DESIGN AND ANALYSIS OF HUMAN COMFORT IN VEHICLE CABIN THROUGH ANSYS SOFTWARE

SWETA TRIPATHI [1] , ALOK KUMAR[2]

[1]M.tech Student, Mechanical Engineering Department, Axis Institute of Technology and Management, Kanpur, Uttar Pradesh, India
[2]M.tech Student, Mechanical Engineering Department, Axis Institute of Technology and Management, Kanpur, Uttar Pradesh, India

ABSTRACT

Thermal Comfort in Passenger Vehicle is of major concern for car manufacturers and customers. One of the defining factor of thermal comfort is air velocity. Conventional fan used in vehicle for circulation of conditioned air does not provide desired air velocity to rear passengers. Fan at its highest speed does produce a lot of noise inside the vehicle cabin which hampers noise comfort as well. Thermal and Noise comfort are two vital factors contributing a safe drive.

The main objective of this work is to improve thermal comfort for rear passengers inside the vehicle cabin and by doing so improving noise comfort level as well. In the present work, low noise axial fans are embedded in headrest whose direction can be controlled independently by rear passengers. Modelling of car seat and fan assembly is done and computer simulated results are used to validate the experimental results.

Keywords*: Thermal comfort; Thermal sensation; Noise comfort; Air velocity; Air temperature.*

1. INTRODUCTION

In modern world, vehicles are supposed to be people's main means of transportation. People spend much of their time in vehicles during a day. Either riding or driving is considered as our part of life. So passengers comfort in vehicle cabin is considered very important. In last few decades scientists are really pushing the limits in the field of thermal comfort in vehicles and have made a lot of breakthroughs. Thermal comfort, traffic safety as well as health of passengers in vehicle cabin are all dependent upon the working and efficiency of air conditioning system in vehicle. Passenger's thermal comfort has been the critical concern throughout the development of automobile as thermal comfort affects the automobile's driver arousal level and ability to concentrate. Nowadays thermal comfort does play an important role in decision making of the customers, and that is why automotive companies do take this reason into account in its automobile development.

1.1 Background and motivation

The reason why enormous effort needs to be put in improving the vehicle thermal environment and comfort is due to significant role it plays in human's life. Passengers cannot stand up the burning hot summer or freezing cold winter without proper conditioning of air in cabin. Especially for kids and old people to survive in a cabin which may reach temperature up to 90 degrees is a bit too risky if vehicle is not air conditioned properly. Lakhs of people have lost their lives and it has been found that in many cases driver's arousal level and concentration ability were not up to the mark which highlights the fact that thermal environment must be well designed and there is a great scope in improving it. On the other hand some regulations have been set to meet the demand of energy conservation and emission reduction. Hence research in field of thermal comfort not only improves thermal environment but also reduces fuel consumption as well.

1.2 Thermal Comfort

ASHRAE standards define thermal comfort as that state of mind which expresses satisfaction with the thermal environment. Thermal comfort in vehicles represents a subjective sensation of heat balance that occurs in the human body when environmental parameters as well as personal factors are considered. Figure 1.1 shows factors affecting thermal comfort.

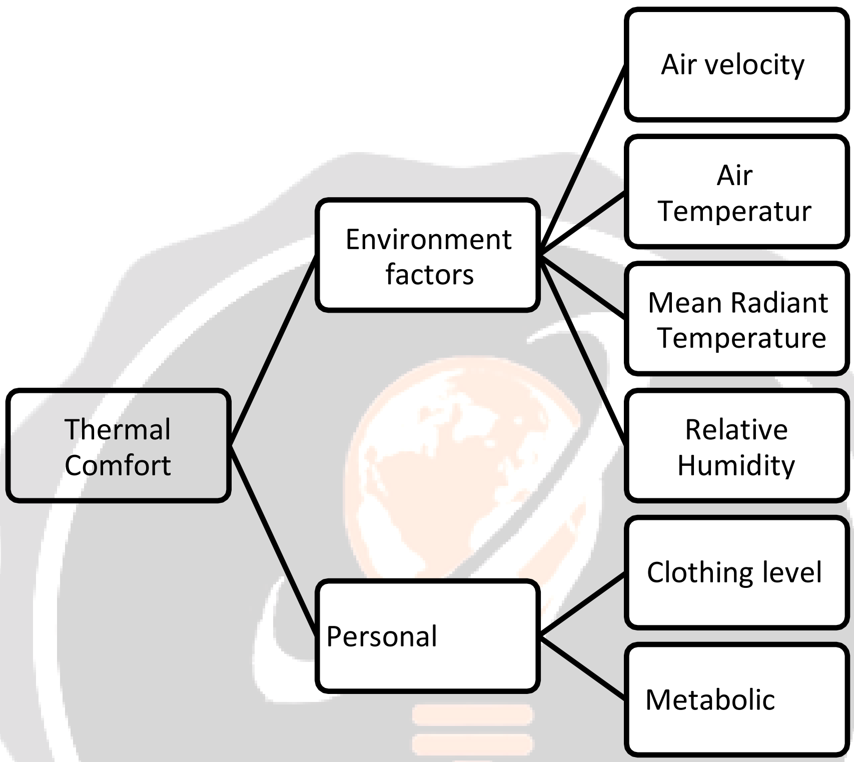

Figure 1.1: Factors affecting thermal comfort

1.3 Area of research

The main purpose of controlling vehicle cabin temperature is being fulfilled by HVAC but to achieve thermal comfort for all passengers is altogether a different task. Two crucial factors affecting thermal comfort are Air velocity and Air temperature. Air velocity inside the cabin should be up to level so that all passengers should have comfort sensation. But in doing so there should not be that much of noise created in air ducts and vehicle cabin so that noise discomfort occurs. Rear passengers do face a problem in having an optimum air velocity and hence thermal comfort of rear passengers is always difficult to achieve as well as to maintain. Hence to provide better air velocity, ducts are provided for rear passengers that acquire a lot of cabin space and also affect the aesthetics of vehicle cabin. This also leads to increase in price of the automobile.

Many vehicles do have separate air conditioning units for rear passengers to provide better air velocity and conditioned air as well which increases the vehicle cost as well. If air velocity and air circulation inside the vehicle cabin is increased and still maintaining noise comfort as it can hampers driver's concentration and by doing so does not increase the price of automobile and can achieve thermal comfort of rear passengers in lesser time than it will be really helpful in saving a lot of money as well as improving thermal comfort in lesser time.

So the sole purpose of research is to provide better air velocity and air circulation for rear passengers at lesser noise level in comparison to conventional design and achieving their thermal comfort in lesser time because 85% of trips have average duration of 15-30 min and in doing this does not increase the price of an automobile.

2. METHODOLOGY

2.1 Introduction

In the present work fans are installed in central air outlet vents of particular dimensions which will fit into vents so that air velocity in rear cabin increases. Also fan assembly is installed in headrests so that more airflow is directed towards rear passengers. Noise comfort is achieved with the help of these fans as at less fan speed e.g. 2, 3 air velocity is more than or equal to air velocity at fan speed 4. Hence by doing so more air flow is directed towards rear passengers at less noise level. Noise reduction in cabin is achieved with a difference between fan speed 4 and 2. But this difference will be very less affected by installed fans as all are silent fans and do not contribute much in terms of noise. Initially car modeling is done in PTC Creo and then air velocity and thermal analysis is done in ANSYS Fluent. Then air velocity and noise readings are taken at different fan speeds using anemometer and sound level meter respectively. PCB installation of 13 LM 35 temperature sensors is done inside car cabin. Temperature monitoring inside the car cabin is done at different fan speeds without any modifications. Then low noise axial flow fans are installed at central air vents and head rests of front seats facing rear passengers. Modelling and analysis steps are repeated for the same. Air velocity, noise and temperature readings for installed set up are taken and comparisons are done.

2.2 Steps executed

2.2.1 Parameters examined in existing model

- Study of cabin temperature at different A.C. blower speed.
- Study of air velocity at different A.C. blower speed.
- Study of noise at different A.C. blower speed.

2.2.2 Modelling and simulation

- Modelling of vehicle cabin as per possible realistic conditions based on initial data.
- Analysis of air velocity at different A.C. blower speed to verify the pattern of air circulation based upon the input parameter from preliminary experiments.

2.2.3 Experimentation

- Validation of air velocity distribution as per simulated results in the cabin.
- Placement of thirteen temperature sensors at different positions in front and rear cabin.
- Study of temperature variation at thirteen prescribed locations at different positions for different fan speed.
- Study of cooling efficiency by installing two auxiliary fans at central air vents.
- Study of cabin noise under proposed conditions.

3. MODELLING AND SIMULATION

Model of car has been generated using modelling software named as PTC Creo and its analysis is done in ANSYS Fluent. Actual dimensions of car have been considered in generating its part model. Figure 3.1 shows the car model designed in creo. Boundary conditions for the analysis are obtained from preliminary experimentation of existing vehicle.

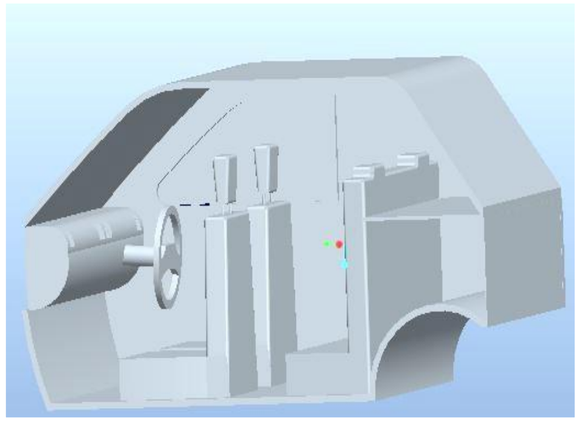

Figure 3.1: Model of car designed in creo

Two fans are installed in central vents of air outlets in dashboard and two fans are installed in front two headrests facing the rear passengers. Air velocity of headrest fan is 4 m/s, hence air velocity at rear corner passengers is approximately 1 m/s. Model of headrest has been developed in PTC Creo. Figure 3.2 shows headrest model designed in creo.

Fan assembly is installed in headrest facing rear passengers. Side grills are provided at both sides of headrest so that enough amount of air can be sucked in. Fins are provided in front grills so that air flow can be maneuvered in desired direction.

Figure 3.2: Headrest model

4. EXPERIMENTAL SETUP

4.1 Introduction

Equipment used in present work:

- Vehicle
- Printed Circuit Board of temperature sensors
- Low noise axial flow fans
- Anemometer

- Sound level meter
- Thermal imaging camera

4.2 Arrangement of PCB and sensors

13 LM 35 temperature sensors have been used and their positions are mentioned below: Sensor 1: Face of rear right corner passenger.

Sensor 2: Face of rear center passenger Sensor 3: Face of rear left corner passenger Sensor 4: In between sensor 1 and 7.

Sensor 5: In between sensor 2 and 8.

Sensor 6: In between sensor 3 and 9 Sensor 7: Back of front driver headrest.

Sensor 8: In between front two seats (head position) Sensor 9: Back of front passenger headrest.

Sensor 10: Driver face.

Sensor 11: Front passenger chest Sensor 12: Driver chest.

Sensor 13: Front passenger chest.

Figure 4.1 shows the sensor arrangement in modeled vehicle cabin. All 13 sensors are placed in their respective positions.

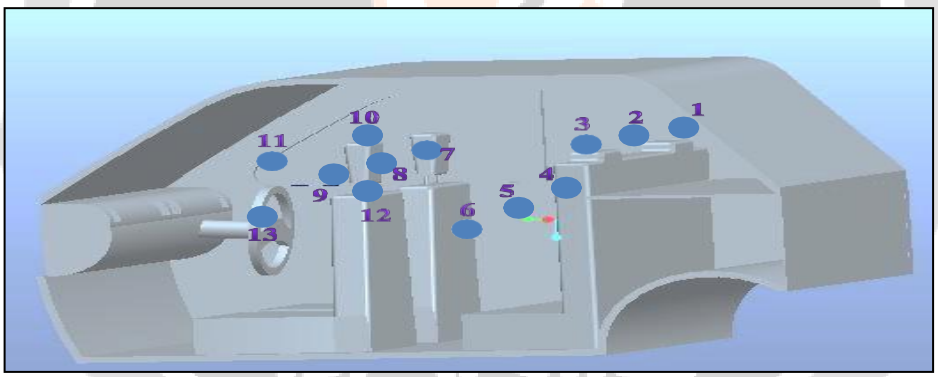

Figure 4.1: Placement of sensors in creo

Figure 4.2 shows the actual sensor arrangement in vehicle cabin. All 13 sensors are placed in their respective positions.

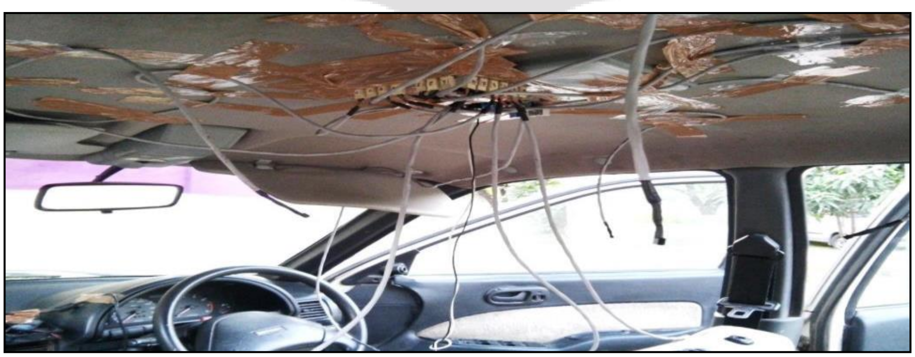

Figure 4.2: Placement of sensors and PCB

5. CONCLUSIONS AND FUTURE SCOPE

5.1 Conclusions

The following conclusions are made after validating the experimental results with the simulated results. The improvements observed in the present study are described below:

Thermal comfort is achieved faster in case of installed set-up in comparison with conventional case at fan speed 2, 3 and 4.

Thermal comfort at fan speed 2 with installed set-up is comparable to fan speed 3 in conventional case.

Thermal comfort at fan speed 3 with installed set-up is comparable to fan speed 4 in conventional case.

Better thermal comfort for all (front and rear) passengers is achieved in approximately 50% less time in the case of installed set-up as compared to conventional case. Effect of installed fans is felt in complete cabin through better air circulation.

Thermal sensation for rear passengers is improved drastically in the first 10 minutes of the drive when car is very hot, as the air flow from headrest fans is directed towards the face from a smaller distance with the required velocity of 1.2 m/s.

Cabin noise level is substantially reduced as A.C. blower speed 2 and 3 with installed set- up provides same thermal environment at A.C. blower speed 4 in conventional case. Hence sound comfort is achieved in vehicle cabin without compromising in cooling efficiency for every passenger.

5.2 Future scope

Head rest fan is of major concern in the present study, hence efforts are required for optimization of its design and operation parameters. The possibility of radial flow blowers in place of axial flow fans can also be investigated.

6. REFERENCES

[1]. Radu Musat, Elena Helerea, Parameters and models of the vehicle thermal comfort, Acta Universitatis Sapientiae, (2009) 215-226.

[2]. Amit K. Ahirrao, H. K. Narahari, S.Umesh, Vivek Kumar, Effect of vent shape on thermal comfort of passengers in a car, SASTech, (2011) Volume 2, Issue 2, 21-28.

[3]. Thermal environmental conditions for human occupancy, ASHRAE Standard 55, Atlanta, U.S.A., 2003.

[4]. Victor Candas, Maurizio Cisternino, Assesement of thermal climate in operator's cabs, Swedish Institute of Agricultural and Environmental Engineering, Florence, 1999, pp. 1- 23.

[5]. Cooling India with less warming, NRDC issue paper IB: 13-04-A, New Delhi, 2003.

[6]. Indian Petroleum and Natural gas statistics, Government of India, Ministry of Petroleum and Natural Gas, Economics and Statistics division, New Delhi, 2013-14.

[7]. Mariana Ivanescu, Catalin Adrian Neacsu, Ion Tabacu, Studies of the thermal comfort inside the passenger compartment using the numerical simulation, International Congress Motor Vehicles & Motors, Kragujevac, 2010.

[8]. All India study on sectoral demand of diesel and petrol, Ministry of Petroleum and Natural gas, Petroleum Planning and Analysis Cell, New Delhi, 2013.

[9]. Jason A. Lustbader, Evaluation of Advanced Automotive Seats to Improve Thermal Comfort and Fuel Economy, Vehicle Thermal management systems conference and exhibition, Toronto, 2005.

[10]. Jan Fiser, Jan Pokorny, Effect of car speed on amount of air supplied by ventilation system to the space of car cabin, EPJ Web of Conferences 67, 2014.

[11]. Madhavi Indraganti, Ryozo Ooka, Hom B Rijal, Significance of air movement for thermal comfort in warm climates, 7th Windsor Conference, Windsor, 2012.

[12]. Dragan Ruzic, Improvement of thermal comfort in passenger car by localized air distribution, Acta Technica Corviniensis, (2011) 63-67.

[13]. Mariana Ivanescu, Catalin Neacsu, Stefan Tabacu, Ion Tabacu, The Human Thermal Comfort Evaluation Inside the Passenger Compartment, World Automotive Congress, Budapest, 2010.