STUDY OF AIR FLOW THROUGH MODIFIED HVAC DUCTS IN A MULTI UTILITY VEHICLE USING CFD SOFTWARE

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Abstract—*The main objective is to enhance the thermal comfort by modifying the HVAC ducts inside a Multi Utility Vehicle (MUV) cabin. A modified Duct is presently established in a Sedan, a four/five seated vehicle. The study relates with a motive for utilizing the same duct for a (MUV) in this case a seven seated arrangement. Since the air flow is hard to model mathematically, multiphase flow analysis is to be carried out by means of CFD software. The interior of the cabin is designed using a CAD software and enables to easily understand the flow procedure within the duct and responsive to flow velocities inside the cabin. The flow parameter involves the selection of appropriate duct model for the prediction. The model of a car is made by SOLIDWORKS software. The airflow velocity and directivity due to the modification in ducts is analysed with the ANSYS fluent software.*

Keywords— HVAC, Duct, Multi Utility Vehicle (MUV), ANSYS fluent.

1. INTRODUCTION

ISHRAE (Indian Society of Heating Refrigeration and Air-conditioning Engineers), proposed an Adaptive Thermal Comfort theory suggests that, indoor comfort is influenced by outdoor climate and aspects such as connection to outdoors and control over the immediate environment allow occupants to adapt to a wider range of thermal conditions. In this case, influence of outdoor air is acted only on the Condenser, and so the cooling rate is optimized with the duct arrangement, provided that the Indoor Air Quality (IAQ), is set to be purified by the circular action of the Automotive Air conditioning arrangement.

Like a normal housing HVAC structure, a Car's Air Conditioning duct is simplified in its design. In this case, a modification is proposed to a Formal HVAC duct. The arrangement is clearly simplified in order to perform Computational study without any drawback over meshing. The modified arrangement already exists, with different forms for different cars. This paper deals with the use of modified duct, replacing the formal duct in a seven seated car cabin. The interior arrangement in the duct enables the flow through system to be easily studied and improvised. The case is completely Transient (time based), model so the reaching of air velocity is studied using the computational model. The result suggested will be comparatively compensating the theoretical factors like cooling rate and Temperature reduction.

2. THERMAL COMFORT

According to the ASHRAE, Air Conditioning is the science of controlling the temperature, humidity, motion and cleanliness of the air within an enclosure. In a passenger/driver cabin of a vehicle, air conditioning means controlled and comfortable environment in the passenger cabin during summer and winter, i.e., control of temperature (for cooling or heating), control of humidity (decrease or increase), control of air circulation and ventilation (amount of air flow and fresh intake vs. partial or full recirculation) and cleaning of the air from odour, pollutants, dust, pollen, etc. before entering the cabin.

While the A/C system provides comfort to the passengers in a vehicle, its operation in a vehicle has twofold impact on fuel consumption: (1) burning extra fuel to power compressor for A/C operation and (2) carrying extra A/C component load in the vehicle all the time. In addition, the A/C running depends on the climatic condition of the concerned geographical region and the time of the year.

Of course, the impact on the fuel consumption is more significant when the A/C is installed in compact and sub-compact vehicles.

Next, in addition to the enhanced A/C system with R134a, the alternative refrigerants (CO2, R-152a, and HC blends) are briefly described to replace R134a for reduction in global warming. While the auto A/C is becoming very sophisticated, the newer systems are becoming more energy efficient for the desired high performance and the cost is continually reducing with the same or better durability and reliability.

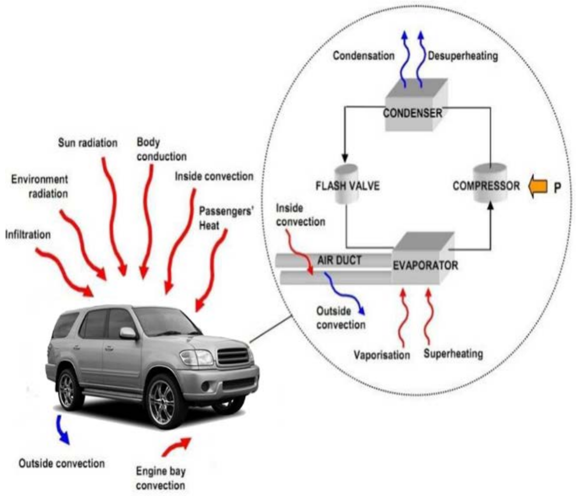

Fig. 1. Aspects of Thermal Loads in Atmosphere

3. WORKING OF AIR CONDITIONERS

Air conditioning like it says 'conditions' the air. It not only cools it down, but also reduces the moisture content, or humidity. All air conditioners work the same way whether they are installed in a building, or in a car. The fridge or freezer is in a way an air conditioner as well. Air conditioning is a field in its own right, but we'll stick to the main points or a car's air conditioning and the main parts used and a few hints to keep the aircon system running.

A number of people don't realize that turning on the air conditioning actually reduces the number of miles per litre of our car. There is energy used in removing the heat and moisture from the air in the car, and this consumes petrol because of the extra Engine load.

Air conditioning's main principles are Evaporation and Condensation, then Compression and Expansion

Evaporation: We may have noticed that if we rub a little surgical spirits on the back of our hand, then our hand will feel cold. It's evaporation. It is because the spirits on the back of our hand starts to evaporate. As the spirit evaporates, it takes away heat from the surface of our skin.

Condensation: When somebody walks in from the cold into a take-away wearing glasses, their glasses steam up. It's condensation. The moist air of the take-away cools as it contacts the cold surface of the glasses and the air has less capacity to hold moisture, so it condenses into water on the glasses.

Heat of Compression: When we pump up a bicycle tire with a hand pump that the end of the pump gets hot. This is because the energy that we have put into the air by pumping it has not only compressed it, but has also caused the air molecules to push closer together so giving off heat with the friction.

Compression: At some point all gases will eventually become liquid. Example a can of deodorant - it's liquid inside the can, but is a gas when it comes. The pressure inside the can is higher, so the propellant inside is liquid.

Cooling by Expansion: In the deodorant, we can notice how cold it feels when it is ejected. That's because the propellant has just expanded in volume quickly.

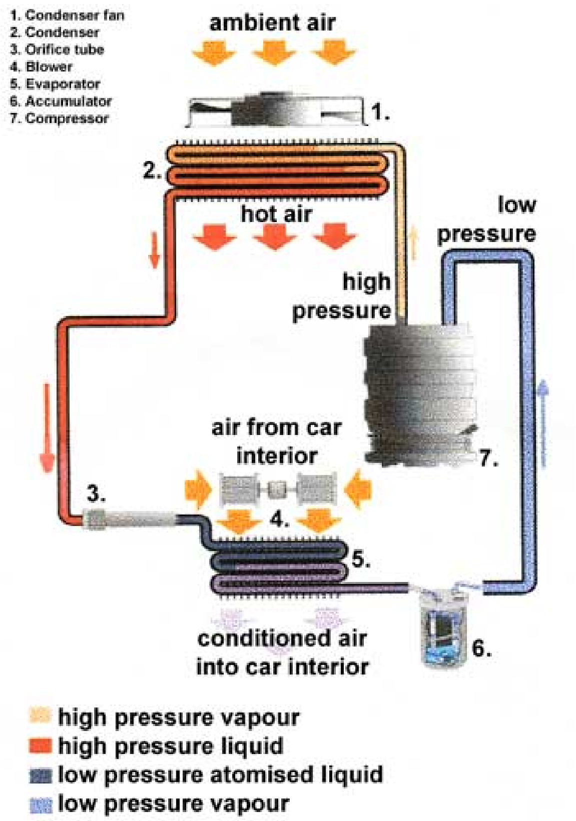

Fig. 2. Working of Car Air Conditioner

4. METHODOLOGY

A. Computational Details:

The car cabin geometry with various vane angle is created in pre-processor SOLIDWORKS. The Duct is designed with the data gathered by Ford Automobiles, where the schematic is designed for an experimental study. The same model is duplicated using the CAD software (SOLIDWORKS).The duct is split according to the vent arrangements; also the secondary part is also designed with a schematic which is suitable for Indian Standard Driving System.

Apart from the duct, in order to study velocity flow details, it has been mandatory to design a Manikin, with several attributes. The manikin arrangement is done with respect to the MUV interior (6 Seated). Since it is costly to perform an experimental setup operation, for this project only computational model is utilized for the study.

B. Boundary Conditions:

Inlet: The inlet boundary condition involves velocity inlet of 20 m/s.
Outlet: Atmospheric pressure is prescribed at the exit of the domain.

Wall: Wall boundary conditions are enforced on all faces bounding the flow including the roofs inside surfaces. Adiabatic, no-slip boundary conditions (i.e. u, v &w = 0) are applied at the walls.

Interior: In order to simulate the flow through various volumes that are a part of the entire domain, interior boundary condition is specified at the interface of every two volumes.

Fluid: This boundary condition is applied to all volumes of the geometry for the fluid to flow through. The direction of the flow is along the axial direction.

C. Geometry Model of Cabin:

A Multi Utility Vehicle (MUV) is considered for in-cabin airflow analysis. The geometry of the cabin was prepared using SOLIDWORKS and imported to ICEM-CFD. Water tight geometry with required surfaces has been meshed to capture the surface details. Figure shows the water tight geometry of the cabin. The geometry of the manikins is designed in order to monitor the airflow velocities in detail. The HVAC system consists of HVAC inlet, Primary outlets, and secondary outlet. Blower is not considered for the simplicity of the model. The flow from the HVAC is divided into two left and right air ducts respectively.

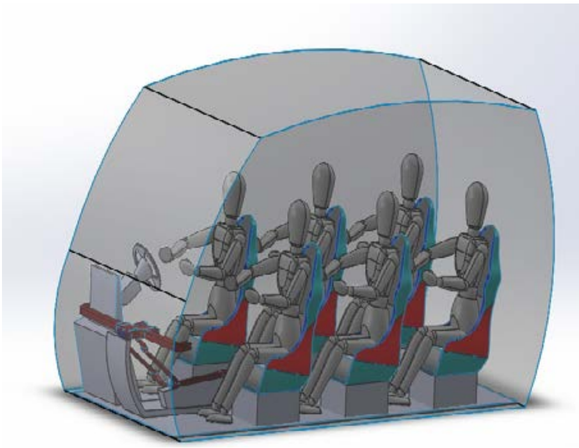

Fig. 3.Car Cabin Arrangement

5. GEOMETRY MODEL OF HVAC DUCT:

The geometry model of the Duct explains the position and the representation of the model.

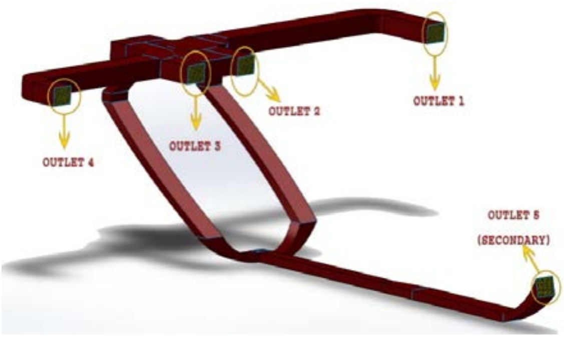

Fig. 4. 3-D View of Modified HVAC Duct

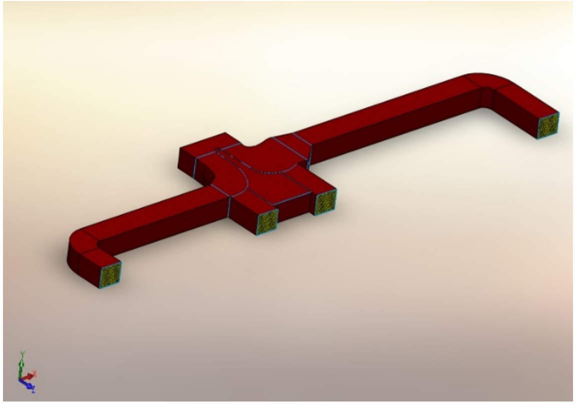

Fig. 5. 3-D View of Formal HVAC Duct

6. HVAC DUCT

The Automotive HVAC Duct are commonly used to distribute the flow from the Compressor through piping arrangements, to the interior of the car. The Ducts are properly designed for the cars pertaining to their holding cum operating capacity. The Ducts are commonly positioned in the frontier arrangement of Driver as well as Co-Driver Platforms/Panels.

The arrangements make sure that the airflow from the Compressor is distributed along to all the passengers, subjected to Static as well as Dynamic Conditions. The flow module suggests that the outlets 2 and 3, will correspondingly have a high velocity flow in order to direct the flow, to the rear passengers.

The Modified arrangement is being currently approached by several car manufacturers and may seem to be varying with next generation cars, promoting air flow regulation for the Rear seat passengers. In this case, the velocity distribution is calculated.

7. SOLUTION PROCEDURE

The Airflow within the HVAC ducts has to be analyzed and studied in order to enhance the Thermal Comfort of rear seat passengers in a Multi Utility Vehicles. The Geometric model of both the formal and modified ducts has been discredited using ICEM-CFD Meshing software.

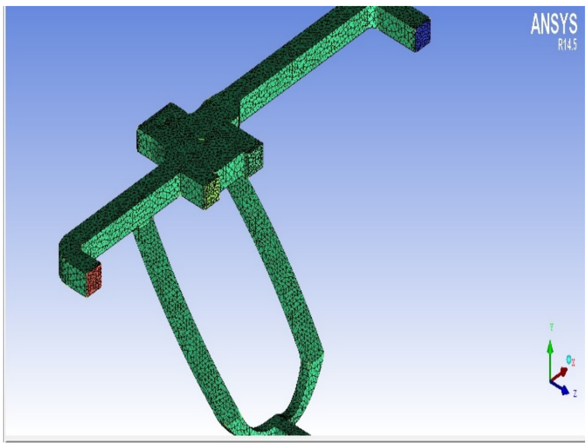

Fig. 6. Meshed View of modified duct

The meshing type used here is Tetra-mixed (Tri-Quad). Reason for preferring this type is due to its aligned discretization of curved ends with smooth finish. The maximum number of elements provided is 8500.

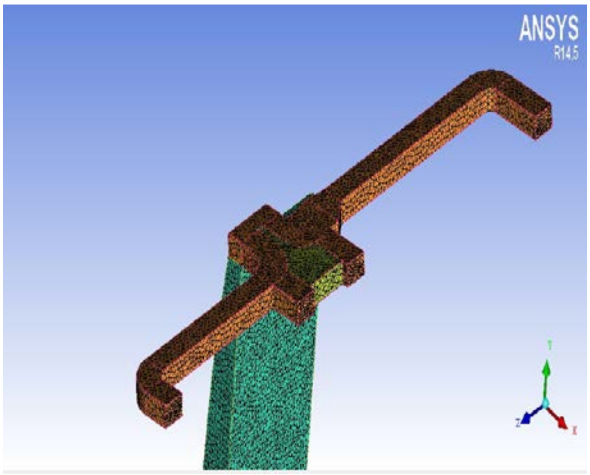

Fig. 7. Meshed view of formal duct

8. RESULTS AND DISCUSSIONS

Airflow directivity within the Ducts are analysed and compared, in order to effectively understand the difference between them. An Inlet velocity of 20m/s is given as the initial condition.

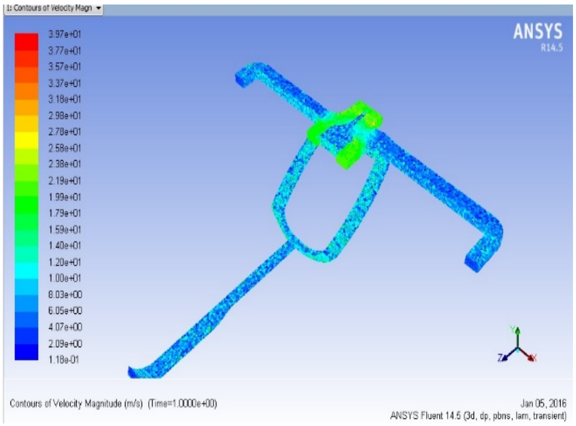

Fig. 8.1. Flow Directivity at T=1s

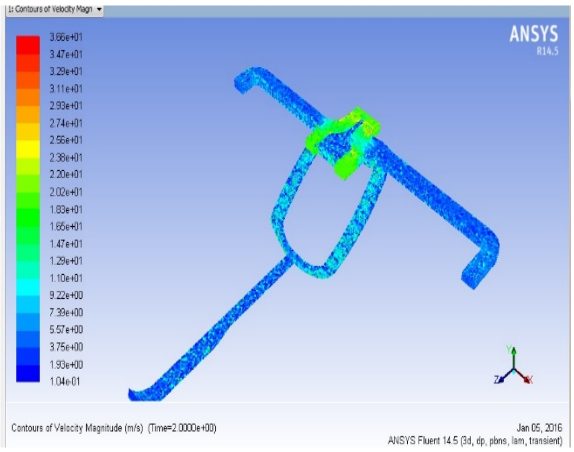

Fig. 8.2. Flow Directivity at T=2s

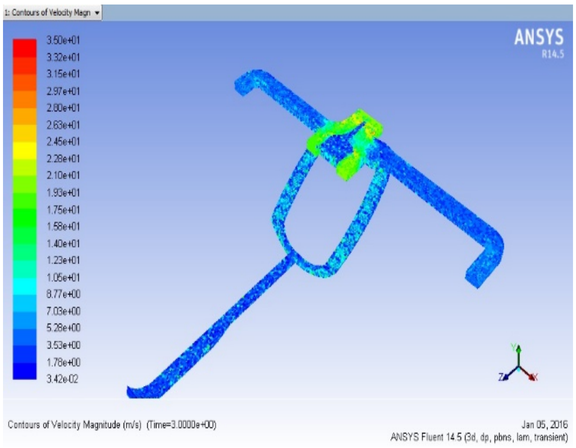

Fig. 8.3. Flow directivity at T=3s

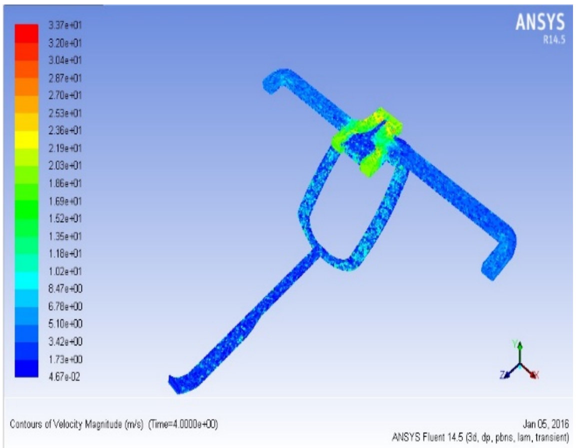

Fig. 8.4. Flow directivity at T=4s

It is noted that the deviation in the modified Outlet 5, seems to be reducing in time comparative to the other formal ducts. The following table provides the necessary result of variation in velocity with respect to time.

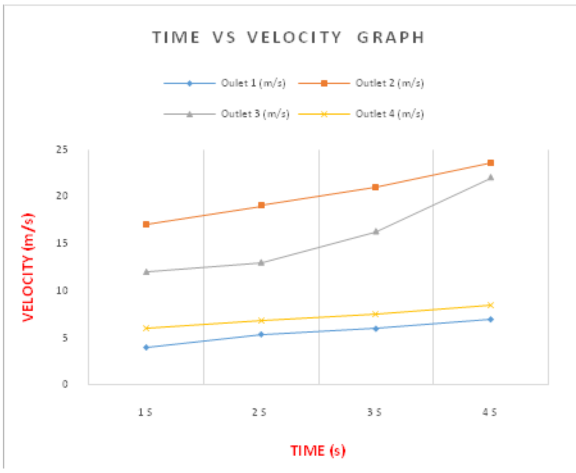

Fig. 9.1 Velocity Deviation (Formal Duct)

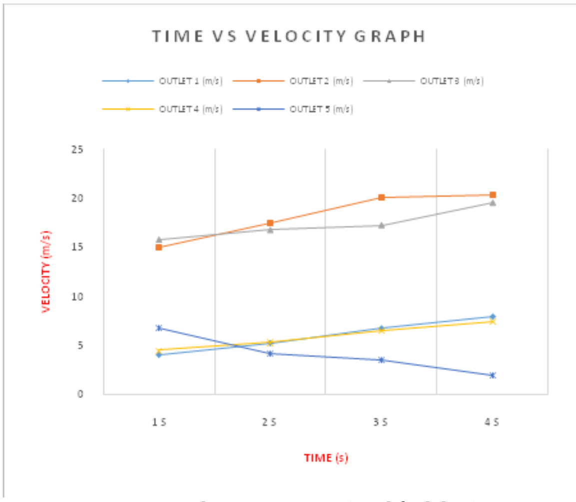

Fig. 9.2. Velocity Deviation (Modified duct)

The above table clearly represents the deviation in Time vs. Velocity deviation for both the ducts. The Secondary outlet 5, has initially been peaked at 6.5 m/s. But lately it disintegrates and reaches a low and constant level of 1.8 m/s.

This representation shows a fluctuation in Outlet 3 and 4, due to sudden impact of air in its path. It is general that the flow direction is consequently, focused on centre ducts (Outlet 3 and Outlet 4), since a high velocity is required to direct airflow towards rear end.

But, in a seven seated arrangement the flow directivity is comparatively slow, regarding our commercial cars, since they use the formal duct for five as well as seven seated. The pressure distribution is tabulated in order to realize the major distribution at each outlets and their impacts. A major fluctuation is observed in the following figures.

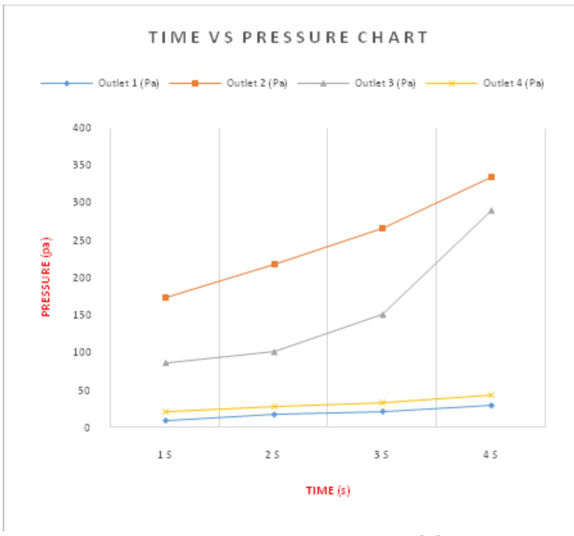

Fig. 10.1. Pressure Deviation (Formal duct)

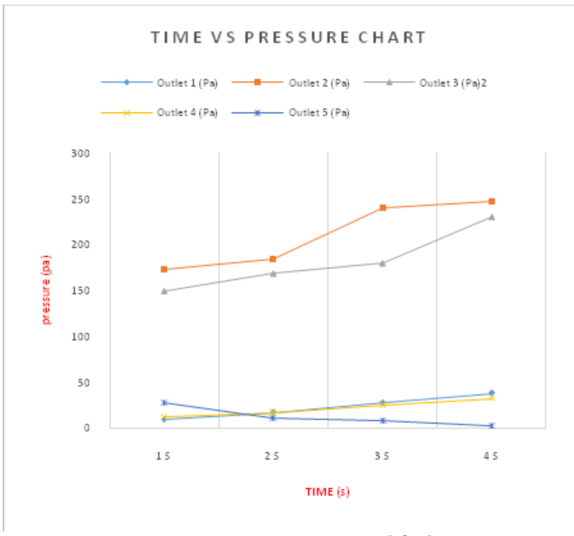

Fig. 10.2. Pressure Deviation (Modified Duct)

Since it is flow analysis the pressure considered here is the dynamic pressure. Because the dynamic pressure is a defined property of the moving flow of gas or liquid. It is represented as,

$$Pd = 1/2\ \rho\ v2 \qquad (1)$$

Where,

Pd= Dynamic Pressure (Pa)

ρ = Density of fluid (kg/m3)

v = Velocity (m/s).

Considering atmospheric air at 20o C.

ρ = 1.2 (kg/m3).

9. VALIDATION OF RESULTS

A. Grid Independence Study:

The CFD results may not be assured after the first run. So in order to facilitate this assurance various grid levels are utilized in order to obtain the necessary similarities between them. Here, Grids consisting of 5, 7 and10 Million Tetrahedral cells are used to study the approximation of the result obtained. So, in this case the variation in the velocities was slightly varied and assuring that the given study is valid. Since higher order grids give more accurate results, the 10 million tetrahedral cells is preferred for the study.

B. Convergence Criterion:

Though a converged solution may not be an accurate one, it can be assimilated that the procedure followed (input parameters) in this case study has obtained the following results.

The overall velocities and the scalar balances are achieved. Also, every cells in the discretization obeys the conservative functions (mass flow, velocity etc.). It provides a stability in the analysis.

10. CONCLUSIONS

In this present study, a modified HVAC duct is proposed to improve the airflow for the rear passengers in a MUV. Apparently, the modification has triggered the air flow for the last compartment as well as the rear seat passengers initially. There is no potential losses occurred in the former outlet ducts for Driver as well as Co-Driver. The velocity and pressure associated with the Secondary outlet 5, has impacted on the distribution of airflow, for the rear seat passengers. Though this model proves to be sufficient for initial kick start, sustaining the flow can be improved by alterations among the flow pathways.

NOMENCLATURE

pd Dynamic Pressure (Pa)

Greek letters

ρ density (kgm-3)

v velocity (m/s)

ACRONYMS

MUV	Multi Utility Vehicle
HVAC	Heating Ventilation and Air Conditioning
CFD	Computational Fluid Dynamics
ISHRAE	Indian Society of Heating Refrigeration and Air-conditioning Engineers.
ASHRAE	American Society of Heating refrigeration and Air-conditioning Engineers.

REFERENCES

[1] VaradM.Limaye. and Deshpande M.D. (2012), Design of Dynamic Air vents and Airflow analysis in a Passenger car cabin, SasTech, Volume 11 issue 1, April 2012.

[2] Ivanesku, Marianna and NeacsuCatalin, (2010), The Human Thermal Comfort Evaluation inside the Passenger Compartment, Auto chassis International Romania, F 2010-C-044.

[3] Ruzic, D. (2011) “Improvement of Thermal Comfort in a Passenger Car by localized air distribution”,Acta Technical Corviniesis-Bulletin of Engineering, ISSN 2067-3809.

[4] Kelecy, F. (2005) “Modeling Transient flows with FLUENT 6”, FLUENT Inc.

[5] Rom,McGuffin and Rick Burke. (2002), Human Themal Comfort model and Manikin, SAE International, 2002-01-1955.

[6] Devonshire.J and Sayer J.R.(2003), Industry Affiliation Program for Human Factors in Transportation Safety, UMTRI-2003-32.

[7] Kuo-huey Chen and ShailendraKaushik(2012), Thermal Comfort Prediction and Validation in a Realistic Vehicle Thermal EnvironmentSAE International, 2012 April.

[8] RaduMusat and Elena Helerea (2009), Parameters and Models of the Vehicle Thermal Comfort, Acta Universities Sapientiae, Volume 215-226.

[9] www.airconcars.com