Design of Comfortable Advanced Ventilated Automotive Seat for Driver using CFD simulation

Aniket A. Gabhane[1], A. V. Waghmare[2]

[1]*Mechanical Department, AISSMS Collage of Engineering, Savitribai Phule Pune University, Pune, India*
[2]*H.O.D, Mechanical Department, AISSMS Collage of Engineering, Savitribai Phule Pune University, Pune, India*

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Abstract - *Driving imposes a lot of physical and mental stress upon the driver. Driver seat design is the important factors that lead to good working conditions for the driver proper working. The optimal design of driver seat in the cabin may be achieved by integrating ergonomics or called anthropometric data with other technical description of the design. Driver also have to handle various controlling functions, the muscular activities also need to be taken into consideration for proper design and comfort of seat. This paper explores the review on the design of comfort seat for driver. As the customer's expectations are rising for comfortable driving the importance of having ventilated seats for thermal comfort is increasing In this paper the 3-D computer simulations using CFD technique to examine these issues of Heat accumulation within the car and driver seat. This paper also identifies the common causes and problem faced by the driver during driving.*

Key Words: Automotive seats, Ventilated seats, Thermal comfort, Driver comfort.

1. INTRODUCTION

Modern technology has brought a lot of changes to the cars we look around in the traffic. The cars have evolved not just in their exteriors but also in their interiors .The luxury segment cars are primarily about the inner comfort. They intend to improve the experience of the passenger within the car.

The problem faced by the cars today is the initial high temperature within the car cabin. This phenomenon of Thermal Accumulation is clearly evident when the car has been parked in the sun for a few hours. The car user is forced to wait for a period of around 2-5 minutes to allow the cabin environment to be like the ambient. The comfort provided by a car to the passengers travelling in it has become a major field of improvement and demand in the Automobile Industry. A perfect HVAC (Heating Ventilation -Air Conditioning) is being explored by the research scientists.

This study presents the used of thermal comfort driving seat. The aim of this project to developed the low cost air ventilated car driver seat and studied the different parameters of human comfort using computational fluid dynamics.

2. WORKING PRINCIPLE

Thermal analysis of a driver seat involves not only geometric complexities but also strong interactions between airflow and the three modes of heat transfer, namely Heat Conduction, Convection and thermal Radiation. Conduction is a mode of transfer of heat which occurs when a temperature gradient exists in a body or two or more bodies in the same phase. The heat transfer rate per unit area is proportional to the normal temperature gradient.

$$q = -kA\frac{dt}{dx} \qquad (1)$$

Where q= Heat transfer rate

dt/dx=Temperature gradient in the direction of flow

k=Thermal conductivity of the material.

A=The area under consideration.

The above equation is called the Fourier's law of Heat Conduction. The convection is important to study for the performance of thermal comfort of seat. Convection is the mode of heat transfer between any two different phases such as a solid and a liquid or a solid with a gas or vice versa. The overall effect of convection is expressed by Newton's law of Cooling.

$$q = hA\Delta T \qquad (2)$$

Where q= Heat transfer rate

h=Convection Heat transfer Coefficient ΔT=Temperature gradient between the two bodies.

Energy transfer can also take place without a medium this mode of heat transfer is called Radiation .The mechanism in this case is electromagnetic radiation. Thermodynamic considerations show that an ideal thermal radiator or a black body will emit energy at a rate proportional to the fourth power of the absolute temperature of the body.

$$Q_{emitted} = \sigma T^4 \qquad (3)$$

Where σ=Stefan-Boltzmann Constant (5.669 x 10-8 W/m2.K4)

3. PARAMETER AFFECTING DRIVER SEAT DESIGN

The different parameters are responsible for the discomfort of human being in car driving. The discomforts are like pain in back, neck, filling lazy etc. This parameters are not variable its changes according to the conditions, but following some parameters which have to be study very essential for design comfortness of car driver seat. For comfortness of driver following some parameters are necessary to fulfil:

- The design of driver seats such that, driver can easily reach to control unit and can easily visualize.
- The driver seat is in anthropometric data, so that any size or shape driver can easily accommodate it.
- The driver should be comfort during the all way driving.

The seat of driver should be providing guard to driver during accidents.

4. COMFORT RELATED PARAMETERS

The comfort is nothing but joyful environment necessary for any work. The comfort activities include the thermal comfort, pressure distribution, geometric parameters and vibration at driver seats.

4.1 Thermal Comfort

Thermal comfort is very important ergonomic parameter on which comfort as well as health of driver reliant. Generally seat cushion materials (including seat cover, PU foam and coconut fibers underneath to foam) absorb heat from driver body any acts as heat reservoir, this event is good for health in winter season but responsible for un-comfort in summer season. This problem can be overcome by using different types of seat covers depending on seasons.

4.2 Pressure Distribution

For comfort and proper maintenance of driver health uniform pressure distribution along the human body over the seat is very significant parameter. Pressure distribution over a seat is dependent on the properties of cushion material such as design of cushion, deflection and stiffness. Also it depends on nature of loading, seat pan design and backrest design. A proper seat pan contour distributes a uniform pressure over seat and avoids concentration of stress in human buttocks. Properly inclined back rest avoids stresses at buttocks.

4.3 Vibration

The roadways followed by vehicles are not uniform. The jerk that impacted due motion of car causes sudden vibration in car and driver seat too. These types of vibration lead greater impact to human body, so it is necessary to design the seat with good quality of suspension system.

5. DESIGN OF THERMAL COMFORT SEAT

It relates to a vehicle seat cooling with the help of air conditioning system, which is used to cool the cabin by blowing out air. Air-conditioning system is so used that the air-conditioned air is supplied through the ducts to the seat from a front duct of the vehicle and blown out from the seat surface where the ports are provided on seat. In this conventional system, a seat cooling air duct is connected as a branch from the main box duct of the front air-conditioning unit, and a seat warming air duct is connected as a branch from the foot duct of the front air conditioning unit. The cooling air duct and the warming air duct merge with each other and finally form a single long seat duct. A cool/Warm air switching damper is arranged at the confluence of the cooling air duct and the warming air duct. As long as the front unit is in face mode, the cool air switching door opens the cooling air duct and closes the warming air duct. Therefore, part of the cooling air from the face duct is supplied through the cooling air duct to the seat duct then it is given to seat through ports provided on it. As a result, the cooling air can be blown out of the seat through the ports on the surface.

When the front unit is in foot mode, on the other hand, the cool/Warm air switching door opens the Warming air duct and closes the cooling air duct, so that part of the Warm air from the foot duct is supplied through the Warming air duct to the seat duct. Thus, the hot air can be blown out of the seat. The above-mentioned conventional seat air-conditioning system is so configured that the cooling air and the Warming air are switched and supplied to the seat through a dedicated seat duct.

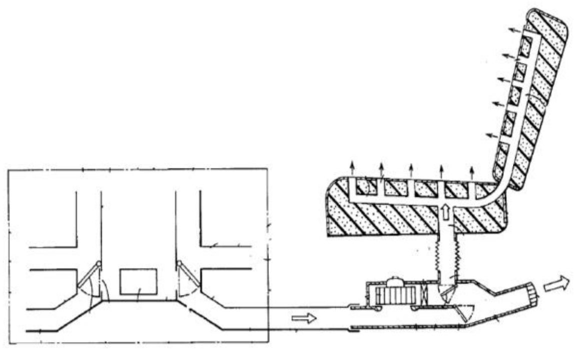

Fig -1: Layout of ventilated seat

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The problem, however, is that a long seat duct, as Well as a cooling air duct and a Warming air duct switched by a door, is required as a component independent of the front air-conditioning unit. This complicates the configuration and poses the problem of higher cost and larger space required.

Fig -2: Isometric view of proposed seat

The object is to provide a vehicle seat air-conditioning system in which the cooling and warming air flows can be switched and supplied to the seat with a simple structure thereby to obviate the problems of the conventional technique. In order to achieve this object, according to the present invention, there is provided a vehicle air-conditioning system as described in the claims attached hereto. In a vehicle seat air-conditioning system according to this invention, as in the prior art, the air-conditioning air is supplied to an occupant's seat through an air duct from a front air-conditioning unit. The configuration unique to the invention is that a branch duct having an air supply port connected with the downstream air duct is formed in the air-conditioning case of the front air-conditioning unit. Thus, part of the air-conditioning air, including a cooling air and a warming air flowing toward the front, is divided in the air-conditioning case. The cooling air and the Warming air are switched by a cool/Warm air switching means and supplied from the air supply ports through the air duct to the seat. As described above, the branch duct for supplying part of the front-destined air-conditioning air to the seat and the cool/Warm air switching means for switching the cool air and the Warm air to be supplied to the seat are all housed in the air-conditioning case of the front air-conditioning unit. Therefore, only the air duct connected to the air supply ports of the air-conditioning case extends from the air-conditioning case to the seat. In this Way, the ducts are greatly simplified and shortened in configuration. Also, with the air inlet to the seat configured in such a manner as to branch off from the existing rear air duct extending to the rear foot air vent, no special air duct is required for the seat.

The proposed ventilated seat is modified with a chamber at its base along with ports emerging from it which will provide cool air. The base chamber is connected directly to the air conditioning outlet pipe. There are 21 aluminum ports in each row with 5mm in diameter.

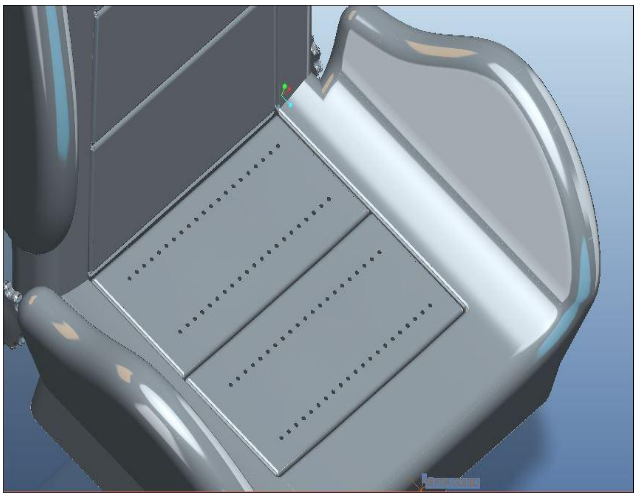

Fig -3: Ports on base of seat

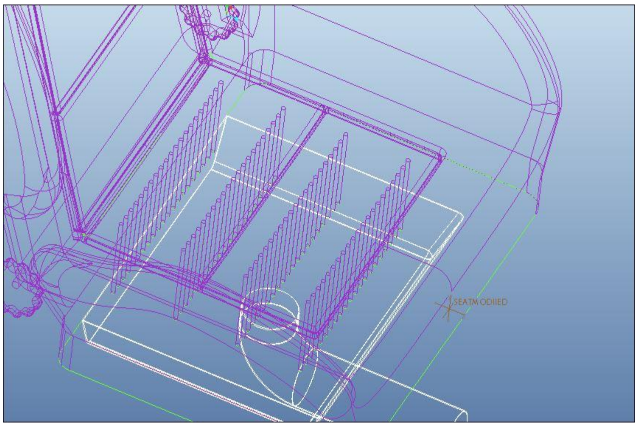

Fig -4: Detailed view of ports

6. COMPUTATIONAL FLUID DYNAMICS OF SEAT

The entire space of the vehicle consists of the computational Domain and the inner surfaces of the car seat are the boundary conditions. The 3D model of the car driver seat was developed using CATIA software. Theventilated seat is provided with chamber underneath of seating pan. The seat pan having dimension of 36 x36x5 cm.Total volume of model is 0.00648 cubic meters. This study concentrates in the thermal distribution within a driver seat of car so as to reduce the complexities in the flow distribution of a seat the ventilated chamber is provided with cushion. The dimensions of the car seat are according to the standards. Inlet and outlet vents have been added to the structure at the specified locations.

A. Meshing Criteria

The meshing of the structure was completed in using the ANSYS. Unstructured grids have been adopted, and most of the grids are tetrahedrons. The mesh has been given a spacing of size 5 units for proper and uniform meshing. Tetrahedral meshing has been preferred over any other because it produces more accurate results than quadrilateral due to the non-uniform geometrical shape of the model under investigation. The meshing yields a total of 5896 tetrahedral element, and 1560 nodes.

B. Boundary Conditions

The inner surfaces of the car have been given boundary conditions. The Window glass is somewhat transparent and the major part of sun radiation can go through the glass. Solar radiations have been assumed to fall on the front wind shield, the side windows and the rear window. The thermal properties of the windows are set with an external temperature of 310K.The properties are that of air. The windows participate in solar ray tracing, the absorptivity and transmissivity are taken as the default values from the fluent database. The other parts are considered as opaque walls which transmit no part other solar radiations inside the cabin. It has been assumed that the other parts are completely adiabatic. They have zero heat flux and heat generation rate. No convection, radiation or any other mode of heat transfer takes place from across its walls. The following are some boundary condition needed to carry out the computational simulation.

6.1 For Inlet & Outlet Vents

The window panes are considered to be semi-transparent, thus allowing some amount of solar radiation to enter inside the car. The boundary condition in this analysis is same as the above section. In addition to that the Inlet vents have been set as velocity inlets and the outlets as pressure outlets. The flow within the cabin has been considered as laminar and steady and the experiment has been conducted in atmospheric pressure conditions i.e.1atm.The pressure is exerted within inlet and outlet port is important to note for proper flow of ventilated air. The material that makes up this 3D model is once again air with properties that are found in normal conditions.

6.2 For Engine Temperature

The Engine of car operates at very high temperatures. The Ignition chambers of engine is reach up to 2000-3000K at the time of ignition .The car has inbuilt cooling systems which do not allow the heat generated to disturb the cabin environment. The Thermostat and Radiator systems help to keep the temperature in control .The heat absorbed by the cooling water causes it to gain temperature. This water circulates within the cabin. The boundary temperatures for this problem have been taken as standard room temperature i.e.300 K.The engine temperature bleeds in over the area under the dashboard. Adiabatic conditions prevail within the car.

6.3 Inlet and Outlet Conditions

The air temperature and velocity at the inlets play an important role in determining car driver seat climate. Steady state conditions are prevalent within the cabin environment and within the ventilated seat. The ambient temperature is considered as 300K while the inner temperatures are relatively high due to the heating environment like solar radiations falling on the window panes or engine heating. The inlet velocity vents blow air at a velocity of 3m/s, 4m/sec and 5m/sec. The velocity of air vent is measured with help of anemometer and controlled with regulator. The inlet is provided with vent from air condition duct while its open in the form of small duct provided on the seat pan.

6.4 Other Miscellaneous Factor

In order to create the role of the size, number and location of HVAC system inlets and outlets, a 3D simulation for various positions of inlet and outlet have been run. There are one inlet vent is provided underneath of car seat of size (10X100 cm) located at centre of car seat pan. The outlets pores on the seat pan size (2x2 cm) are provided below cushioning with 40 in numbers.

7. RESULTS AND DISCUSSION

7.1 Pressure contours

Computational Fluid Dynamics (CFD) analysis on ANSYS Simulation software is used for the purpose of obtaining the pressure, density and velocities of the perforated seat pan so that the performance of the seat can be judged. The cold is passed into the seat air chamber provided below seat pan by means of air conditioning hose of car.

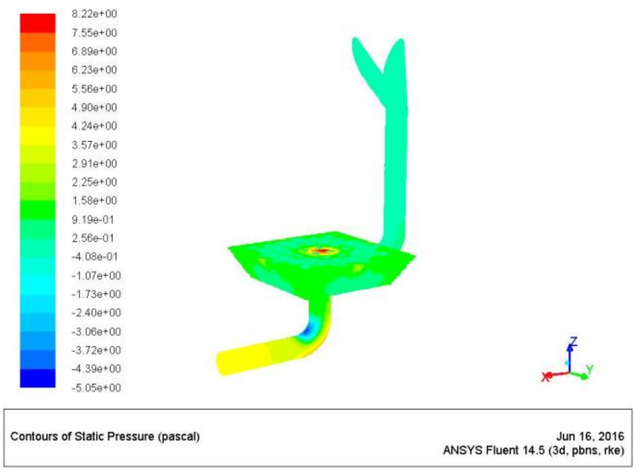

Fig -5: Pressure contours at 3m/sec

The computational fluid analysis of comfort seat shows the distribution of cold air flow over pan of the seat and back rest. It predicted the flow of the cold air over the seat. The analysis is carried out at different velocity of cold air for 3, 4 and 5m/sec.The distribution of pressure with different velocity of air is predicted with given contours plots.

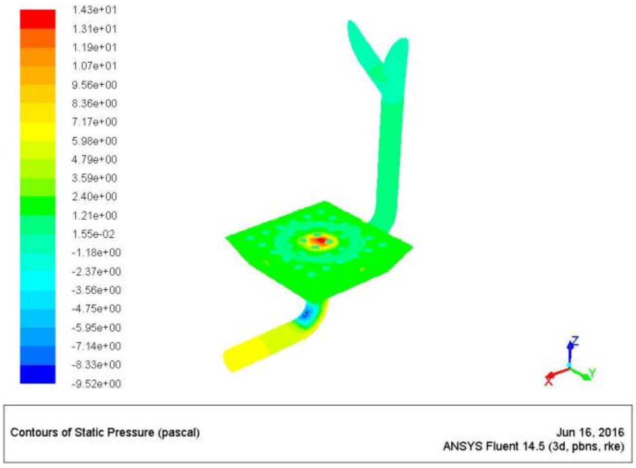

Fig -6: Pressure contours at 4m/sec

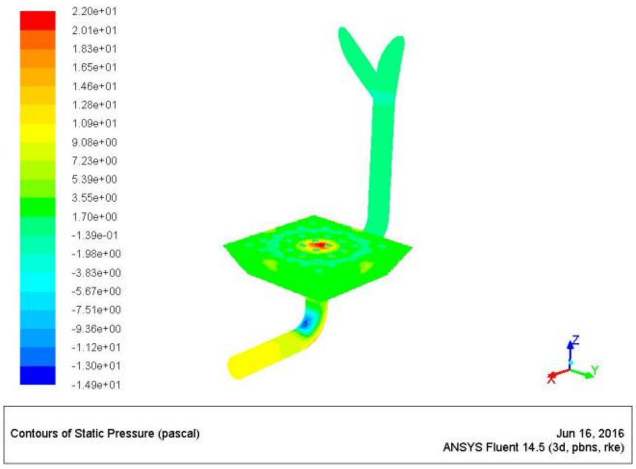

Fig -7: Pressure contours at 5m/sec

The maximum pressure air obtained at 2m/sec velocity of air. The pressure distribution of the air over the seat pan is very important to study in order to predict flow of air. The speed controller can regulated the speed coming inside the seat pan and back rest. The high pressure region is observed at the center of the seat pan with maximum value of 8.22 Pa, while other inlet hose bend shows the considerably low pressure.

7.2 Velocity contours

Carefully studying the contours and vector plots, we can see that there is almost no difference in the flow fields in between the unsteady results at this time and the steady state results. Because the flow rate in the steady state model is slightly smaller than that seen in the unsteady model, the magnitudes seen in the velocity fields is slightly lower.

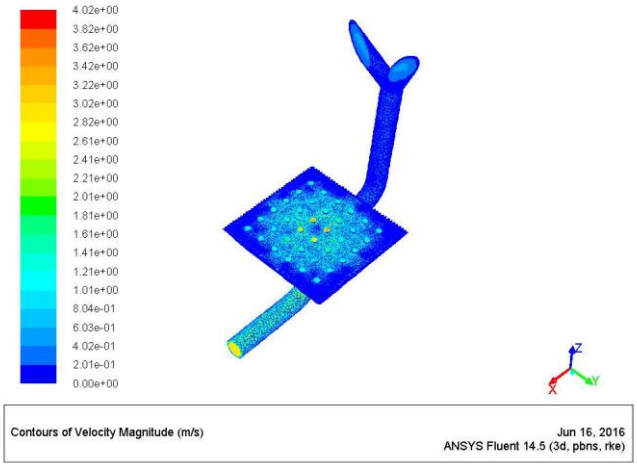

Fig -7: Velocity contours at 3m/sec

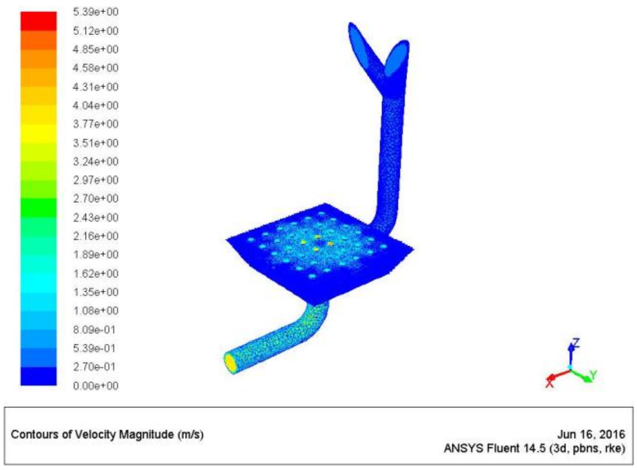

Fig -9: Velocity contours at 4m/sec

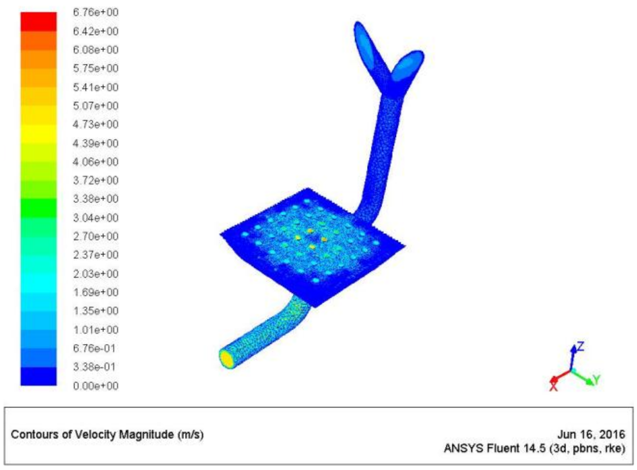

Fig -10: Velocity contours at 5m/sec

If the inlet velocity was identical between the two models, probably be exactly the same. In addition to the magnitudes being very similar, the vortice formation is also the same between the steady and unsteady models. The following fig.8 to 10 shows the velocity contours at different velocity inputs of cold air.

The flow of air over the seat pan is distributed uniformly. The increasing in the velocity of cold air results to turbulences in flow.

7.3 Density contours

The density contours shows the accumulation of the mass of air over a volume of seat. The cold air is passed over the seat pan is distributed over seat. The density of cold air is uniform over whole surface.

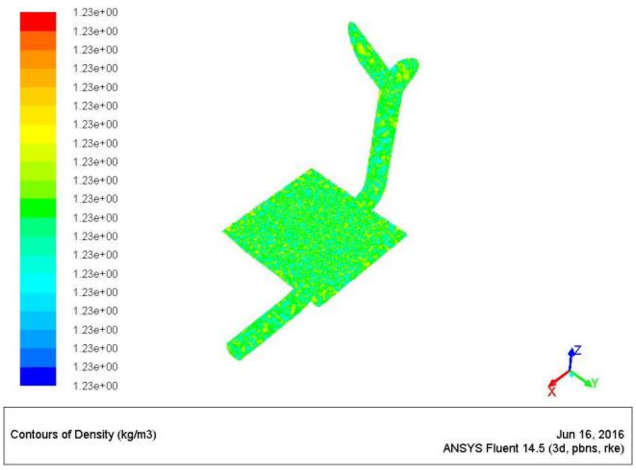

Fig -11: Density contours at 3m/sec

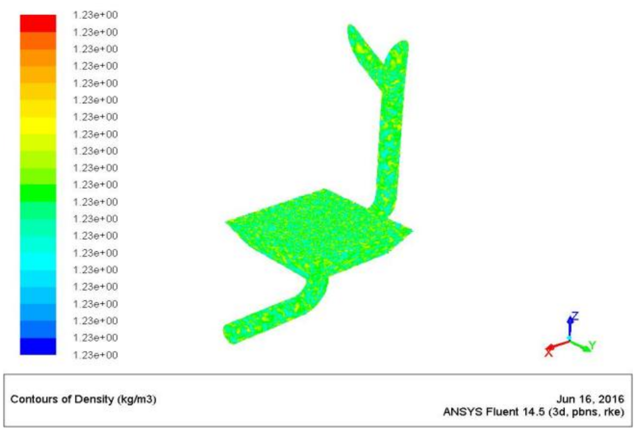

Fig -12: Density contours at 4m/sec

The above fig.11 to fig.13 shows the contours of the densities. The densities do not affected the velocity of air. The developed design of seat shows good match with computational analysis.

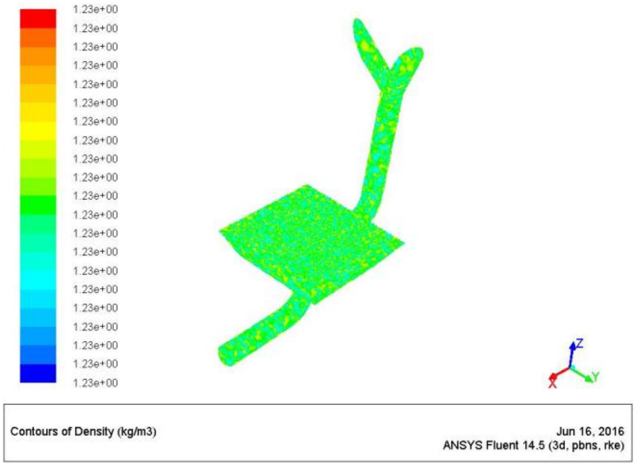

Fig -13: Density contours at 5m/sec

8. CONCLUSIONS

Detail study has been done to formulate a generalized process for designing and developing a ventilated seat for an automobile. Ventilation of an automobile seat may help to improve human comfort, ventilation can reduce the temperature of the seats if the vehicle was parked in the sun and they became hot. The research articles explain about the use of thermal seat for car driver comfort. The research study formulating the used of computational fluid dynamics to predicts the flow of cold air over the fabricated seat. Overall the thermal comfort of seat through computational fluid analysis studied.

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