International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 2 Feb 2021, pp: 566-473 www.ijaem.net ISSN: 2395-5252

Modeling and Fluid Flow CFX Analysis of Indoor Air Purifier

Prateek Srivastava, Rishabh, Basant Kumar Bhuyan
Faculty of Engineering and Technology, Manav Rachna International Institute of Research and Studies, Faridabad, Haryana, India

Submitted: 10-02-2021 Revised: 20-02-2021 Accepted: 24-02-2021

ABSTRACT: We live in a society where the contamination level is rising and sometimes we can't even breathe properly. Our metro cities like Delhi are one of the most polluted cities. To overcome this problem we use air purifier system especially in India where the moisture content is high. In this project design of a new chamber model represented by line diagram, compatible for use of different filters like hepa, carbon activated, photocatalyst and antibacterial filter. Through which it easy for replacement or clean the filters. Also the design is contemplate to make proper flow of air inside the chamber also consider there is no direct flow of air for reducing uneven feeling for human beings. Analysis is done in Fluid flow CFX for calculating Heat transfer, moment and mass flow, Turbulence (Kinetic Energy), Pressure gradient flow, Velocity stream line flow throughout the chamber.

Keywords: Air Purifier, Hepa filter, Carbon Activated Filter, Anti bacterial Filter, Photocatalyst Filter, ANSYS, Catia;

I. INTRODUCTION:

Air purifying and the air cleaner is a gadget which expels contaminants from the air inside the environment. The economically reviewed air purifiers are engineered as both little remain solitary unit or bigger gadgets that can be joined to an air handler unit (AHU) or to a central air unit found logical, business, and business ventures. Air purifiers may likewise be utilized as a part of ventures to expel polluting influences, for example, CO_2 from air sooner than preparing. As of late we remain in that society where in contamination is rising so much that some time or another we are not ready to breathe pleasantly. Especially in metro urban areas where guests is an over the top measure of and substantial ventures are found. Contamination is rising every day and it achieves a level of marker wherein as in standard towns contamination level is in this way we need more decontaminated air in residencies locales. Air contamination in India stop a difficult issue is the first resources being gas wood and biomass consuming, fuel corruption, auto start and guests clog. In harvest time and frostiness months, immense scale trim deposit consuming in agribusiness region a low value other option to mechanical working is a central supply of smoke, exhaust cloud and particulate poisons. India has low per capita discharge of nursery gasses anyway the U.S.A is a whole greatest after china and joined nation.

Air Quality Index (AQI)

An air quality record (AQI) is a number utilized by government associations to address people in general how contaminated the air at present is or how dirtied it is conjecture to rise as. Since the AQI builds, an inexorably more enormous level of the populace is more than likely to appreciate an expanding number of unreasonable dangerous wellbeing results. Calculation of the AQI requires an air poison fixation over a correct averaging period, gained from an air screen or form. Taken together, focus and time constitute the measurements of the air contamination. Wellbeing results like a surrendered measurement are set by epidemiological research. Air toxins extend in power, and the trademark used to change over from air poison focus to AQI shifts by method for contamination. Air superb record esteems are regularly gathered into levels. Each range is allocated a descriptor, a hue code, and an institutionalized open wellness warning.

II. LITERATURE REVIEW:

As in many research papers which explain about the different parameters and experimental results which used in Air purification technique and the advancement of air purification techniques.

Takash kato et al in 1974 gives an air cleaner comprises of structure for disposing of different sorts of tidy, vapor, fog, microorganisms, fuel and scent from contaminated air by methods

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for passing the dirtied air through a progression of various channels composed inside a packaging. [1] Golstein et al in 1980 gives that a room air cleaner for unobtrusively disposing of on edge orharmful contaminations from the air circling inside the room. The cleaner disposes of from room air, trash down to 0.3 microns in estimate with 99.9% effectiveness. [2] J. Dormandy et al in 1983 gives P.G. The essential topic on our posting for nowadays is a discourse of sorts of channels. To begin with, dr schmid-schonbein will demonstrate his film on rbc conduct in vitro and in vivo.[3]

Davis et al in 1986 gives the versatile room air purifiers having replaceable and generally barrel shaped high proficiency particulate air channels that are set up to get hold of approaching air that is drawn there through by utilizing radiating enthusiasts situated adja penny diverters in such a way, to the point that air is coordinated radially apparently through regularly annular fumes openings in a calm but then really proficient way. [4] Pittman et al. In 1987 gives that a high effectiveness particulate air get out is revealed which has a divert shaped in the front fringe floor thereof, with the channel being apparently loaded with a sealant which obliges an essentially non-unstable and non-solidifying gum-like texture. [5] S payet et al in 1992 offers the tests and a rendition have been result of the outcomes of mass stacking of a hepa fiber sift through amid filtration of submicron fluid airborne particles. The estimations screen that infiltration of the investigate medium increased amid stopping up by a fluid vaporized, regardless of molecule measure inside the picked go (0.024).5/~m) [6]

Bert brunekreef et al in 1995 offers that since the change of the field wellbeing organization (WHO) air quality proposals for europe, an expansive assortment of epidemiologic investigations had been distributed recording aftereffects of dominating air poisons on wellbeing at focuses underneath current insights and models. [7] Tsai et al. 2002 gives the overarching development is guided more like a sift through media for a superior particulate air ("hepa") sift through which incorporate a variety of connecting electrostatically charged heaps of nonwoven material. The innovation additionally incorporates a strategy for making a hepa channel. [8] C.h. Ao et al in 2003 gives the opposition affect between water vapor and poisons at PPB arrange for adsorption sites has been beforehand said. To upgrade the picture debasements of poisons at PPB organize and at high mugginess levels, tio2 is immobilized on an enacted carbon (air conditioning) filter. 200 PPB of nitrogen oxide (NO) and 20 ppb of benzene, toluene, ethyl benzene and o-xylene have been picked as objective toxins. [9]

C.h. Ao et al in 2004 gives the upgrade impact of utilizing TiO_2 immobilizedon enacted carbon (Ti_2/air conditioning) filter for pushing off indoor air poison at parts in venture with-billion (PPB) degrees has been in the past said. [10] Scahill et al. In 2004 gives a photocatalytic air cleaner is given which incorporates a tubular lodging having an interior and an external divider, a basic hub , a first quit having a halfway situated air admission spout , a second end having no less than one air deplete port , an air debilitate plenum between the internal lodging divider and an outspread porosity medium.[11] Grinshpun sa et al in 2005 offers various systems were advanced after some time for bringing down vaporized exposure in indoor air situations. Among indoor air purifiers of various sorts, ionic producers have increased expanding interest and are by and by utilized for getting rid of tidy trash, aeroallergens and airborne microorganisms from indoor air. [12]

Yx sun et al in 2005 gives the investigation exhibited in this report progressed toward becoming performed in a mimicked plane lodge to evaluate the air cleaning impacts of air sanitization contraptions utilizing photocatalytic oxidation (PCO) period. [13] Weiss et al in 2006 gives a photocatalytic air chemical is revealed wherein the photocatalytic air purifier incorporates a bright gentle source that produces warm and a guide part having a picture impetus lined on an essential floor of the help part. [14] Halloran et al in 2007 offers that an air chemical is accommodated purging air in room of a residential, work environment, or diverse business the norm. Air is separated by method for a mechanical channel, at that point scents are disposed of from the air, and the air is revealed to germicidal lights for eliminating microscopic organisms, at that point the air passes by means of an over the top execution electro statically more alluring channel out, after which it's far back to the room through blowers. [15]

Anju mohan et al in 2007 gives the air great file (AQI) is a list for detailing day by day air high caliber. A see at the yearly and occasional renditions of air brilliant file over a span of nine years (1996– 2004) basically in view of every day found the middle value of mindfulness measurements of gauges air poisons has been led for delhi. [16] Engelland et al. In 2008 gives an air purifier course of action or meeting is provided. The air cleaner affiliation comprises of a functional get out cartridge. The air purifier meeting likewise

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comprises of a relationship for situating the get out cartridge directly into a favored, fixing, and introduction and for anchoring the sift through cartridge in that area. Wanted useful channel cartridges are given, and in addition techniques for meeting and utilize. [17] Biswanath bishoi et al in 2009 gives that there are various diverse air fine files, which constitute the worldwide city air poisons circumstance. Despite the fact that the list proposed with the guide of usepa offers a common evaluation of air fine, it does now not include the blended outcomes (or synergistic results) of the significant air. [18]

James et al in 2011 gives that air filtration is regularly supported as a component of ecological oversees measures for patients with hypersensitive respiratory issue. Private air filtration can be given by entire house filtration through the home's warming, ventilation, or aircon gadget, by methods for convenient room air cleaners. [19] Bogna goetzendorf-grabowska et al in 2015 cetrains that the paper examinations the properties of sift through nonwovens changed with triclosan-containing microspheres with the goal to accomplish antibacterial results. The transporter of triclosan incorporates microspheres result of corrupted polylactide (PLA) that bit by bit discharges triclosan, offering a uniform dosing of the antibacterial effect. [20]

III. FUNDAMENTAL AND DESIGN MODEL OF AIR PURIFIER:

In this Air purifier model which is basically design in such a way that is used to arrange the purifier filter so that to get the maximum efficiency and provide fresh and clean air. The modeling of air purifier is done in such a way that the air which is enters inside the box is at the bottom of one side and the fresh and purified air is get at the top of purifier and inside the air purifier Thermocol or PVC foam is used to paste on the wall for making the Box air tight, So that the fresh air is not easily spread throughout. Modeling is done with the help of Catia V5 R20 software.

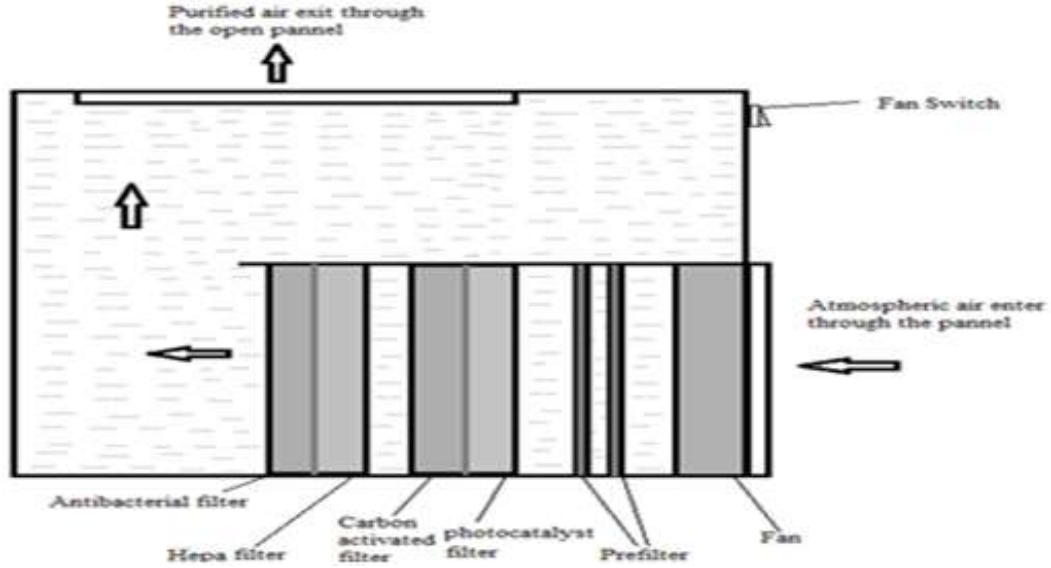

Fig1: Line Diagram of Air Purifier

In this particular arrangement the modeling of air purifier is done in such a way that the air enters at the back side of air purifier at their exhaust fan is installed which used to suck the air at the bottom side and the fresh air which we get is at the top of the air purifier. In this model the air travels a L shape area which is basically design in such manner that the purified air does move in the ground portion of that room and does not fell a high pressure flow of air. And the switch is given at the back side of air purifier to control the speed of fan and also used to regulate the fan.

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Fig 2: Inside arrangement of air purifier

Fig 3: block arrangement of air purifier

The model is basically design in a specific manner that the replacement of purifier filters is easily done. One side of air purifier is used in such that it can easily open and closed with the help of magnetic lock. Inside the air purifier where the filter are used to installed the blocks are made where it is used to give the specific space for the movement of air and specify the particular gap between the two filters that with the help of that maximum purification is done, as we used to keep the 2 inch distance between the two adjacent filter. this will help the air to flow in a laminar flow and there is no gap while fitting in the filters, in which not allow to flow of impure air after which allow only a constant flow of air regulate.

In this block arrangement we used to manage the fixing of filters in such a proper manner to get maximum efficiency as it always used to fix in proper manner so that filtration of air is done. In this filter we used to set two pre-filters adjacent to fan and then hepa filter and carbon activated filter after that antibacterial and photocatalyst filter to get the maximum efficiency.

IV. ANALYSIS ON FLOW OF AIR INSIDE PURIFIER:

In the model of air purifier the analyzing is done with using Ansys 17.2 software using fluid flow CFX work bench. In which we use the parameters that the air enters at the bottom part of the air purifier and exits at the top side. In this we use Hepa filter, carbonactivated filter, antibacterial filter, photocatalyst filter and pre-filter which are used to clean the impurities of air purifier.

For calculation of Air flow in purifier

(1). Mass of air in control volume

= (mass flow entry) – (mass flow exit)

$= p_{1\,x}\, a_{1\,x}\, v_{1} - p_{2\,x}\, a_{2\,x}\, v_{2}$

(2). Mass during t minutes of operations

= mass flow x time

(3). Pressure gradient

Using bernoulli equation

$$\frac{P_1}{\rho g} + \frac{(v_1)^2}{2g} + z_2 = \frac{P_2}{\rho g} + \frac{(v_2)^2}{2g} + z_2$$

(4). Work done

$WD = (p_1 - p_2) \times \text{mass} / \text{density}$

(5) Kinetic Energy

$KE = \frac{1}{2} mv^2$

2. To calculate efficiency of Air

$$\frac{\text{(Amount of air enters in the air purifier – Amount of air Ejected by air purifier)}}{\text{(Amount of air enters in the air purifier)}} \times 100$$

3. To calculate AQI we use these terms as

$$I = \frac{I_{high} - I_{low}}{C_{high} - C_{low}} (C - C_{low}) + I_{low}$$

Where,

I = the air quality index

C = the pollutants concentration

C_{low} = the concentration breakpoint i.e., less than C

C_{high} = the concentration breakpoint i.e., more than C

I_{low} = the index breakpoint corresponding to C_{low}

I_{high} = the index breakpoint corresponding to C_{high}

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Fluid flow CFX Analysis on flow of air inside air purifier

a) Heat Transfer analysis

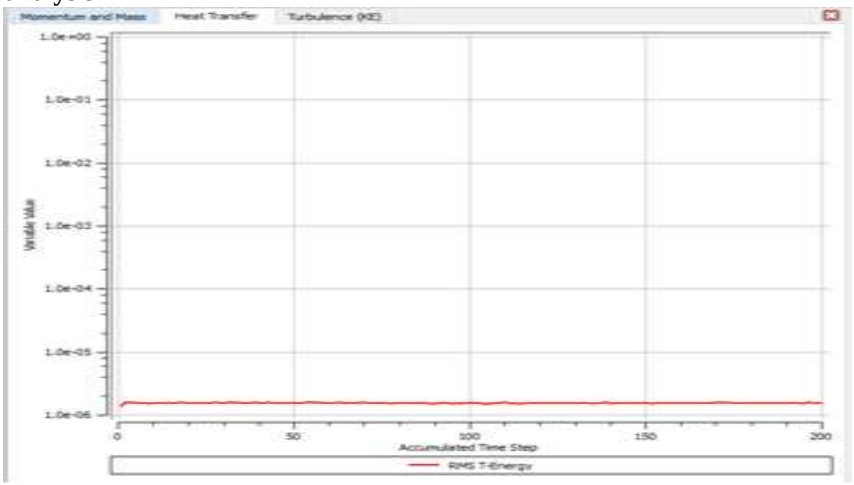

Fig 4: Heat transfer showing variable value vs accumulated time graph

In this graph red line represent RMS T–Energy. Heat transfer corresponding to given rpm of fan is constant. Rotation of fan increases the pressure and velocity but the heat transfer within the control volume remain constant. This analysis of heat transfer is bound for control volume only. Here control volume is the portion where the fan rotates and the atmospheric air gains velocity. Value of heat transfer is about the range of 10^{-6} which is negligible; hence we can say that there is no heat transfer takes place within the control volume.

b) Momentum and Mass analysis

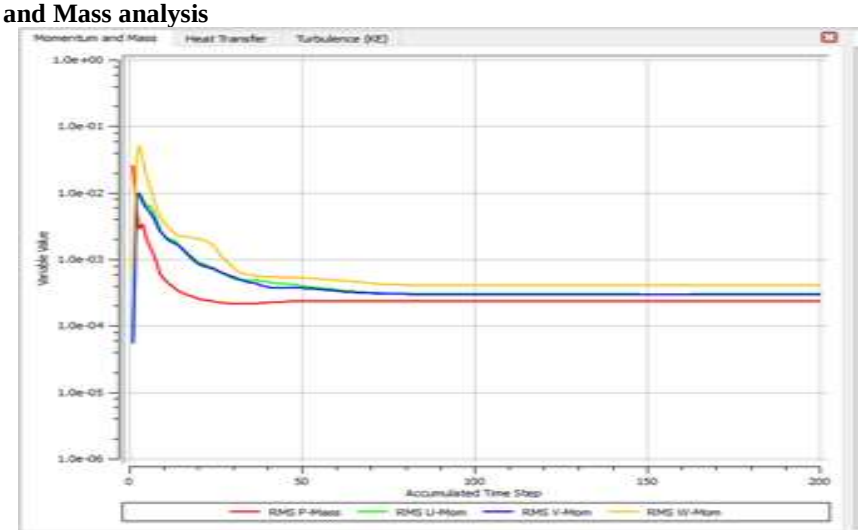

Fig 5: Momentum and Mass showing variable value vs accumulated time graph

In this graph red line represent RMS P-Mass, green line represent RMS U-Momentum, blue line represent RMS V-Momentum and yellow line represent RMS W-Momentum where U, V, W represents the momentum in x, y and z direction respectively. As shown in the graph for particular rpm of fan the particles of air shows variation i.e. the mass and momentum of air is negligible at the entry point just before the rotating fan. After striking with fan the mass and velocity of the air particles is suddenly increases therefore the momentum of air particles suddenly increases in x, y and z direction. The mass and momentum of the fluid continuously decreasing once the air particles moves away from the rotating fan.

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c) Turbulence (kinetic energy)

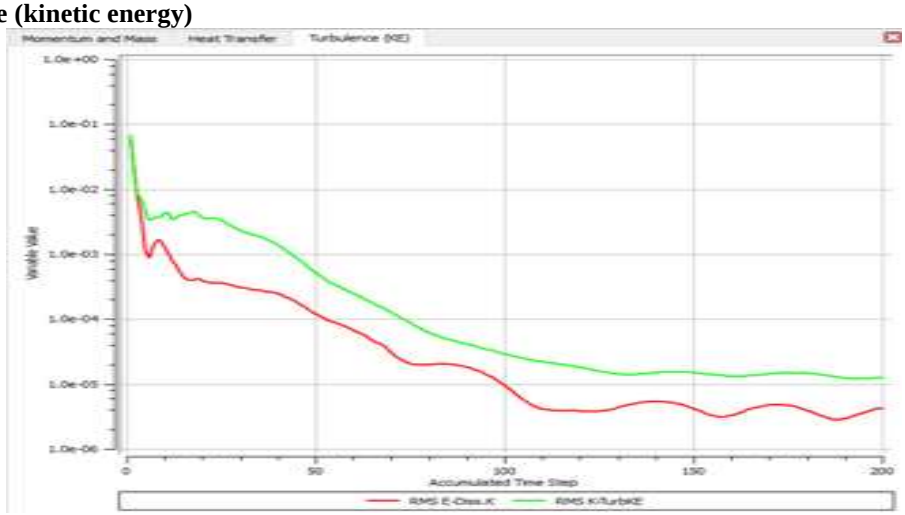

Fig 6: Turbulence (kinetic Energy) showing variable value vs accumulated time graph

In this graph red line represents RMS E-Dissipation kinetic energy and green line represents RMS K-Turbulence kinetic Energy. After striking the air particle with the rotating fan as velocity increases, kinetic energy of the air particles also increases and obtains a maximum value just after the collision process. The kinetic energy of the air particles is then continuously decreasing as velocity decreases from moving away from the rotating fan. Turbulence kinetic energy is more than dissipation kinetic energy because rotating of fan induced turbulence to the air.

d) Pressure gradient flow

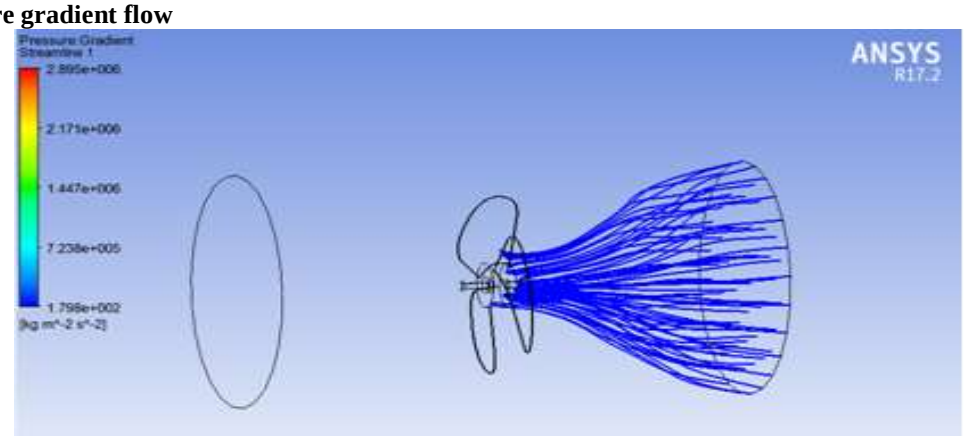

Fig 7: Pressure gradient of air when the air strikes the fan rotating blade

The blue line shows the pressure gradient as the fan exhaust the air from the atmosphere and the air strikes on the blade of the fan with a specific speed. The pressure just before the collision is zero because the air is at atmospheric pressure and after the collision the pressure increases drastically because as air is moving from the impeller hub to blade tips it gains kinetic energy and this kinetic energy is converted into pressure head by following Bernoulli equation. As shown in the figure the pressure is maximum just after the collision and it is keeps on decreasing as we move away from the rotating fan.

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e) Velocity stream line flow

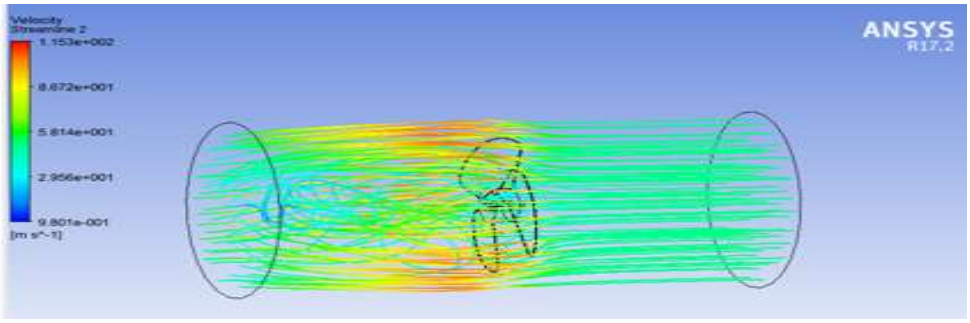

Fig 8: Velocity streamline of air when the air move inside the air purifier

In this the air moves inside the air purifier with some specific velocity and the movement of air inside the purifier is shown in the figure. The streamline of fluid particles shown above is horizontal before striking with the fan blade. After the collision the flow is turbulence hence the velocity streamline is randomly ordered. The fluid particles which are away from the fan blade follows the laminar flow and stays in control volume for short duration but the particles which are towards the center follows turbulent flow the fluid particles corresponding to it stays in control volume for longer period.

V. RESULT AND DISCUSSION:

In this analysis we used CFX software in which we analyze the flow over fan blade which is used in air purifier. Here our solid domain is a rotating fan encloses by a stationary fluid domain i.e. cylindrical volume. One side of the enclosure assigned as inlet, the other as outlet and rest of them as walls. Fluid i.e. air flows through the enclosure and passes over the fan blade or propeller and the resultant motion after collision of air and fan blade are shown in the figure above.

Air flows through inlet with subsonic flow regime having mass flow rate of 0.2 kg/s and turbulence is medium with intensity of 5%. The pressure measured at outlet is average static pressure of 120 Pa with subsonic flow regime. The pressure profile blend value is 0.05 which is used to blend between specified pressure profile and floating pressure profile where the pressure averaging is constrained. Here pressure averaging is average over whole outlet. The fan i.e. made up of steel is a solid domain having rotating speed of 150 rpm about z axis.

Figure 4 shows plot of root mean square thermal energy (RMS T-energy) curve which shows for increase in accumulated time step the variation of thermal energy is about constant. Figure 5 shows mass and momentum curve for accumulated time period. Continuity equation is applied to get the results of (P-mass), (U-mom), (V-mom) and (W-mom) i.e. momentum in x, y and z direction. It is clear from the curve that maximum momentum value is in z direction whereas minimum is in x and y direction. Moreover, we can also say that the curve of momentum in x and y are about overlapped. Figure 6 shows Turbulence (KE) curve in which root mean square energy dissipation k and root mean square k-turbulence kinetic energy is plotted with increase in accumulated time step. Energy equation is applied to solve the problem in CFX solver. It is clear from the plot that turbulence kinetic energy exceeds energy dissipation.

Figure 7 shows pressure gradient streamlines from inlet to the fan or propeller. Pressure at the fan stator is maximum and negligible near the blades. The intensity of 100 streamlines is used in the calculation. Figure 8 shows velocity streamlines consider all domains. Fluid flows from inlet to outlet with equally spaced sampling and maximum number of points i.e. 100 with velocity in forward direction. The velocity profiles are laminar near the fan blades and turbulent near the stator and as we go towards the center of the fan the velocity of the fluid decrease and it is maximum at the fan blades periphery.

VI. CONCLUSION:

From the given results it is observed that for the inlet velocity of 15.80 m/s, the velocity at the outlet is vary with radius of enclosure at the outlet. The velocity is maximum i.e. 31.34 m/s at periphery of the fan blades due to laminar flow and due to turbulence it is 3.60 m/s at the rotor of the fan. The pressure gradient at the inlet and at the center is constant i.e. 13.28 Pa. Presence of filters i.e. pre filter, photo catalyst filter, carbon activated filter, Hepa filter and anti bacterial filter doesn't affect the flow of air through fan only intensity of pressure reduces with reduce in velocity of flow. Overall setup removes 99.9% contamination and provides fresh air. In this hepa purifier removes chemicals, bacteria and viruses which can't look

with naked eyes, carbon activated filter remove chemical emission, gases, tobacco smoke and odors, photocatalyst filter removes nasty air pollution and bad odour, antibacterial filter removes particulates and harmful irritation and pre filter removes the hair and large dust particles.

Why to use this Air purifier over others

In this design arrangement is done in such a way that as the impure air from the bottom and the fresh air is exit at the top of the filters so that there is no need of any stool or any block to fit on it. This purifier is easily installed inside your house or in any business place. You can put anything over it as it made of wood to get better durability and for attractive look with wooden polish. It doesn't require any space specific space you can place in a dark room also it easily work on it. This air purifier work on inverter also, as it consumes less electricity because it has only a exhaust fan. In this air purifier filters the arrangement of filter is easily done by you without any technician, filters are also easily available for replacement and are of standard size. it has pre filters which are washable and the filters are easily cleaned by yourself.

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International Journal of Advances in Engineering and Management
ISSN: 2395-5252

IJAEM

Volume: 03 Issue: 02 DOI: 10.35629/5252

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