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Optimisation of Angular Air Flow Distribution System using Symmetrical Air Foil Louvers in General Operation Theatres

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Abstract— ***Operation theatres (OTs) require ultra-clean, unidirectional airflow to minimize surgical site infections. This study presents a comprehensive Computational Fluid Dynamics (CFD) analysis using ANSYS Fluent to evaluate airflow distribution using symmetrical air-foil louvers with different cases like 30°, 45°, 60°, and 90°. Performance is assessed through velocity uniformity, turbulence intensity, streamline behaviour, and airflow penetration. Results demonstrate that air-foil based diffusers significantly outperform conventional straight-blade systems. The 60° configuration yields optimal laminar flow characteristics, with maximum uniformity and minimum turbulence, making it ideal for critical OT environments.***

Keywords: CFD, ANSYS Fluent, Operation Theatre, Air-foil Diffuser, Laminar Flow, HVAC.

I. INTRODUCTION

To design effective air conditioning system for hospital operation theatre is very challenging task for HVAC engineers. Mostly, air conditioning system with laminar air flow is designed for operation theatre to reduce the risk of infection of the patient and surgical staff and also provide thermal comfort. During surgery, patient body is continuously revealing the bacteria and thermal plume in surgical area, which result in increasing the risk of surgical site infection (SSI) and post-operative infection (POI). Effective air distribution plays an important role to overcome the above problem. In previous research turbulent flow was allowed, but laminar air flow system is mostly accepted in recently published standards of various countries. Although standards and guidelines of every country for designing ventilation system for operation theatre is available. Some of them are preferred. These preferred standards and guidelines are ASHRAE, DIN 1946/4, VDI 2167, GIS, ISHRAE etc. [1-5].

According to standards the OT room should be positive pressurized to prevent the mixing of outside contaminated air in OT environment. OT interior and air distribution system is designed on the bases of type of surgery conducted. In most of surgery unidirectional air flow system is preferred. Many numerical and experimental studies were presented on ventilation system of operation theatre for thermal comfort and infection factors. Contanious Balaras et al. [6] investigated 20 OTs in 10 major Hellenic hospitals revealed that ventilation requirements influence humidity control depending on climate condition because high humidity causes thermal discomfort and low humidity level results blood coagulation, he suggested the range of indoor parameters such as temperature and humidity. Van Gaver [7] summarised the technical data for thermal comforts of surgical staff to work efficiently. Zang rui et al. [8] state that bacteria colony forming deposition would increases if air velocity increases beyond certain velocity 0.45 m/s. The most common ventilation system used in OT.

i.e. laminar air flow, in this system large amount of air is uniformly flow over the critical zone. Laminar air flow system is again classified in two types depending upon the obstacle present in flow i.e. horizontal and vertical flow [9] which covered only operating bed area. Kameel and Khalil [10] proposed the interior and HVAC guideline to optimize the comfort and hygienic condition in OT, later Kameel and Khalil [11] recommended the three different air side designs for development of optimum HVAC system in health care application. Junjie Liu and et al [12] investigated an alternative of horizontal flow pattern and air flow performance in an OR. He also investigated that unidirectional air flow pattern can easily affected by the medical lamp and thermal plume around the wound, to overcome these disadvantages new horizontal air flow pattern is introduced. Annette Erichsen Andresson et al. [13] described the Importance of laminar air flow in operating room as protection from surgical site infection, laminar air flow pattern offers high quality of air during surgery, with very low level of colony forming units near the operation table. Rafat Al-Waked [14] proposes the investigation of different ventilation option for the operation theatre, both standard and orthopedic. He modelled commercially available UCV system and more economical alternatives to determine if a satisfactory sterile environment can be achieved without UCV’s. Lester E Patridge et al. [15] described the CFD analysis of two different air conditioning

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systems for operation theatre. the first is a standard overhead ac system providing supply from the center of the ceiling through a number of four way diffusers. The second is a laminar flow system using 4 x HEPA filters centrally mounted directly above the patient in the operating theatre ceiling. He suggested that air velocity over wound site should be less than 0.25m/s to avoid drying out the wound. Francesco Romano et al. [16] explain numerically and experimentally investigation an OT with a layout according to the Standard DIN 1946-4. He analyzed the effectiveness of a differential airflow diffusion system on reducing the particle concentration above the operating table. The modelling of the flow inside the operating room is developed by applying the conservation equations of continuity, momentum, and energy. This equation is solved by computational fluid dynamic software. CFD has gained in popularity as a design and analytical tool. Memarzadeh and Manning [17] simulate the bacteria particle deposition in OT using CFD tool and showed that laminar air flow system is best choice in ventilation system.

Most of the international organisation of ventilation suggested that Laminar Air Flow system is best option for OT, in terms of contamination control. LAF system maintain the laminar flow in surgical area only, it formed the constant column over operating bed area, which result to swipe out the contaminated air from surgical area, where they might be deposited on nonsurgical area of OT. LAF is available in two form depending on the location of installation, Horizontal and vertical laminar air flow. In India it is observed that in most of the hospital LAF system is not used because of its huge installation area, less false ceiling height. It also restrict interior of OT such as installation of operating lamp and other equipment. It is found that surgical staff is feeling temperature draft when they move from surgical zone where LAF is present to the non-surgical area where LAF is not present. Due to temperature draft, Indoor obstacles such as personnel, operating lamp, surgical instrument and movement of surgeon can easily affect the unidirectional flow pattern of ventilation system, which result in vortex formation or turbulence formation. Because of turbulence bacterial dispersion is increase from surgical area to non-surgical area, surgical staff is affected by such bacteria which cause the SSI to staff as well as to patient. To overcome this problem plenum type air flow pattern is used in which air is supply from the whole ceiling area and exhausted through the floor. By using such type of system will affect the interior of OT and it increase the volume flow rate of OT which result increase in energy consumption of system.

In view of these contradictory results and worldwide increases in health care costs and increasing difficulties in financing and providing all modern medical advances in OT, the Angular Air Distribution (AAD) System is designed whose primary goal is to provide unidirectional flow in whole OT and reduced the temperature draft to provide comfortable environment to patient and surgical staff. AAD ventilation system is designed in such way that, square ceiling supply diffuser with 4 number of louvers equally spaced from edged of diffuser is located in central zone of ceiling, that guide the unidirectional and angular flow by varying angle of louvers. This ceiling slot diffuser needs same installation area as of LAF. The study is carried out on scale model of OT. The scale model dimension is calculated with the help of geometrical similarity concept. Initially the scale model of OT is examined by numerical simulation by varying inlet angle at constant inlet velocity and temperature. For numerical simulation Computational Fluid Dynamics (CFD) technique with fluent software is used. The CFD modelling technique solved the continuity, momentum and energy conservation equation in addition to standard k-e model equation for turbulence closure. The boundary conditions of numerical results are tested with grid independency test. The numerical results are validated with the help of experimental readings of scale model of OT. The air flow pattern of AAD system in OT with various inlet angles are tested with the help of smoke test. The flow pattern obtained by smoke of AAD system is capture by Camera Target Method (CTM) and it is validated with streamline results of CFD. To check the human comfort and effectiveness of air distribution system, the obtained results are compared with the international standard parameter for ventilation system such as Air Diffusion Performance Index (ADPI).

II. METHODOLOGY

As a patient health and recovery time is completely depends on the environment present in operation theatre. The operation theatre is divided in two zones, one is critical or surgical zone which cover the operating bed, surgeon and equipment near the operating bed. Another zone is non-surgical zone where the surgeon may walk during surgery to accesses the equipment. In previous research healthy environment is control in critical zone by providing laminar flow. It is observed that there is temperature draft found between surgical zone and non-surgical zone which result in thermal discomfort to surgeon and patient. Mostly laminar air flow is maintained in critical zone to swipe out the bacteria from the critical zone or to avoid recirculation of air. In existing laminar air flow system the conditioned air is flow from diffuser outlet, to the operating bed. The flow of air strike on patient body which lay on operating bed, the flow carry the bacteria from patient body and move from surgical zone to non-surgical zone. Because of above mechanism the flow is mixed and turbulence is created. To provide and maintain comfortable environment for surgical staff and patient in OT international standards guidelines are considered. This HVAC standards guidelines control the indoor air quality and thermal comfort by prescribing the use of laminar air flow system. This ceiling mounted system provides the continuous unidirectional downward flow of

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conditioned air to protect the critical zone and instrument table against the airborne bacteria. The design criteria of LAF for OT are temperature, air velocity, and relative humidity. The inlet supply temperature of LAF must be lower than room temperature which overcome the temperature draft cause by thermal plume of surgical staff and patient which results in turbulence in unidirectional flow. As temperature difference is increase the air velocity is also increase with decrease in size of air flow area of diffuser due to construction of air column concept. The temperature ranges for OT for different country is shown in Table 1.

Table 1. Indoor air condition requirement

	ASHRAE for Healthcare facility [1]	ASHRAE for ventilation for healthcare facility [2]	NABH [3]	AIA [4]	GIS [5]
Temperature (°C)	17-27	20-24	21+/-3	20-23	22-26
Relative Humidity	45-55	30-60	40-60	30-60	50-60
ACPH	25	20	25	15	20
	5	4	4	3	3

The supply air velocity for LAF system defines the unidirectional air flow in critical zone of OT. To prevent turbulence due to thermal draft, supply velocity is maintained at 0.40 m/s but with this velocity a large velocity gradient is formed at the edge of boundary laminar zone which result in flow mixing. Thus, some HVAC standards recommended 0.2 m/s – 0.35 m/s is optimum velocity for laminar flow in critical zone.

2.1. Concept of Angular Air-Foil Air Distribution (AAD) System

Recently in various researches different types of ventilation systems are investigated. The horizontal, vertical, mixed ventilation with laminar air flow is preferred for operation theatre. The major problems were defined i.e. uneven cooling in operation theatre especially in critical zone, turbulence in air stream in critical zone which carries the bacteria from the patient body and surgical instrument toward the surgeon. These bacteria carrying air circulated in OT instead of exhaust toward outlet which cause the infection to occupant. This problem specified the further study for air flow distribution in OT over the conventional ventilation system.

According to literature survey above problems are overcome by various types of air flow pattern, velocity and by maintaining indoor air quality in OT. By studying literature angular diffuser ventilation systems was designed by varying diffuser inlet angle condition, it compared with HVAC standard. All Existing designed unidirectional ventilation system covers the critical zone of operation theatre, but if the same flow is given with specific angle, it will cover the maximum area of OT with minimum recirculation as shown in Fig. 1. The AAD system is designed in such way that air flow is maintained as laminar because it reduces turbulence in OT room which causes the bacterial dispersion.

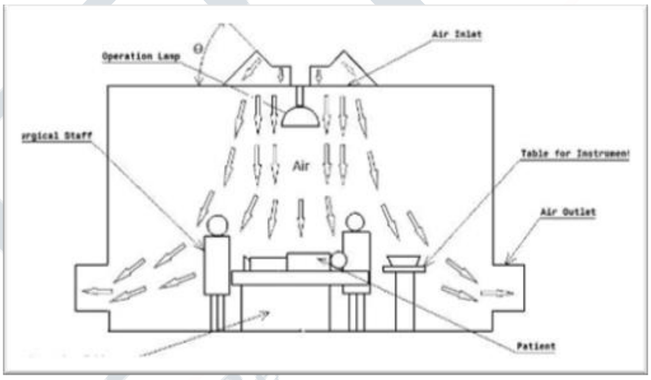

Figure 1. Conceptual layout of AAD system

2.2. Geometrical Similarity

A reduced scale model is used to conduct a series of model experiments and investigate of ventilation system of OT. For geometrical similarities between scale model and prototype model, scale model is made with 1:4 ratios. The geometrical similarity is considered as follows

$$\frac{L_p}{L_m} = \frac{W_p}{W_m} = \frac{H_p}{H_m} = L_r \quad (1)$$

$$\frac{A_p}{A_m} = L_r^2 \quad (2)$$

$$\frac{V_p}{V_m} = L_r^3 \quad (3)$$

Where Lp, Wp, Hp is length, width and height of prototype model. Lm, Wm, Hm is length, width and height of Scale model. Lr Is Geometrical ratio as explain in equation (1), (2) and (3). Table 2 shows the ratio of geometrical similarity between scale and prototype model. From Table 2 It is conclude that Lr = 4.

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Table 2. Dimension of Full scale and scaled model by geometrical similarity

Geometrical Similarity					
	Length (L)	Width (W)	Height (H)	Area (A)	Volume (V)
Actual (Prototype) Model	6 m	6 m	3 m	36 m^2	108 m^3
Ratio	0.25	0.25	0.25	0.0625	0.015625
Scaled Model	1.5 m	1.5 m	0.75 m	2.25 m^2	1.6875 m^3

III. OBJECTIVES OF STUDY

1. Examination of parameters like Air flow pattern, temperature distribution and velocity distribution
2. To implement numerical method CFD technique is used to simulate and visualize the air flow pattern.
3. Conducting experiment and validating the obtained results with standards.

IV. NUMERICAL SIMULATION

4.1 CAD Model

The square shaped prototype scale model of OT is used for this study. The dimension is finalized by geometrical similarity concept with 0.25 scale ratio. The room dimensions are 1.5 m (length) X 1.5 m (Width) X 0.9 m (Height), with interior as shown in Fig. 2. The operating bed 0.47m (L) X 0.19 m (W) X 0.135 m (H) and it is located at middle of the OT under the area of Laminar flow. The 05 surgical staff is standing around the operating table. They were modelled in cylindrical shaped with 0.0762 m diameter and 0.3048 m height. Anesthesia machine of size 0.075 m (L) X 0.0625 m (W) X 0.425 m (H) is placed head side of patient. The OT is provided with vertically downward air flow system with different angle. The supply ventilation system is installed in such way that its flow will cover the critical zone or flow will wash out the critical zone. The ceiling supply diffuser is 0.5 m X 0.5 m in dimension with equally spaced four louvers which guide the flow as shown in Fig. 2.

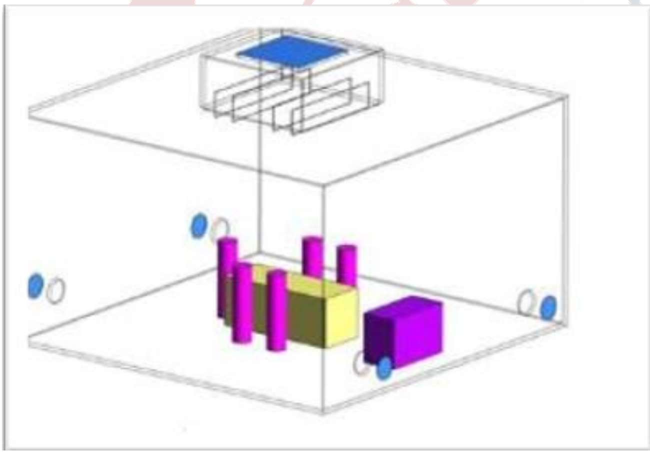

Figure 2. Solid model of OT with interior features

The OT air exhausted out by four low level exhaust ports which is in round cross section whose center is located 0.2 m from floor level. This is able to provide washing effect against the bacteria settlement on floor. In this study different ventilation system cases are studied. The AAD system is tested with different inlet supply angle (louvers angle) such as 30°, 45°, 60°, and 90° with respect to vertical plane.

4.2 Numerical Solution

The numerical study was made in Ansys Fluent. A solid and fine tetrahedron elemental auto-mesh is used to generate mesh model. The software ANSYS mesh was used for meshing of OT geometry with many elements. The different mesh size is considered for mesh independence study. Tetrahedron cells were used with varying number of elements of 256916, 287258, 312761, 39844, and 586479. The velocity plot for different mesh size is plotted and it was approximately same for last four numbers of elements. The criteria for converged numerical solution are taken as 1e^{-3} RMS with element size 586479 as shown in Fig. 3.

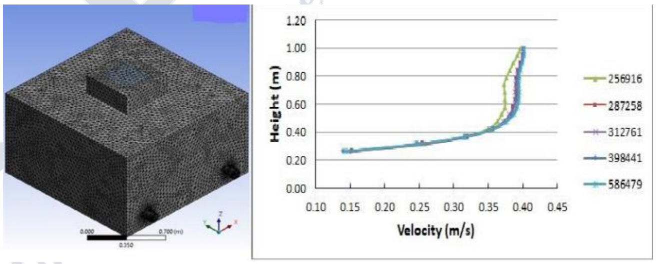

Figure 3. Mesh Independency

Reynolds Averaged Navier Stokes (RANS) equations were employed at steady state condition to simulate the air flow field as shown in equation (4), (5), (6) and (7). The two equation RNG k-epsilon model is used for indoor airflow simulation. This model was developed using renormalization. K-epsilon (k-ε) turbulence model is the most common model used in CFD to simulate mean flow characteristics for turbulence flow conditions [23]. It is a two-equation model which gives a general description of turbulence by means of two transport equations (PDEs). The first transported variable determines the energy in the turbulence and is called turbulent kinetic energy (k) as shown mentioned in equation (8). The second transported variable is the turbulent dissipation (ε) which determines the rate of dissipation of the turbulent kinetic energy as shown mentioned in equation (9). K-epsilon (k-ε) turbulence model is the ratio between Reynolds stress and mean rate of deformations is the same in all directions (Ansys 2015)

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Conservation of mass equation:

$$\nabla\,(\rho\,\vec{v}\,) = S_{m.} \tag{4}$$

Momentum:

$$\nabla\,.\,(\rho\,\vec{v}\,\vec{v}\,) = -\nabla p + \nabla.\,(\bar{\bar{\tau}}) + \rho\vec{g} \tag{5}$$

Table 3. Physical Properties of material used in numerical simulation

Material	ρ (kg/m³)	Cp (j/kg°k)	K (w/m°k)
Wood	700	2310	0.173
Air	1.225	1006	0.02435

The turbulence model used was k-ε, with Pressure-Velocity coupling type Coupled and Least Squares Cell Based, Second Order Upwind. The initialization was set to hybrid. Incompressible air was used as a fluid, with the gravity force activated. The convergence set for all residuals was 10^{-3}. According to HVAC standard for OT for vertically downward flow air velocity should be maintain at 0.4 m/s for maintaining the bacteria free environment and laminar flow in critical zone. Hence in this study supply air velocity is set at 0.4 m/s with supply temperature 20 ±3°C. In order to avoid addition of outside contaminated air from outside OT is provided with positive pressure.

V. EXPERIMENTAL SETUP

5.1 System Layout and Specification

The general layout of experimental setup is shown in Figs. 4 and 5. It consist of three main parts such as air distribution system i.e. supply diffuser, Air Conditioning unit or Air handling unit (AHU) and testing room. Air handling unit is simple unit of vapour compression refrigeration cycle. Fan is pushing the atmospheric air over evaporating coil to get conditioned cooled air. Testing room is fabricated by the plywood of 12mm thick for three side and floor and top surface, front side of testing room is made by acrylic sheet for capturing the images of smoke test. The round supply duct of 100 mm diameter is used to supply the conditioned air from AHU outlet to inlet of test room. Four exhausts are connected to exhaust fan with the help of exhaust duct.

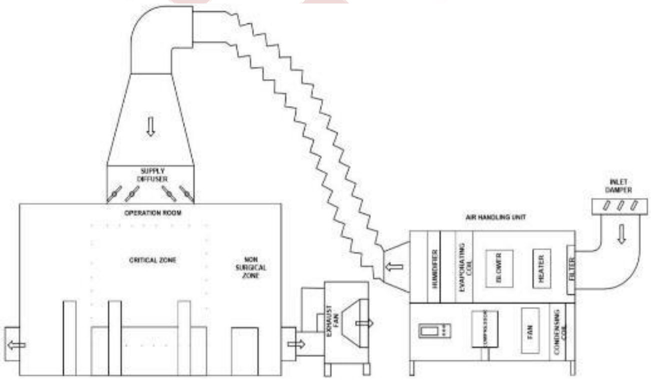

Figure 4. Schematic layout of experimental set up

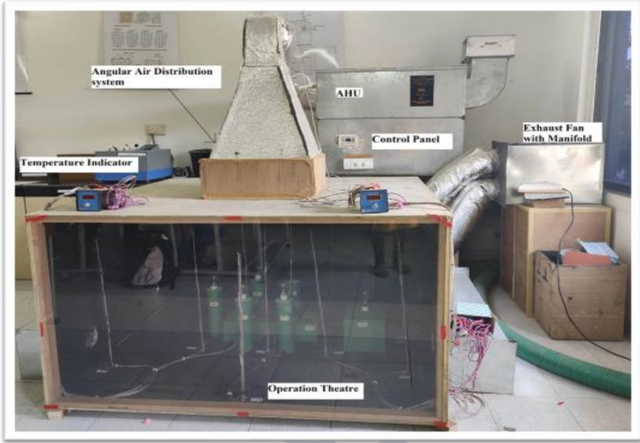

Figure 5. Experimental set up of OT

5.2 Operation Room Configuration with 4 Cases of AAD System

The scale model of OT is fabricated by the plywood of 12mm thickness. The size of OT room is 1.5 m X 1.5 m. All side wall and top-bottom is made by plywood only front side is made by acrylic sheet for visualization of smoke test. The OT is composed of 5 surgeons standing around the operating bed, one anesthesia machine is place on head side of operating bed. These interior features are the representation of actual obstacles present inside the OT. The aim of the test is to observe the airflow pattern and its distribution throughout the OT. The designed AAD system is tested for four cases. All four cases are differing by inlet flow angle of angular air distribution system as shown in Fig. 6.

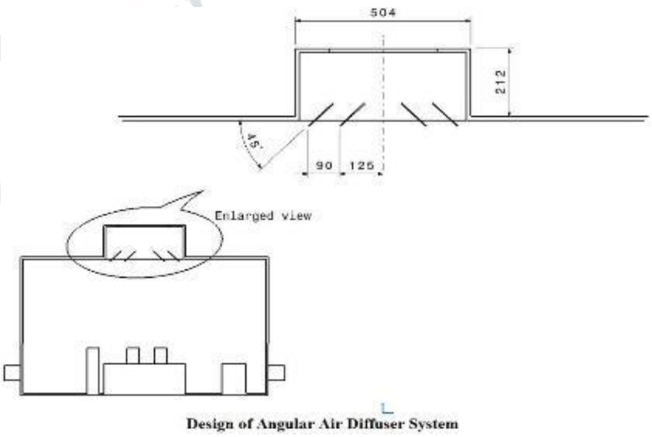

Figure 6. Layout of mechanism of angular diffuser.

Square ceiling supply diffuser with 4 number of louvers equally spaced from edged of diffuser is located in central zone of ceiling, that guide the unidirectional and angular flow by varying angle of louvers. The purpose of investigation of these four cases is to check the total volume coverage by different angle, which results in minimum temperature draft in OT environment. The case is defined in Table 4.

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Table 4. Angular Air Distribution system configuration for four cases

Sr. No	Cases	Air Distribution System	Louvers Angle
1	Case-1	Traditional Air distribution system (LAF)	90^o
2	Case-2	Angular Air Distribution System	30^o
3	Case-3	Angular Air Distribution System	45^o
4	Case-4	Angular Air Distribution System	60^o

5.3 Measurement Techniques

5.3.1 Smoke Test

Clean air and many air contaminations are invisible under normal condition. It is, however, often desired to actually see the movement of air, or emission and transportation of contaminations in order to ensure good air quality. The methods aim at the visualization of air flow pattern and its transportation from surgical zone to non- surgical zone. The main aim of air flow visualization is to make the air flow field visible and thereby possible to study.in technical term, flow visualization gives the possibilities to study air flow pattern and its changes in it depending upon the changes in geometry, boundary condition, inlet-outlet air flows. To meet the above technique, smoke generator (Power 900watt, heat up time -12 min, capacity-3 litre) with fog fluid (white cloud) is used mentioned in Table 5. The blower is inbuilt in smoke generator.

Table 5. Technical data of measurement and testing instrument

Anemometer	Measuring Range:- NTC: -20 to 60°C, Accuracy:- ±(0.1 m/s + 5 % of mv) (0 to 2 m/s)
Smoke Generator	Power:- 900watt, heat up time -12 min, capacity-3 litres

A common principal of smoke generation is to evaporate a mineral oil by electrically heating it and mixed the vapour in into air. The smoke is fed in AHU to mixed smoke vapour into air. The volume flow rate of smoke is controlled by supply fan speed of AHU. Initially smoke is fed inside the OT through AAD system i.e. supply diffuser with high pressure to check any leakage in system. The smoke enters from inlet diffuser and exhausted from outlet which is placed at the bottom of the walls. Four outlets are used which is connected to exhaust box through exhaust manifolds Further smoke visualization test was carried out to identify the air flow pattern with different inlet angle of AAD system and to evaluate the effectiveness of the same. These methods are the simplest, cheapest, and practically most accessible for airflow visualization.

5.3.2 Temperature Measurement

As the Human comforts is depend on the temperature draft in occupied zone. To investigate the temperature draft in whole OT temperature measurement at various points is needed. According to temperature reading the effectiveness of air distribution system is calculated.

K-type washer thermocouple with ± 2.2°C accuracy and temperature range -50^o to 400°C is used. For temperature measurement fixture is design and fabricated as shown in Fig. 7. As the geometry of scaled OT room is symmetrical with respective central plane, the temperature measurement is taken at on side of central plane of OT. To evaluate the performance of distribution system the temperature is measured at different plane of OT. The fixture is designed in such way that, on each fixture three measuring points are located at different 200 mm, 500 mm, and 700 mm from bottom level of OT. The 700 mm height plane is near to ceiling, 500 mm plane at middle of OT, and 200 mm height plane near to operating bed. Total nine fixtures are fabricated. Total 30 temperature readings are taken out of 27 is on fixture line and three are at AHU outlet, diffuser inlet and atmospheric for each case For temperature measurement at different location, the fixture is placed at different location who’s coordinate as mentioned in Table 6.

Figure 7. Temperature measuring fixture

5.4 CFD Simulation

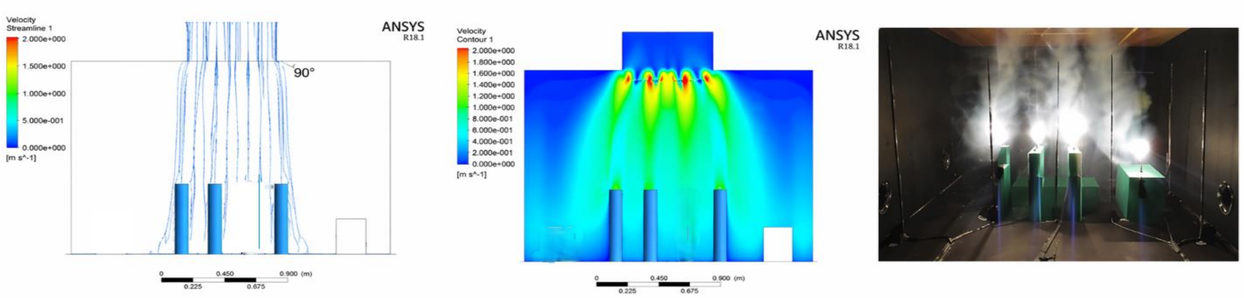
The numerical analysis was performed using the commercially available Ansys Fluent R15 software. Based on previous research, the Reynolds average Navier-Stokes turbulence model, with K- epsilon (ε) equation with enhanced wall treatment, was used (Chow & Yang, 2003) [7]. Reynolds Averaged Navier Stokes (RANS) equations were employed at steady state conditions to simulate the air flow field The two-equation RNG k-epsilon model is used for indoor airflow simulation. This model was developed using renormalisation. The k-ε (k-ε) turbulence model is the most commonly used model in CFD to simulate mean flow characteristics under turbulent flow conditions (H. Ufat et al., 2017). The article submitted to Nanyang Technological University, Singapore (2014), by the author said that a two-equation model provides a general description of turbulence through two transport equations (PDEs). The first transported variable, which represents the energy in the turbulence, is called turbulent kinetic energy (k). The second transported variable is the turbulent dissipation (ε), which determines the rate of dissipation of the turbulent kinetic energy as shown in equation. Cassie k. B, (2006) explained "the K-epsilon (k-ε) turbulence model is the ratio between Reynolds stress and the mean rate of deformation, which is the same in all directions (Ansys, 2015)" (Cassie K.B. 2006).

VI. RESULTS AND DISCUSSION

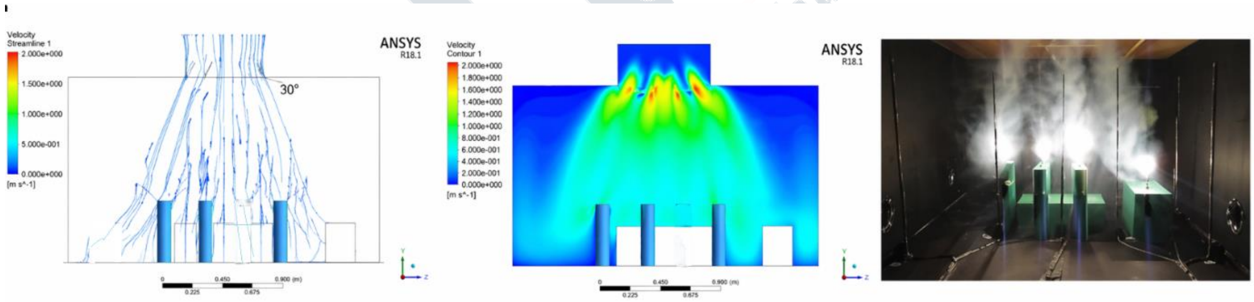
In this research, various airflow distribution systems for operating theatres were studied, and a new system was designed and tested for use in the operating room. The CFD results for the designed ventilation system of full-scale OT and reduced-scale OT were validated against numerical simulations and the ASHRAE standard.

6.1 Air Flow Pattern

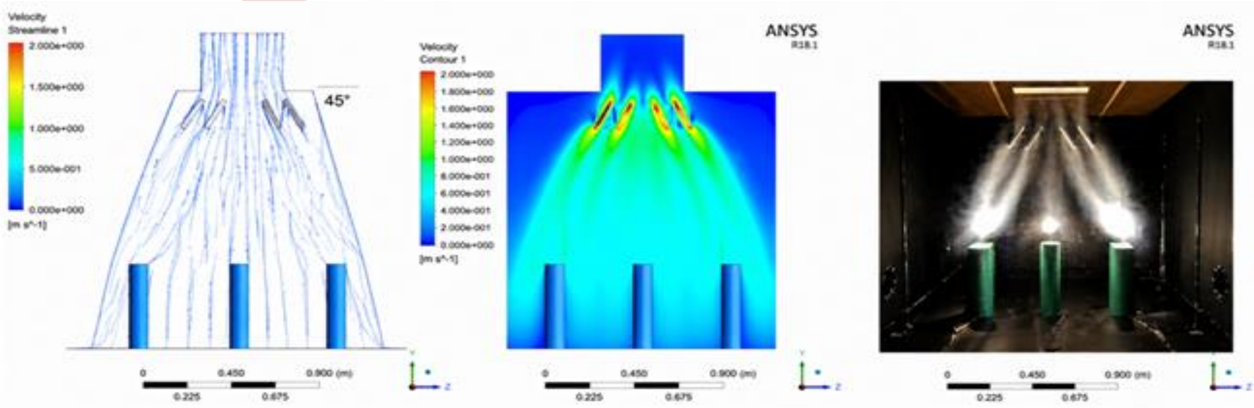
Case 1) Symmetrical Air foil louvers with 90 degree angle



Case 2) Symmetrical Air foil louvers with 30 degree angle



Case 3) Symmetrical Air foil louvers with 45 degree angle



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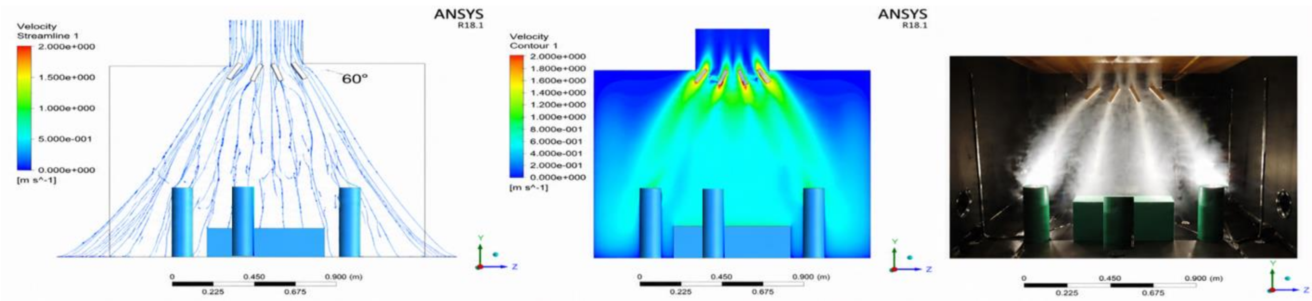
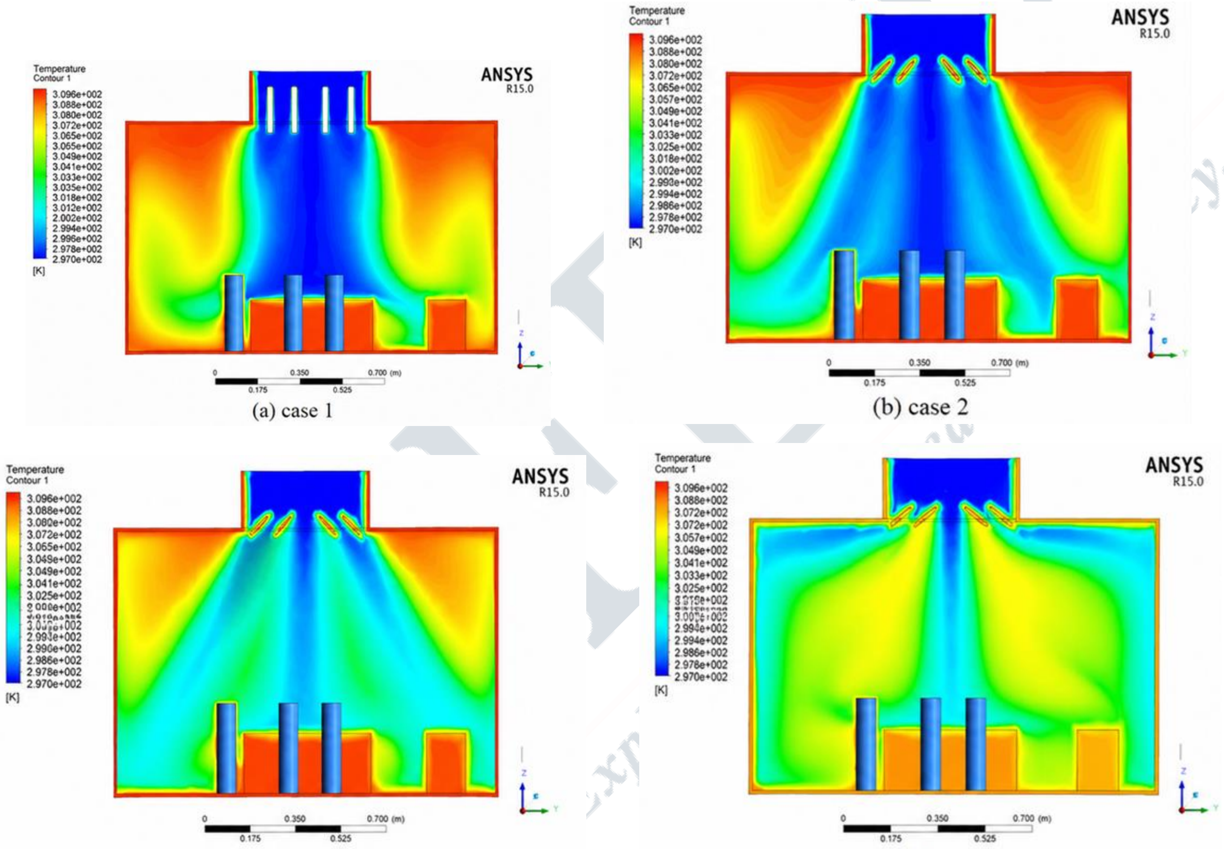
Case 4) Symmetrical Air foil louvers with 60 degree angle



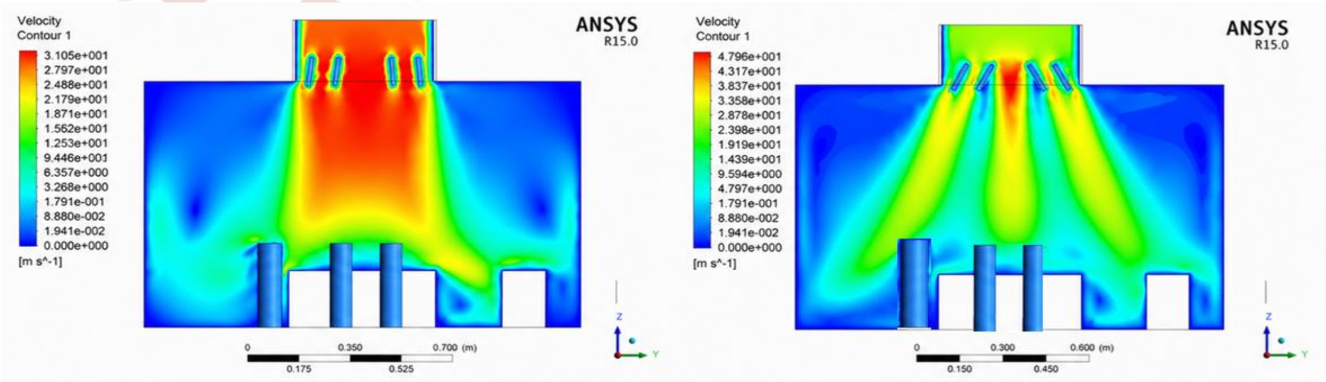
6.2 Temperature Distribution



(a) case 1 (b) case 2

(c) case 3 (d) case 4

6.3 Velocity Distribution



(a) Case 1 (b) Case 2

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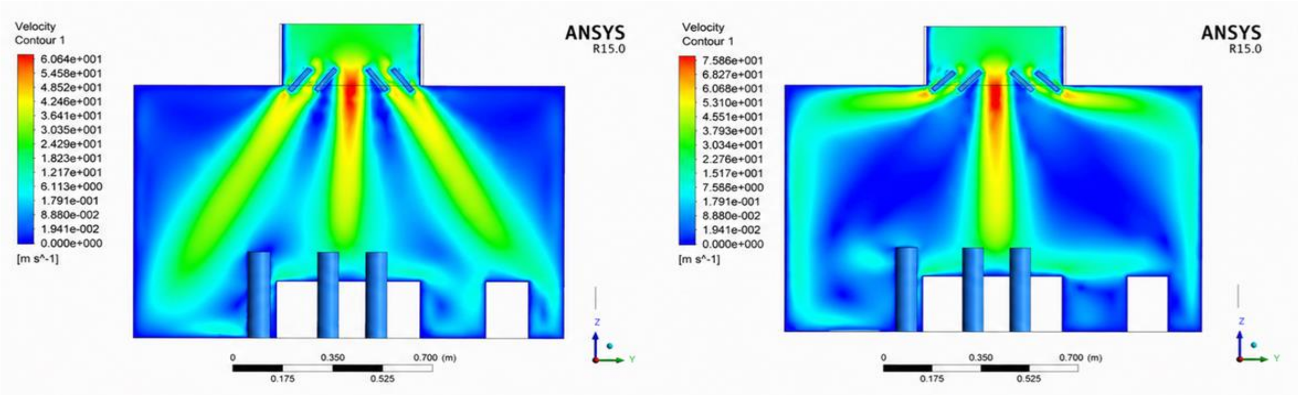
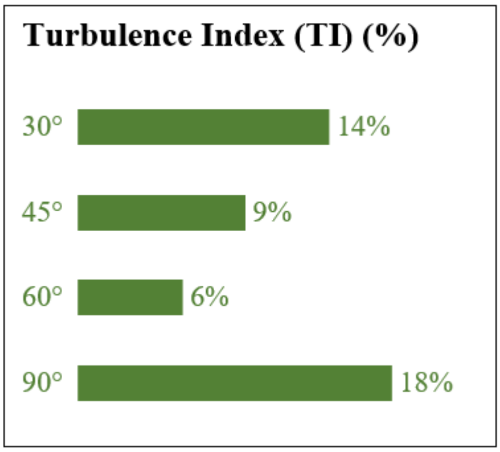
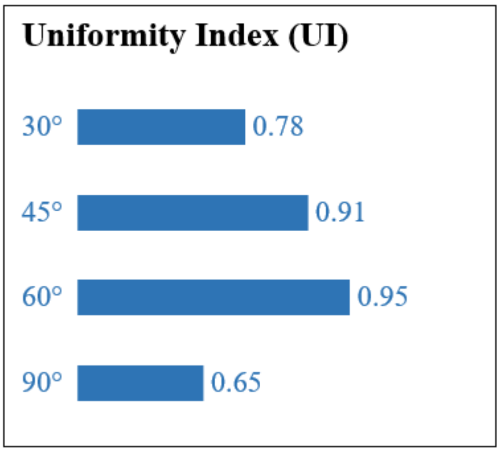


(c) Case 3 (d) Case 4

Comparative Table

Angle	Uniformity Index (UI)	Turbulence Index (TI)	Performance Index (PI)
90°	Low	Very High	Poor
30°	Medium	High	Fair
45°	High	Low	Good
60°	**Very High**	**Very Low**	**Best**





VII. CONCLUSION

The present CFD investigation demonstrates that the use of symmetrical air foil louvers significantly enhances airflow distribution within an operation theatre compared to conventional straight-blade diffusers. By systematically analysing louver angles of 30°, 45°, 60°, and 90°, it was observed that airflow behaviour is highly sensitive to angular orientation. Numerical evaluation of airflow performance was carried out using uniformity index, turbulence intensity and performance. The optimal airflow range for operation theatres (0.25–0.35 m/s) was used as the benchmark. A uniformity index above 0.9 and turbulence intensity below 6% were considered indicative of near-laminar sterile airflow conditions. Based on these criteria, the 60° symmetrical airfoil louver configuration demonstrated superior performance with a velocity of 0.31 m/s, UI of 0.95, and TI of 6%."

REFERENCES

[1] M. Rossi, "Publications from international organizations on public health," 2017. [Online]. Available: https://core.ac.uk/download/pdf/230130372.pdf

[2] S. Kanj, G. Kamel, L. Alamuddin, N. Zahreddine, N. Sidani, and Z. A. Kanafani, "Epidemiology of hospital-acquired infections at a tertiary care center in Lebanon," *BMC Proceedings*, vol. 5, suppl. 6, p. P242, 2011.

[3] Nguyễn, H. H., Choi, J. I., Kim, H. K., & Lee, B. Y. (2019). Effects of the type of activator on the self-healing ability of fiber-reinforced alkali-activated slag-based composites at an early age. Construction and Building Materials. https://doi.org/10.1016/j.conbuildmat.2019.07.113

[4] "Operating, minor surgery and examination lights," Bender UK.

[5] M. L. Pereira and A. Tribess, "A review of air distribution patterns in surgery rooms under infection control focus," *Revista de Engenharia Térmica*, vol. 4, no. 2, pp. 113–121,

2005.

[6] J. H. Lim, "Comparative study on the measurement and analysis methods of heart rate variability in human body for occupants' thermal comfort evaluation by considering physiological response," *Journal of the Korean Solar Energy Society*, vol. 41, no. 3, pp. 79–89, 2021. doi: 10.7836/kses.2021.41.3.079.

[7] T. T. Chow and X. Y. Yang, "Performance of ventilation system in a non-standard operating room," Build. Environ., vol. 38, no. 12, pp. 1401–1411, 2003.

[8] Memarzadeh, F., " RISKS SURGERY," ASHRAE journal, 2003.

[9] Health care facilities, in: HVAC applications handbook, American Society for heating, refrigerating and air conditioning engineers Inc. Atlanta, GA, 2006.

[10] ASHRAE standards 170P, Ventilation of Health care facilities, American Society for heating, refrigerating and air conditioning engineers Inc. Atlanta, GA, 2006.

[11] Guide book to NABH standards for hospitals, 25 August 2010, pp. - 114-115.

[12] AIA guidelines for design and construction of hospital and healthcare facilities, The American Institute of Architect Press, Washington, DC, 2006.

[13] M. Melhado, J. Hensen, and M. Loomans, "Review of Ventilation Systems in Operating Rooms in View of Infection Control," 6th Int. Postgrad. Conf. Built Hum. Environ., pp. 478–487, 2006.

[14] S. Rahate and A. Sarode, "A novel approach of angular air distribution system for hospital operation theatre," in *Proceedings of ICTEA: International Conference on Thermal Engineering*, Gandhinagar, India, May 2019

[15] Tousif Bin Alam, "CFD analysis of Thermal Comfort & Contaminant removal from a typical Hospital Operation Theatr," PhD, Department of mechanical engineering and chemical engineering,Islamic University of technology, Dhaka, Bangladesh, 2012.

[16] S. S. Harsoor and S. Bala Bhaskar, 2007, "Designing an Ideal Operating Room Complex", Indian Journal of Anaesthesia, 51 (3), pp. 193-199

[17] F. Memarzadehand A. P. Manning, "Comparison of operating room ventilation systems in the protection of the surgical site," *ASHRAE Transactions*, vol. 108, no. 2, pp. 1–12, 2002.

[18] K. W. D. Cheong and S. Y. Phua, "Development of ventilation design strategy for effective removal of pollutant in the isolation room of a hospital," *Building and Environment*, 41,pp. 1161-1170, 2006, doi: 10.1016/j.buildenv.2005.05.007.

[19] Junjie Liu, Haidong Wang and Wenyong Wen, 2009, "Numerical Simulation on Horizontal Airflow for Airborne Particles Control in Hospital Operating Room" Elsevier, Building and Environment, 44, pp-2284-2289.

[20] J. McNeill, J. Hertzberg, and Z. Zhai, "Experimental investigation of operating room air distribution in a full-scale laboratory chamber using particle image velocimetry and flow visualization," *Journal of Flow Control, Measurement & Visualization*, vol. 1, no. 1, pp. 24–32, 2013, doi: 10.4236/jfcmv.2013.11005

[21] G. Cao, A. M. Nilssen, Z. Cheng, L. I. Stenstad, A. Radtke, and J. G. Skogås, "Laminar airflow and mixing ventilation: Which is better for operating room airflow distribution near an orthopedic surgical patient?," *American Journal of Infection Control*, vol. 47, no. 7, pp. 737–743, Jul. 2019

[22] N. Massarotti, A. Mauro, D. Sainas, S. Marinetti, and A. Rossetti, "A novel procedure for validation of flow simulations in operating theaters," *Science and Technology for the Built Environment*, vol. 25, no. 3, pp. 343–354, 2018, doi: 10.1080/23744731.2018.1556053.

[23] A. E. A. Eldegwy, E. E. Khalil, S. M. Morcos, and E. M. ElBialy, "Numerical investigations of indoor air quality in infection isolation rooms," *[13th International energy conversion engineering conference]*, pp. 3820–3832, 2015.

[24] A. Aganovic, G. Cao, L.-I. Stenstad, and J. G. Skogås, "Impact of surgical lights on the velocity distribution and airborne contamination level in an operating room with laminar airflow system," *Building and Environment*, vol. 124, pp. 42–52, 2017.

[25] A. Aganovic, G. Cao, L.-I. Stenstad, and J. G. Skogås, "An experimental study on the effects of positioning medical equipment on contaminant exposure of a patient in an operating room with unidirectional downflow," *Building and Environment*, vol. 137, pp. 1–10, 2018.

[26] K. Y. Wong, H. M. Kamar, N. Kamsah, and A. S. Norazam, "Effects of surgical staff turning motion on airflow distribution inside a hospital operating room," *Journal of Mechanics in Medicine and Biology*, vol. 19, no. 06, pp. 52-58, 2019