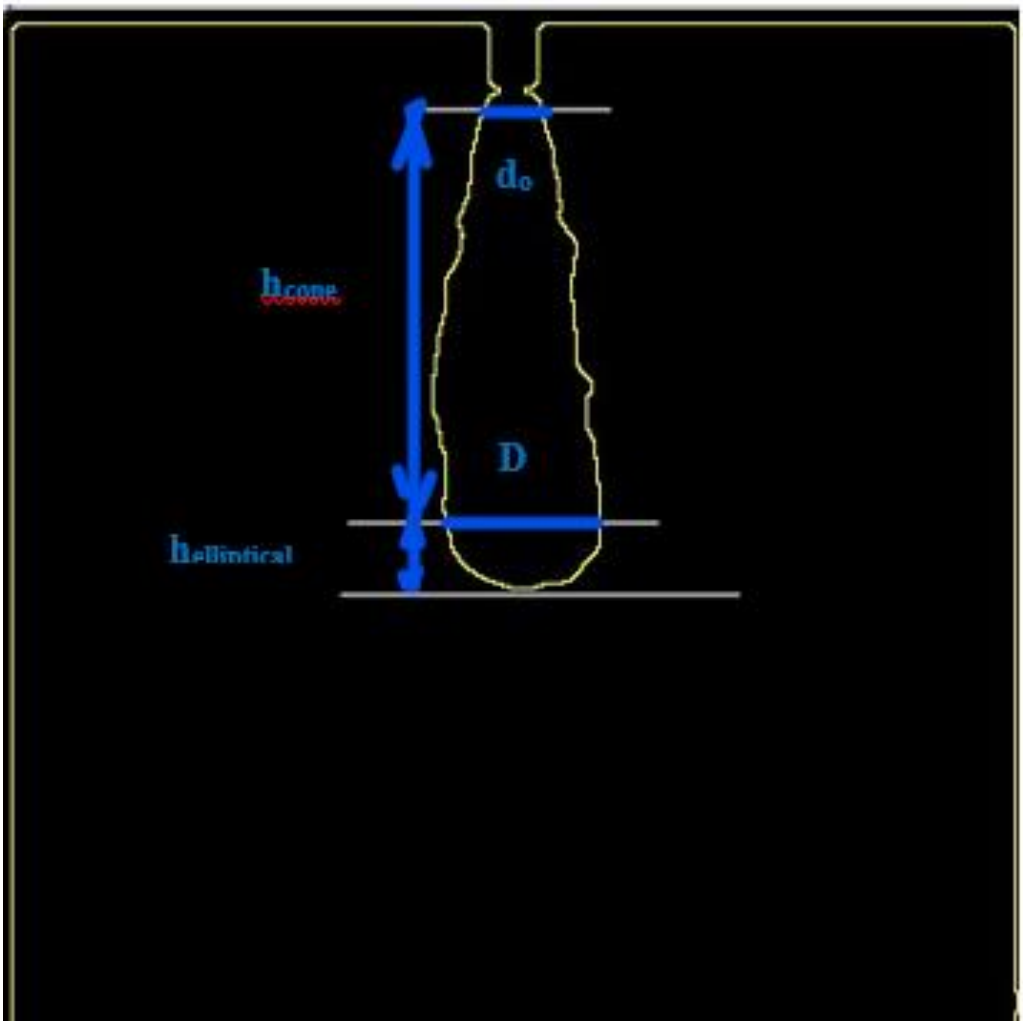


Figure 3-8 : Parameter of the spray

The spray image was transformed into boundary lines using the ImageJ programme, as shown in Figure 3-8. There will be two parts to calculate the spray spread volume by referring to [41]. The volume of the cone shape can be calculated using the formula below :

$$V_{cone} = \pi \cdot h_{cone} \cdot \left(\frac{D^2}{4} + \frac{d_o^2}{4} + \frac{D \times d_o}{4}\right) \cdot \frac{1}{3} = \frac{\pi \cdot h_{cone} \cdot (D^2 + d_o^2 + D \times d_o)}{12}$$

where,

V_{cone}	= volume of the conical bottom of the spray in m3
D	= inside diameter of the shell of the spray in m
h_{cone}	= total height of the conical discharge of the spray in m
D_o	= diameter of the outlet of the spray in m

Next, the volume of the elliptical cover can be calculated by using this formula,

$$V_{elliptical} = \frac{2}{3} \cdot \pi \cdot h_{elliptical} \cdot \left(\frac{D^2}{4}\right)$$

where,

$V_{elliptical}$	= volume of the elliptical top of the spray in m3
D	= inside diameter of the shell of the spray in m
$h_{elliptical}$	= height of the elliptical cover in m

Then, the total volume of spray is equal to:

$V_{spray} = V_{cone} + V_{elliptical}$

After calculating the total volume of spray spread, we can calculate the percentage of the volume occupied by dividing it with the total volume of the living room.

$$Percentage\ of\ volume\ occupied = \frac{V_{spray}}{V_{total}}$$

CHAPTER 4 RESULT AND DISCUSSION

4.1 Grid Independent Test

It is essential to know the optimal grid designing when the computational fluid dynamics (CFD) is used to find the accuracy of simulation analysis results. Based on the examination of multiple grid conditions, the grid independence test is a procedure used to discover the ideal grid condition with the fewest number of grids without causing a difference in numerical results.[42] The parameters that varied in this test are the mesh element size and smoothing level. There will be three different element size and smoothing level which is low, medium and high. The result for the independence test by low smoothing level with element size of 150mm (319,462 elements), medium smoothing level with element size of 113mm (444,228 elements) and high smoothing level with element size of 103mm (504,465 elements) can be shown in Figure 4-1.

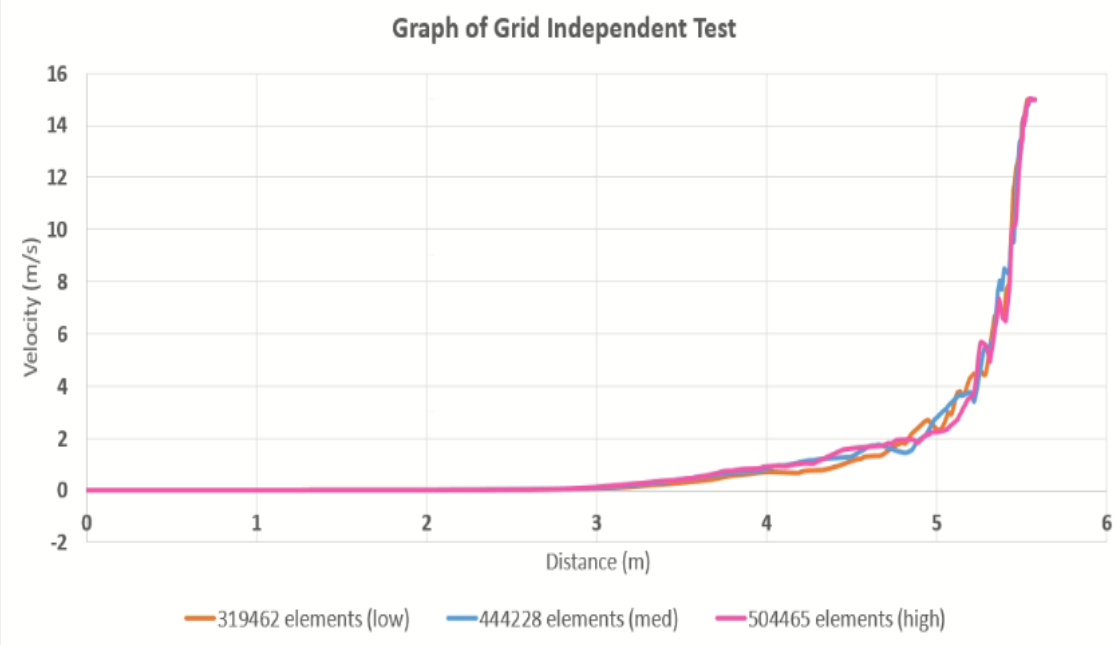


Figure 4-1 : Graph of grid independent test

As shown in Figures 4-1, all the three graph have a slightly different patterns. The reason why this happen because of the element size affecting the result of the calculation. The higher the mesh elements value, the longer the calculation time which resulting in a more expensive calculations. Hence, it can be concluded from the grid independent test that recommended mesh elements is equal or higher than 504465. However, resolution of mesh elements dependent on the application and we need to consider the limitation of the mesh elements value can achieve. This Ansys Software is an education version, therefore the highest value of mesh elements that this software can go is 512 000 elements. If we get higher than this value, it will affect the calculation which means the calculation cannot be run and the software will be crash. Higher mesh elements value will be in a more accurate results yet expensive.