IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

ANALYSIS OF CO CONCENTRATION DISPERSION IN A GEOMETRICALLY ASSUMED UNDERGROUND PARKING AREA USING JET FAN VENTILATION SYSTEM

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Abstract: Adequate ventilation of enclosed parking areas is required to ensure the concentration of vehicle exhaust pollutants, especially CO so that the concentration do not reach the level, high enough to threaten the safety of the car park occupants. So an attempt has been made to observe the maximum amount of CO Ventilation for three different velocities of exhaust fans. The simulation of the whole setup is done using Computational fluid dynamics (CFD) via the software ANSYS. With the development of CFD tools, car park ventilation can be shifted from code-based approach to performance based approach, and then using CFD methods the authenticity of the proposed design is confirmed. The proposed underground parking is a trapezoidal type area with dimensions are of 35m and 25m non parallel sides, 35.35m parallel sides and height 4 m. Here in the model two inlets and two outlet is considered. The modeling shows the CO concentration variation considerably with no fans and different positions of jet fans. So using the results showing the level of CO dispersion for the 3 observed cases of jet fan positions, a comparative analysis is concluded for CO concentration within the parking area. A considerable improvement of CO concentration has been observed after using Jet fans in arrangement 3.

Key Words **– Underground Parking, exhaust gases of a car, CO emission**

I. INTRODUCTION

Cars have become an inevitable part of the modern lifestyle and its number on globe is assumed to have exceeded a billion, and with everyday increase in car ownership consequently the demand for car parking lot has increased significantly, specifically underground parking system. Because with rise in the land values, the underground parking structures tend to be more efficient as they provide long term benefits and comparatively proven to be more convenient for built under offices, housing complexes, malls, hotels etc. Therefore, in cities and large towns the need to customize and obtain optimal constructional data as per requirement for the considered location has become a prime necessity.

Since the conventional open car parking areas engage far too much space which is meant for some other purposes, underground car parking is one of the best alternatives. It not only saves land but also safe and secure from adverse climatic condition and prevention of vandalisation of the parked cars. And thus, the demand for underground car parking is increasing evermore.

Whether it's an office complex, residential accommodation or industrial building, every construction has its specific requirements with regards to the ventilation system. And certain challenges are encountered when underground single or multi-story car parks are taken into considered, since the air within the parking lot proximity gets severely contaminated by the harmful car's exhaust gases, namely carbon monoxide (CO) , nitrogen oxide (NOx) **[2]** liquefied petroleum gas (LPG) and benzene (C6H6) etc, out of which high CO concentration is deadly. Therefore it is the most widely used parameter to determine ventilation rate **[3].** The amount of CO in the car parking area depends on several factors like vehicle type, ambient air and engine operating mode **[4]**. Depending upon the concentration and the duration of time spent in the car park, it raises an alarm for health concern of the users. So, it is required that the exhaust gases are extracted quickly and efficiently CO is one of the prime environmental pollutants and it is very lethal for human beings when exposed for prolonged amount of time ie asphyxiation and researches have also found that CO exposure on a regular basis, leads to serious health complications ie central nervous system damage. Hygienic limit of CO for eight hour exposure 30 ppm and 75 ppm for 15 minute exposure **[1].** Different organizationS have set permissible exposure time as follows [3].

Table1: CO permissible limit of various standards

Standard and Organization	Permissible limit	Exposure Time
American Conference of Governmental Industrial Hygienists (ACGIH 1998)	25 ppm	8 hours
Environmental Protection Agency (EPA 2000)	35 ppm	1 hour
	9 ppm	8 hours
Occupational Safety and Health Administration (OSHA 2012)	50 ppm	8 hours

Car Parking Model:

A 3D computer model layout of certain dimension is created and a detail analysis is done on it. The model is run with four jet fans and two supply and two exit i.e to observe any areas of stagnant air within the parking contour. This initial process allows the primary airflow paths from the supply point to the extract points and the areas of re-circulation, if any exists within the car park. Several iterations of the model has been done to obtain the optimum CO dispersion with the most efficient airflow is performed, then at the end a detailed report of the results are observed for the performed processes, ie streamline, volume rendering, gauge pressure contour, velocity profile , temperature contour etc

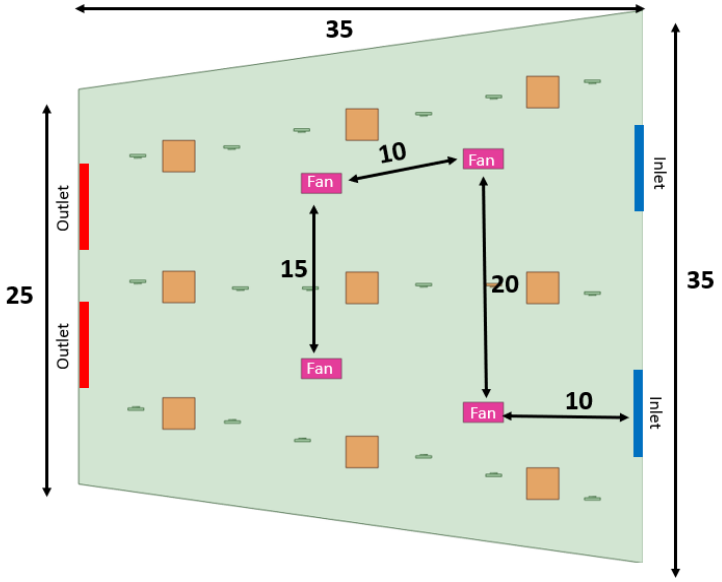


Figure 1: Car parking model layout

Mesh Generation:

Meshing of the computational domain *fig:2* has been done with tetrahedron geometry to reduce the computational time unlike octahedral mesh. In this meshing the nodes are well connected to each other and accuracy level in the numerical study is very high.

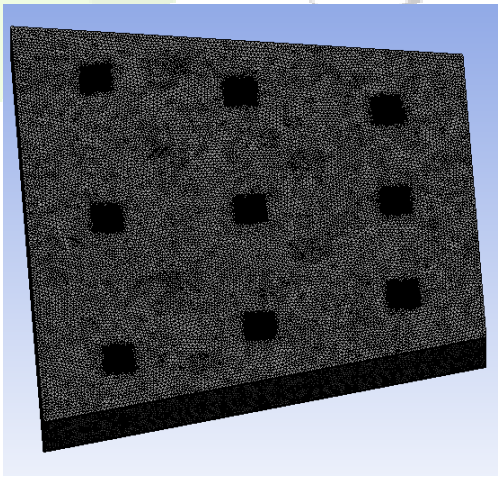


Figure2: Meshing Car parking model layout

Initial design parameters of the car parking area

Input conditions	Magnitude
1. Column size	0.25m x 0.25m
2. Length of the parallel sides	i. 135 m ii. 225 m
3. Length of the non parallel sides	35.35m
4. Height of the structure	4 m
5. Size of the parking area	1012.18 Sq. meter
6. Effective parking area	1011.67 Sq. meter
7. Number of cars that can be parked	18
8. CO produced by a single car	8.2 mg/s
9. Constraints for CO emission , i. Long term exposure ii. Short term exposure	 30 ppm 200 ppm
10. Reference operating temperature	298
11. Number of axial exhaust fans used	4

Results and Discussion:

The domain which replicates the actual car parking area is analysed considering four numbers of jet fans working at a time and one without considering the jet fan. In the parking area two inlet fans are connected through a duct having a velocity of 3m/sec and outlet is considered as pressure outlet. In general all cars do not start at a time but to study in extreme condition, CO dispersion analysis has been done computationally for exhaust gases of all the eighteen vehicles exhausting gases at a same instance of time. Here alteration of arrangement of jet fans has been done for three arrangements arrangement 1(a1), Arrangement 2 (a2) and arrangement 3 (a3) to find the best arrangement for maximum CO dispersion. Finally a comparison has done for variation of velocity and stream line in all arrangement of the jet fans

Arrangement 1

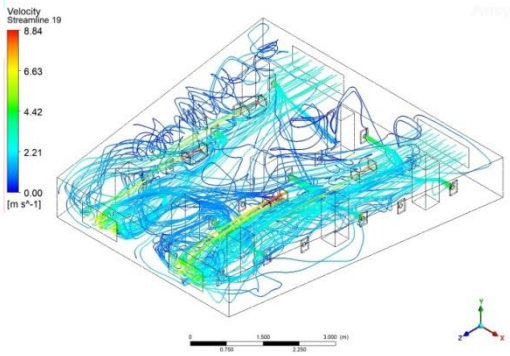


Figure 3:Velocity Streamline of a1

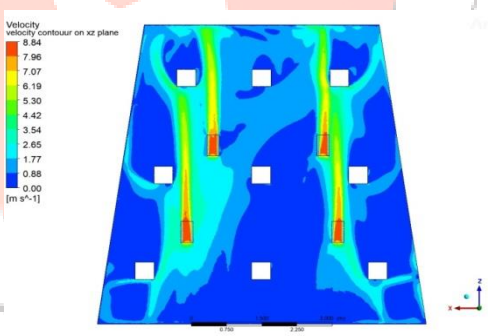


Figure 4:Velocity contour of a1

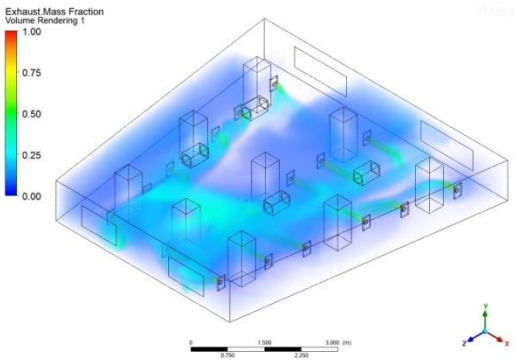


Figure5:3D Dilution Pattern a1

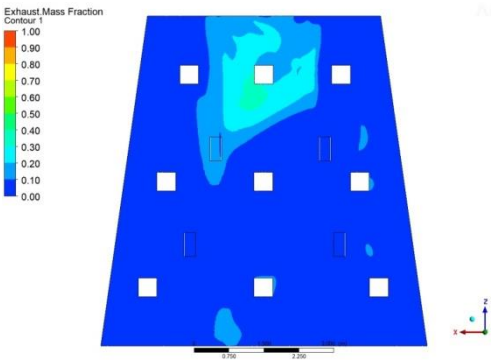


Figure 6: CO dispersion pattern of a1

In jet fan arrangement 1 the jet fans are not placed just behind the other fans in short not in the same axial line. The velocity distribution throughout the entire area is not uniform. The highest velocity can be seen around the jet fan areas. No major vortices have been seen in the velocity streamline diagram. In the CO concentration diagram for the entire area concentration level is very less. Although in sideways near the left and right boundaries of the parking area has very low velocity of air but no CO concentration has been observed. CO mass fraction has been seen in between the areas of exhaust passages near the wall.

Arrangement 2

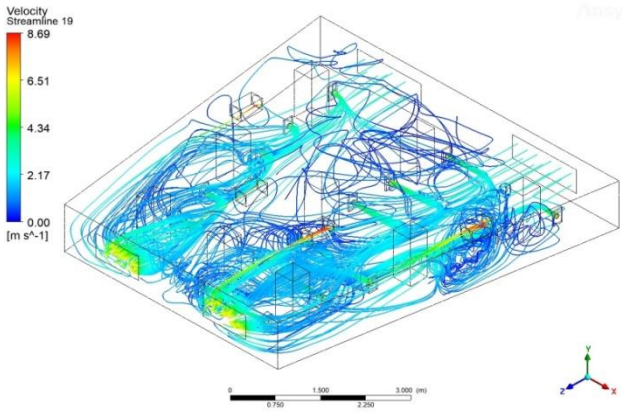


Figure 7:Velocity Streamline of a2

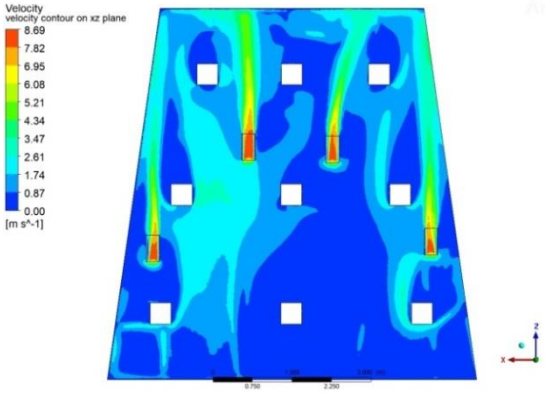


Figure8 :Velocity contour of a2

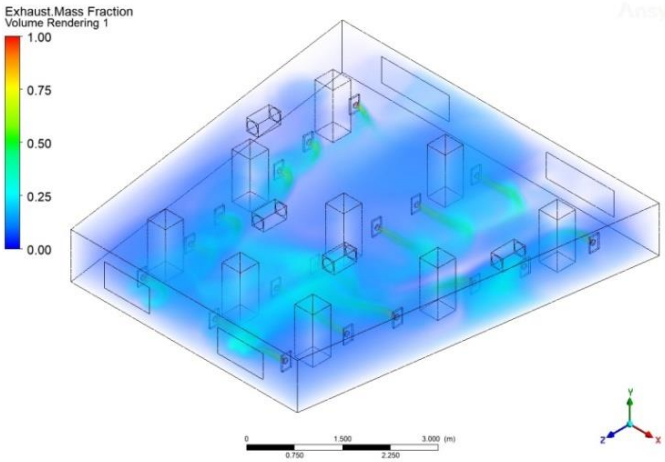


Figure 9:Dilution pattern of a2

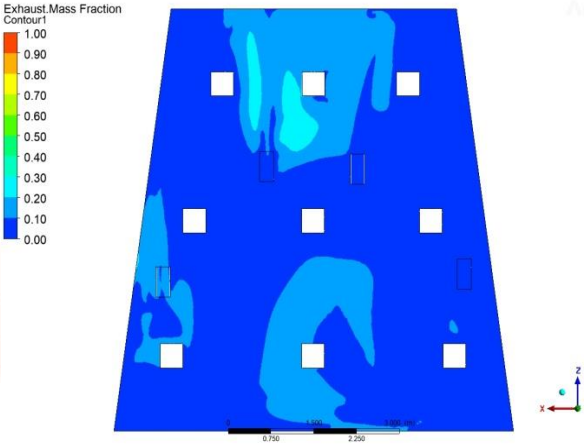


Figure 10:CO dispersion pattern of a2

In jet fan arrangement 2 all four jet fans are arranged in different places and all are not in line. No major vortices have seen in the velocity streamline plot. Movement of air has been seen without any obstructions in the contour plot. The CO mass fraction has been seen in left sideways and between the areas of inlet and exhaust passages near the wall.

Arrangement 3

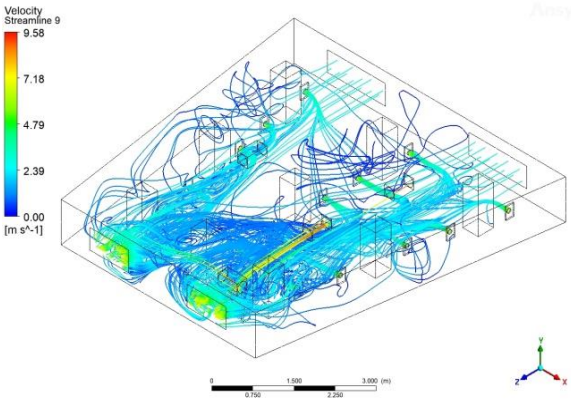


Figure11:Velocity Streamline of a3

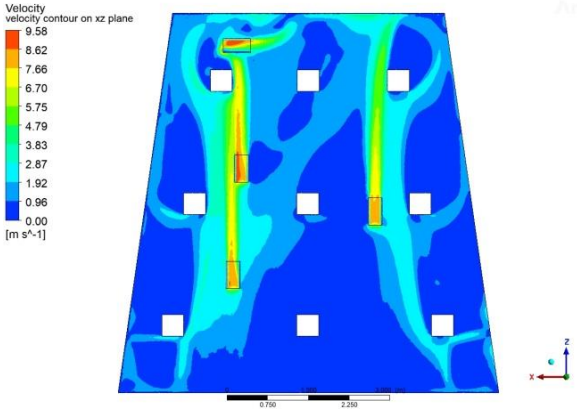


Figure 12:Velocity contour of a2

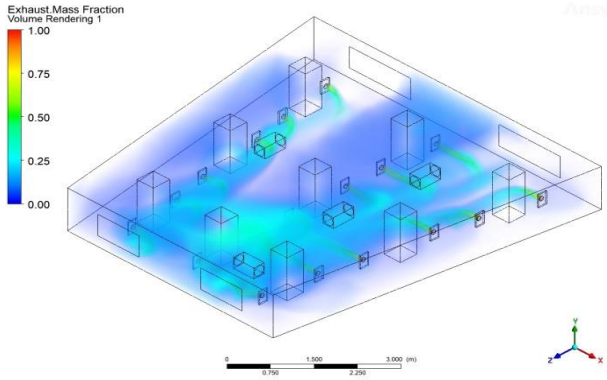


Figure13:Dilution pattern of a2

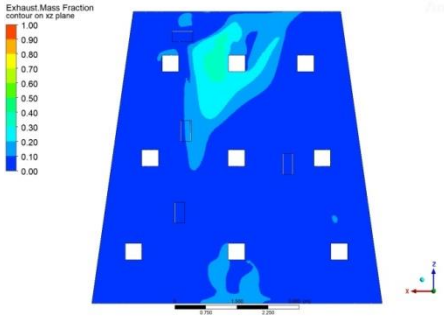


Figure14:CO dispersion pattern of a2

In jet fan arrangement 3 three fans are arranged in such a way that their thrusts are in the same direction and the fourth one is placed perpendicular to the direction of thrust of the other three. Here no major vortices have seen in the velocity streamline plot. CO mass fraction has been in between the exhaust passage near the wall. A trace amount also seen near the inlet passage.

Without jet fan:

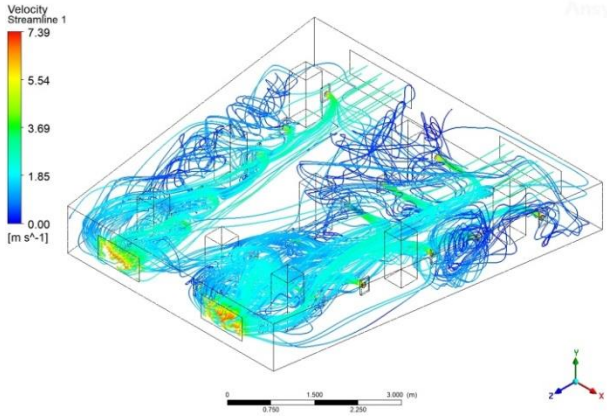


Figure15:Velocity streamline with no fan

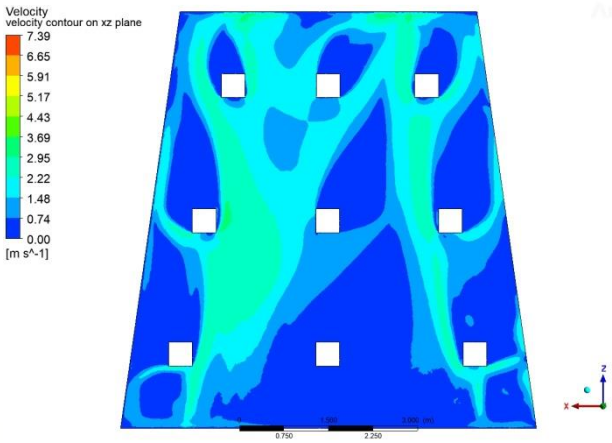


Figure16:Velocity contour with no fan

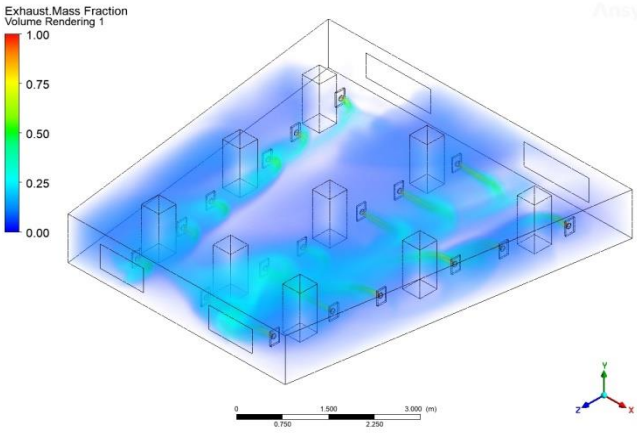


Figure17:Dilution pattern with no fan

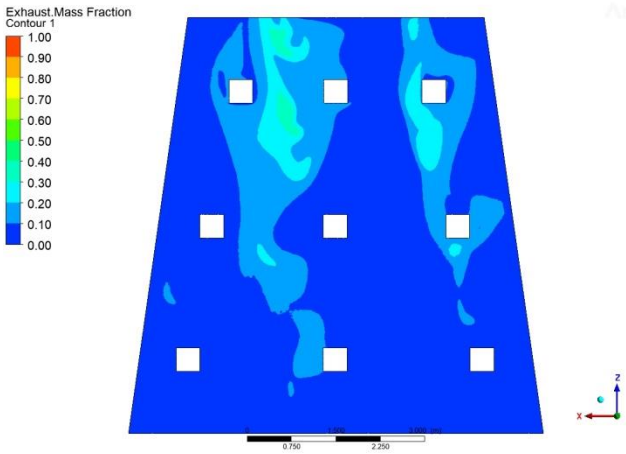
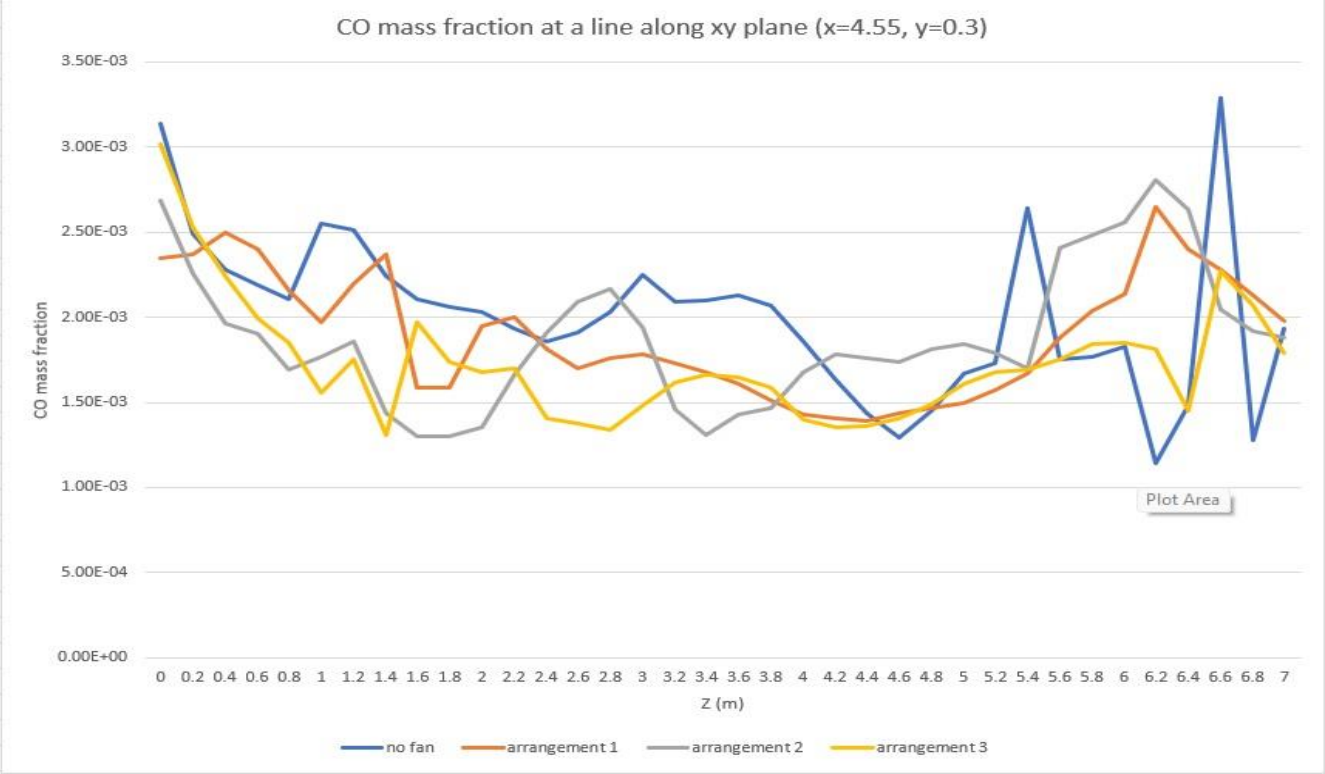


Figure18 :CO dispersion pattern with no fan.

When there no jet fan is running only inlet and out air systems are functioning vortices and CO mass fraction can be seen in the entire parking area. If it is compared with the arrangement 3 a significant improvement for disposal of CO mass fraction can be seen.

CO mass Fraction Curve: A line along xy plane (x=4.55, y=0.3) is constructed in the computational domain and concentrations of CO has been determined for various jet fan positions of arrangement 1, 2 3 and no fan and it is seen that except few places in



the domain CO concentration considerably decreases in arrangement 3

Conclusion:

Many external parameters should be taken into consideration, like the boundary conditions applied during the architectural design as well as the configuration of the underground car parking area for the optimal result. The aim of this research study is to analyse the CO concentration dispersion for maximum removal.

Essentially many car parking spaces do not pose health hazards to their users, although some by way of design, construction, site configuration, position and poor maintenance, inadequate number of fans and their positioning ,the users may get exposed to severe hazardous elements.

The main objective of the research study is to analyse the Carbon monoxide dispersion and it's flow in the considered geometrical configuration where total 18 cars were releasing exhaust gases at a time by using CFD. Where, it can be concluded that for the garage design in particular, two numbers of inlet air arrangement, two numbers of outlet air arrangement and four numbers of jet fans operating decently, distributing the airflow to all areas of the garage uniformly and ensuring the removal of any stagnant areas of air, ie CO.
Furthermore, it has been observed that for the arrangement 3, the concentration level of CO is lowest.

Thus, we can conclude that the preference arrangement is 3, since minimal amount of CO remnants is observed in this case.

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