Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 11, No. 3, November : 2023

DESIGN OF ROOM GEOMETRY ON AIR DISTRIBUTION SYSTEM IN OPERATION THEATRE (OT) AND ITS IMPACT ON FLOW CHARACTERISTICS AND RISK CONTAINMENT: A LITERATURE REVIEW

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Abstract:

The proper management of air flow patterns and temperature distribution in operation theatres (OTs) plays a critical role in maintaining a clean and sterile environment. In order to maintain the comfort level in Operation Theatres it is important to follow the required guidelines provided by different standards like ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers). These guidelines are minimum but not optimum design considerations in case of Operation Theatres Therefore, this literature reviews are conducted in-depth to study various papers involving experimental and numerical investigations to analyze the airflow patterns, temperature distribution, relative humidity and the air inlets, outlets of OTs. Furthermore, this research will explore the utilization of Angular Air Flow (AAF) systems to enhance the efficiency and effectiveness of air flow management in OTs by varying the ceiling heights. The ultimate goal is to provide valuable insights and practical guidelines to Operation Theatres to ensure optimal air quality and patient safety.

Keywords—
Optimization, Operation Theatre (OT), Angular air Flow (AAF), ceiling heights.

1. INTRODUCTION

The main task of Heat Ventilation and Air Conditioning (HVAC) system in the modern hospital Operation Theatre (OT) is to provide a comfortable and healthy environment to the patient and surgeon. As ventilation system play important role in HVAC to keep OT environment free from bacteria. The poorly ventilated system not only affect the health of patient and surgeon from infection but also feel them uncomfortable [1]. In previous standard and guidelines, turbulent air flow was allowed in OT, but recently published standards suggest to use Laminar Air Flow (LAF) systems [2]. Many national and international standards and guidelines are available for every country to design a ventilation system with environmental parameters for OT [3-6]. Alternate methods are mixing and displacement ventilation system which differs by the position of supply and an exhaust port in OT. Indoor obstacles can easily affect the unidirectional flow pattern of the ventilation system. Ventilation and air distribution pattern have a great effect on indoor air quality which includes indoor temperature, relative humidity, air flow velocity, pressure relationship, air movement's efficiency. Therefore, in this work new AAD system is designed in such a way that it will distribute the air in laminar pattern in whole OT.

As per national and international standards and guidelines, the temperature in OT should be maintained at 18-22oC with minimum temperature draft because it affects human comfort. Relative humidity should be maintained 45 – 55% because high humidity causes thermal discomfort and low humidity results in blood coagulation. The laminar air flow is a common to design for OT with air velocity 0.2-0.4 m/s to maintain unidirectional airflow pattern in the critical zone [7]. Chow and Yang[7] had investigated that, thermal comfort is achieved by controlling the temperature, the humidity, and air

movement. In laminar air flow, supply is given at the rate of 0.46 m/s, there are two types of LAF one is horizontal and vertical. In this literature velocity is measured by using hot wire anemometer and compared it with a mathematical k-e model for validation purpose [9- 11]. Sasan Sadrizadeh et al. [12] investigated the vertical and horizontal ventilation system in terms of sedimentation and bacteria distribution in operation theatre. He used the CFD software for numerical calculation and validate it by comparison with experimental data reported in the literature. Liu et al. [13] investigated an alternative of horizontal flow pattern and air flow performance in an OT. He also evaluates the effectiveness of the horizontal unidirectional airflow to control infectious airborne particles in operation theatre. In this study, the above drawbacks which is observed in literature is overcome by designing Angular Air Distribution (AAD) system. In AAD system, conditioned air is thrown in OT with some angle so it can cover the maximum area of OT with laminar flow and minimum installation area. The designed AAD ventilation system is examined with the help of numerical simulation by varying inlet angles at, constant value and 0.4m/s inlet velocity. It is validated by experimental measurement and observations performed on prototype OT model. The air flow pattern of AAD system by varying inlet angles were tested with the help of smoke test. The air flow pattern obtained by the smoke of AAD system is captured by Camera Target Method (CTM) and it is validated with CFD contours plot results air condition requirement.

2. Literature review:

No	Research Paper Title/publication year	Research Summary	Research Gap
1.	An experimental and numerical study of air flow pattern and temperature distribution of angular air distribution system in hospital operation theatre *Swati Rahate[1] and Avinash Sarode[1]*	Mostly Laminar air flow system is used in OT, which covered the surgical zone. The temperature draft observed between surgical and nonsurgical area which result in uncomfortable environment to patient and surgeon. To overcome such problem Angular Air Distribution (AAD) system is designed which covered the both area of OT.	. the flow and quality of air get affected due to presence of blower and optimisation of number of blowers required in OT is not discussed. 2. Room geometry has not be discussed
2.	Design of Air Distribution System for Operation Theatre Using Flow Visualization Techniques to Improve Flow Characteristics. *Swati Rahate[1] and Avinash Sarode[1]*	This work aims to study and visualize the airflow distribution of conventional flat air diffuser ventilation system and newly designed angular air ventilation system in OT. Angular Air Distribution (AAD) system is designed in such way that, conditioned air is throw in OT with some angle so it can cover the maximum area of OT with laminar flow and minimum installation area.	1.The paper has not discussed about the removal of air trace available at critical area which can be removed by adding some blowers on side-top of wall. 2. Room geometry has not been discussed

3.	Optimization of Air Distribution Patterns by Arrangements of Air Inlets and Outlets: Case Study of an Operating Room. *Vahid Gholami Motlagh, Mohammad Ahmadzadehtalatapeh*	The study shows that the LAF and LAF with the air curtain cases as the proposed configurations have an acceptable capability to maintain the indoor air conditions within the range recommended by the standards and verified by numerical methods	1.Not discussed about Angular Air Distribution Flow. 2. Room geometry has not been discussed
4.	Design and optimization of operating theater ventilation and contamination control system through an experimentally validated CFD model *Tesi di Laurea di*	The aim of this work is the creation of a CFD model of an existing operating theater which is mainly used for the cardiac-surgery, equipped with a partial unidirectional ventilation system and classified, ISO 5 'in operational' conditions, according to the UNI EN ISO 14644-1.	1.Not discussed about Angular Distribution Flow. 2. Room geometry has not be discussed.
5.	Airflow dynamics in an emergency department: A CFD simulation study to analyse COVID-19 dispersion Odi Fawwaz Alrebi, Bushra Obeidat, Ibrahim Atef Abdallah, Eman F. Darwish, and Abdulkarem Amhamed	In this work Turbulence Kinetic Energy and Velocity profiles were analyzed to determine which areas of the ED were most susceptible to virus spread. After using CFD analysis, arrangement of inlets and outlets, the separation of spaces, and the interior design of the spaces and hallways has been presented to the hospital administration.	1.Not discussed about Angular Distribution Flow. 2. Room geometry has not been discussed.
6.	Role of air changes per hour (ACH) in possible transmission of airborne infections Farhad, Memarzadeh, Weiran Xu	Using a scientific approach and convincing data, this paper hypothetically illustrates how a ventilation system design can be optimized to potentially reduce infection risk to occupants in an isolation room based on a thorough risk assessment without necessarily increasing ventilation airflow rate. A computational fluid dynamics (CFD) analysis was performed to examine the transport mechanism, particle path and a suggested control strategy for reducing airborne infectious disease agents.	1.Not discussed about Angular Distribution Flow. 2. Room geometry has not been discussed.

7.	Development of ventilation design strategy for effective removal of pollutant in the isolation room of a hospital Author links open overlay panel. K.W.D. Cheong, S.Y. Phua.	This paper investigates the airflow and pollutant distribution patterns in a "negative pressure" isolation room by means of objective measurement and computational fluid dynamics (CFD) modeling based on three ventilation strategies. The strategies include 3 different positions of diffuser and exhaust grills in Operation Theatre and studies the effect of air flow.	Paper has not taken the room geometry into consideration i.e., ceiling height and its effect on air flow distribution.
8.	REFINED DESIGN OF VENTILATION SYSTEMS TO MITIGATE INFECTION RISK IN HOSPITAL WARDS: PERSPECTIVE FROM VENTILATION OPENINGS SETTING Chen Ren , Junqi Wang , Zhuangbo Feng , Moon Keun Kim , Fariborz Haghighat, Shi-Jie Cao	This study investigates the effectiveness of pollutant removal and infection risk mitigation for three ventilation modes, consisting of displacement ventilation (DV), downward ventilation (DWV), and stratum ventilation (SV), under different scenarios (locations and number) of ventilation openings (inlets/outlets) and infected patients in hospital wards.	Paper has not taken the room geometry into consideration i.e., ceiling height and its effect on air flow distribution.
9.	**I.** EXPERIMENTAL ASSESSMENT OF DIFFERENT MIXING AIR VENTILATION SYSTEMS ON VENTILATION PERFORMANCE AND EXPOSURE TO EXHALED CONTAMINANTS IN HOSPITAL ROOMS *F.A. BERLANGA , I. OLMEDO , M. RUIZ DEADANA , J.M. VILLAFRUELA , J.F. SAN JOSÉ , F. CASTRO*	Two supply configurations were studied: grilles in the upper part of a wall (G) and swirl ceiling diffusers (S), combined with two different exhaust grilles positions in the opposite wall: upper part (U) and lower part (D) are tested using typical IHR(individual hospital room) set up.	Paper has not taken the room geometry into consideration i.e., ceiling height and its effect on air flow distribution.
10.	The impact of the air distribution method in ventilated rooms on the aerosol particle dispersion and removal: The experimental approach. Andrius Jurelionis, Laura Gagyt, Ta das Prasauskas , Darius Čiužas , Ed vinas Krugly , Lina Šeduikytė , Dai nius Martuzevičius	The tested ventilation strategies based on mixing ventilation with one-way and four-way air supply, as well as the displacement ventilation supply, revealed different effects on particle dispersion, and subsequently, its removal from the chamber. At lower air exchange rates, one-way mixing ventilation was more efficient in preventing particle transport	Paper has not taken the room geometry into consideration i.e., ceiling height and its effect on air flow distribution.

		across the analysed section of the test chamber, while four-way mixing ventilation enabled more particles to remain airborne.	

III. EXPECTED CONTRIBUTIONS:

This research is expected to contribute to the field of operation theatre design and optimization by providing:

1. Improved understanding of airflow patterns and temperature distribution in operation theatres.
2. Insights into the limitations of existing air inlets and outlets, and novel designs for improved air flow distribution.
3. Optimization techniques for operation theatre geometry to enhance air quality and contamination control.
4. Evaluation of the effectiveness of Angular Air Flow (AAF) systems in operation theatres by varying height of ceiling.
5. Practical guidelines and recommendations for the design, operation, and optimization of OTs to ensure optimal air quality and patient safety.

By addressing these research objectives, this work will make significant contributions to the field, promoting advancements in operation theatre design and optimization for improved patient outcomes and infection control.

IV. CONCLUSION

In support of literatures, which have discussed the effect HVAC on room temperature, humidity, flow distribution and risk containment by using experimental set up and have been justified by numerical methods following ASHRAE standards for Operation theatre. With this study, it will be providing valuable insights and practical guidelines to OTs to ensure optimal air quality and patient safety.

V. REFERENCES:

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3. Optimization of Air Distribution Patterns by Arrangements of Air Inlets and Outlets: Case Study of an Operating Room. *Vahid Gholami Motlagh, Mohammad Ahmadzadehtalatapeh*
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*5.*Airflow dynamics in an emergency department: A CFD simulation study to analyse COVID-19 dispersion. Odi Fawwaz Alrebi, Bushra Obeidat, Ibrahim Atef Abdallah, Eman F. Darwish, and Abdulkarem Ahamed
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