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Application of I-Cool Materials and Experimental Thermal Analysis of Temperature Rise Inside the Parked Vehicle

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Abstract: The human comfort inside the vehicle is main problem when vehicle is parked in hot sunny condition for 30 to 180 min. As India is tropical country where temperature during summer increases above 450C. If we park the vehicle in such severe condition for few hours then inside temperature increases up to 800C. In such condition if vehicle owner or driver enters in vehicle then it is impossible to travel because of heat suffocation inside the vehicle. If the child or pet is remaining inside parked vehicle then child or pet will die due to heat stroke and many cases happen in world wide. Now a days to control the inside temperature driver or owner will swich on the air condition or open all the windows. To overcome this problem by controlling the heat transfer inside the vehicle by using different I-Cool materials like phase change materials, thermoelectric materials and organic dye cell materials. In this paper focusing on phase change material which is having good thermal conductivity and they can change phase by absorbing the high amount of latent heat from sun to maintain temperature inside the vehicle.

Index Terms **- Latent heat, Phase Change Material, Specific heat, Thermal comfort**

I. INTRODUCTION

Today's HVAC system is used to control the inside temperature but this system works when vehicle is in running condition. To run air conditioning system in vehicle significant amount of energy is required, it can be greater than engine energy required to run the small size vehicle at a constant speed of 56 km/hr. if engine is having 400 W load on then it reduce the fuel economy by 0.4 km/L[1,2]. Now a day's many of the automotive industries are doing the research to control the inside climate of their vehicle during standalone condition in severe hot condition. During summer ambient temperature is very high during 12 to 3 pm at this time need to maintain the temperature inside the standalone vehicle because sun light directly come on the roof and door panel. The temperature rise inside the vehicle cabin is very high during this time due to sun angel.[3]

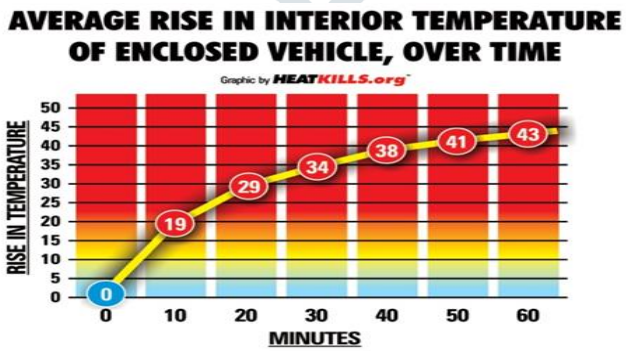

Figure 1: Average rise in temperature inside the vehicle over time [1]

The figure 1 shows average temperature rise inside the vehicle over a time. As vehicle is parked in sunny condition having high ambient temperature for 60 minutes then inside temperature rise is about 43^0 C. Many of the accidents happen due to heat stroke involving child or pets remain inside the parked vehicle. In last decade (2011 to 2020), 40 fatalities of children occurred in 23 incidences across India. All these incidences occurred during the summer. The 65% of child's were 4 to 6 years of age, died due to heat stroke and hyperthermia injury [4]. Now a days most of the vehicle owner, cab driver will swich on the air conditioning system to control the temperature but this system consumes more amount of fuel and cause the pollution. Other option used by the drivers by keeping windows open but internal climate will not remain clean and high domain noise will disturb the driver. So many of the phase change material having ability to store the heat during change of phase.

1.1. Factors affecting vehicle inside temperature:

The evaluation of human comfort inside vehicle is related with different factors like environmental, factors regarding the human organism and factors regarding the clothing [5]. By considering the comfort of most of passengers the influencing factors are considered [6]. Mainly there are the two factors such as measurable and personal factor. The measurable factors include air velocity, air temperature, radiant temperature and relative humidity. The personal factors include clothing insulation and activity level. The factors are shown in figure [7]

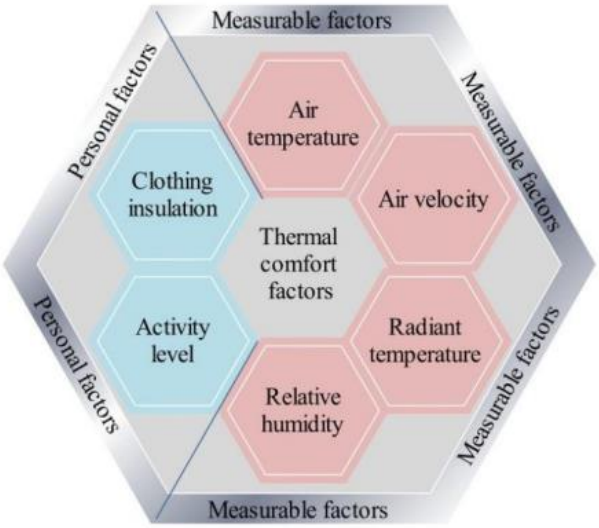

Figure 2: Factors affecting the thermal comfort [6]

The air speed, air temperature, relative humidity and radiant temperature are the environmental factors. The age, weight, gender, type of activity and metabolic rate are the human organism factors. The material structure, thermal resistance of wear and number of layers are the factors of clothing. All these factors affect the thermal comfort of passengers. The sun light is the major factor to affect the human comfort when shining on peoples enclosed spaces such as vehicles [8]. As shown in figure when sunlight exposed inside the vehicle will affect the passenger's comfort and to control this air conditioning energy is required.

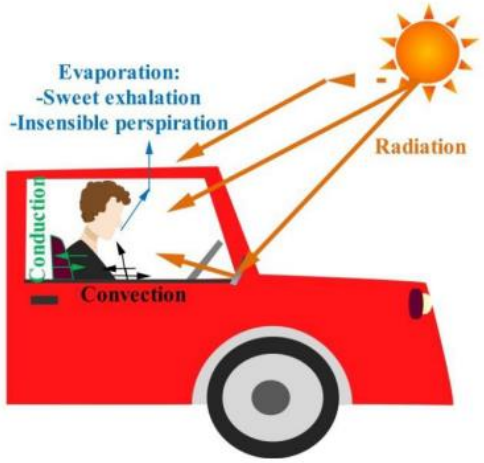

Figure 3: Sunlight contribution to thermal comfort [6]

When vehicle is parked in sunlight the inside components like seat, dashboard absorb the heat by solar radiation transmitted through roof, door panel and glass the thermal radiation takes place inside the body. The amount of heat absorbed by component is depends on effective projected area and absorptivity of component materials [9]. The heat transfer can take place by conduction, convection and radiation. The conduction is take place when sunlight passing through roof, glass, the convection is take place inside the vehicle and radiation takes when inside vehicle due to components [10]. The figure shows that how the heat transfer can take place inside the cabin.

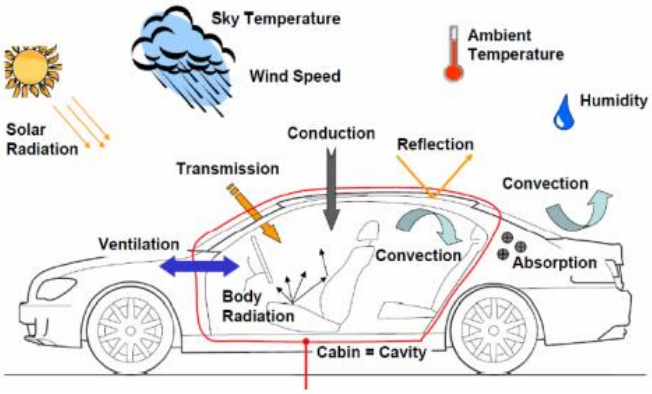

Figure 4: Energy conservation inside the body [11]

The vehicle is parked in environmental conditions suffers from fluctuations in air velocity, sun radiations and air moments. These fluctuations create some problem in evaluation of thermal condition inside the vehicle [12].

The thermal comfort of passenger inside the vehicle is rising concern due to health and safety of passengers. The automobile industry focus on improving efficiency of vehicle by efficient use of energy resources [13,14]. The thermal comfort in vehicle is reduced due to two reasons in earlier days vehicle design and solar radiation. To increase the thermal comfort must focus on vehicle design to reduce heat load that enter the passenger compartment and less amount of solar radiation enter in the vehicle. To increase thermal comfort in vehicle must concentrate on heating and cooling of vehicle cabin and efficient use of energy resources [15,16]

To improve the thermal comfort inside the parked vehicle, need the effective heating, cooling and ventilation system in vehicle. When vehicle is parked only heating takes place, for the cooling and ventilation we need to switch on the air conditioning system or open the windows at the time of parking and which in not possible due to many reasons. Another option to maintain thermal comfort inside the vehicle is use of different I-Cool materials like phase change materials, thermoelectric materials and organic dye cell materials [17].

II. THERMAL ANALYSIS

As India is a tropical country where during summer temperature rise above 45^0C. The thermal analysis is carried out with help of conduction, convection and radiation equations for hottest cities of India. The below figure shows the thermal analysis of hottest cities.

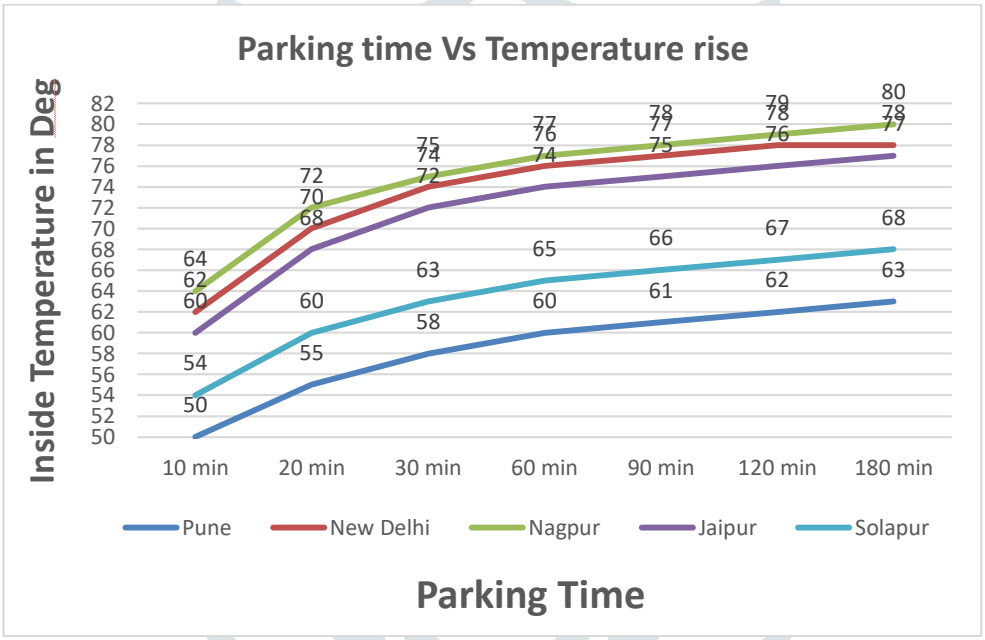

Figure 5: Thermal analysis of temperature rise inside the vehicle

The above figure shows that temperature rise inside the vehicle is high when it is parked in hot sunny condition. To control this temperature, rise the I-Cool material is used in various parts of vehicle here in this paper main focus is on phase change materials.

Phase change materials (PCM) is one of the I – Cool materials having a high heat of fusion that melts and solidifies at some temperatures. This material is capable of storing and releasing a large amount of energy. Heat is released or absorbed when the material changes its phase from solid to liquid and vice versa. Thermal energy stored in phase change material is one of the promising materials to control the temperature fluctuation in the vehicle cabin in both summer and winter [18].

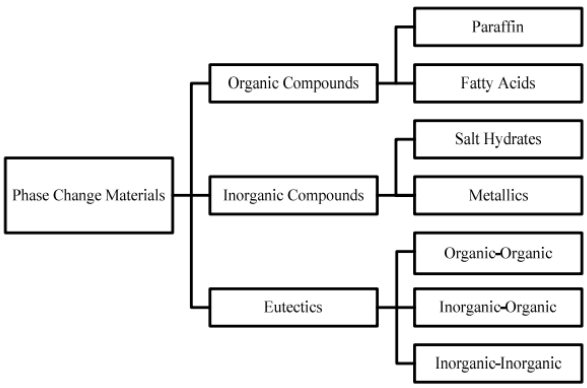

Figure 6: PCM Classification [17]

PCM most commonly divided into three groups first organic PCM, second inorganic PCM and third eutectic. Organic PCM are compound based on paraffin where the melting temperature of the material varies in relation with the number of carbon

atoms present. Pure paraffin contains 14 to 40 carbon atoms whereas in paraffin waxes contain 8 to 15 carbon atoms are present. This type of PCM have more advantages like wide range of melting points, nontoxic, noncorrosive, non-hygroscopic, chemically stable, compatible with most building materials, has a high latent heat per unit weight, most importantly exhibit negligible supercooling. these PCM materials possess some limitations as high cost, low density and low thermal conductivity.
Inorganic PCM contains the chemicals such as hydroxides or oxides, that have been diluted in acid solutions and are known as salt hydrates or molten salt. The advantages of this type of PCM are low cost as compare with organic PCMs, having high latent heat per unit mass and volume, having high thermal conductivity, and a wide range of melting points from 7 – 1170C. The main disadvantage is that there will be decomposition of salt hydrates over a time due to the process.
Eutectic PCMs are the combination of two or more compounds of organic, inorganic or combination of both. The main drawback of this PCM is to have high cost [19].

At the time of selection of phase change materials thermal, chemical and some physical properties, its economic and availability of material are considered. The selected phase change material should have high latent heat, high physical heat storage, high the thermal conductivity [20].

III. Selection of Phase Change Materials:

The selection of proper phase change material is important aspect to control inside vehicle temperature during standalone condition. The below figure shows that different types of phase change materials and its temperature range of phase change.

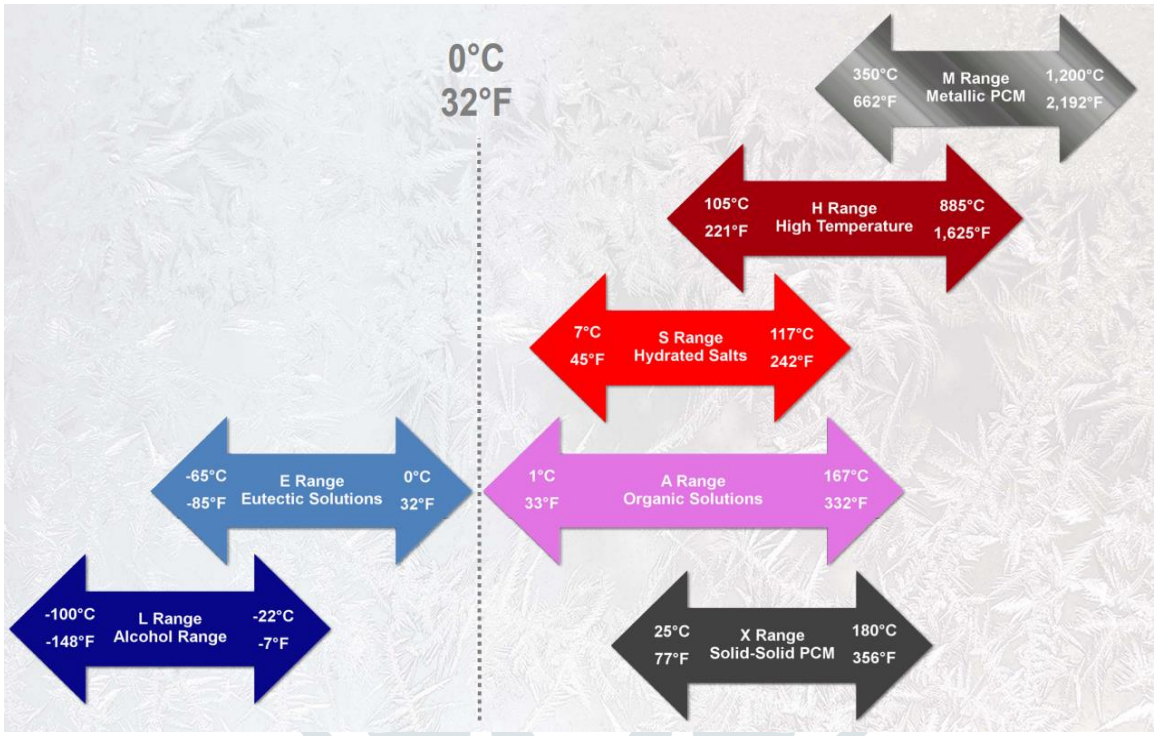

Figure 7: Different types of Phase Change Materials.

PCMs are classified in two groups; based on temperature first type is the material that's works below 00 C and other are ones that works above 00 C. The PCM works below 00 C have two groups first is eutectic solutions and another alcohol range. The eutectic solutions (E range) work between -650 C to 00 C and alcohol range (L range) works between -1000C to -220 C.

The PCM works above 00 C have five groups works in different temperature range. The metallic PCM (M range) works between 3800 C to 12000 C. Another group of PCM is high temperature (H range) works on 1050 C to 8850 C whereas hydrated salt group (S range) works between 70 C to 1170 C, organic solution group (A range) works between 10 C to 167^0 C and solid PCM works between 250 C to 1800 C [21,22].

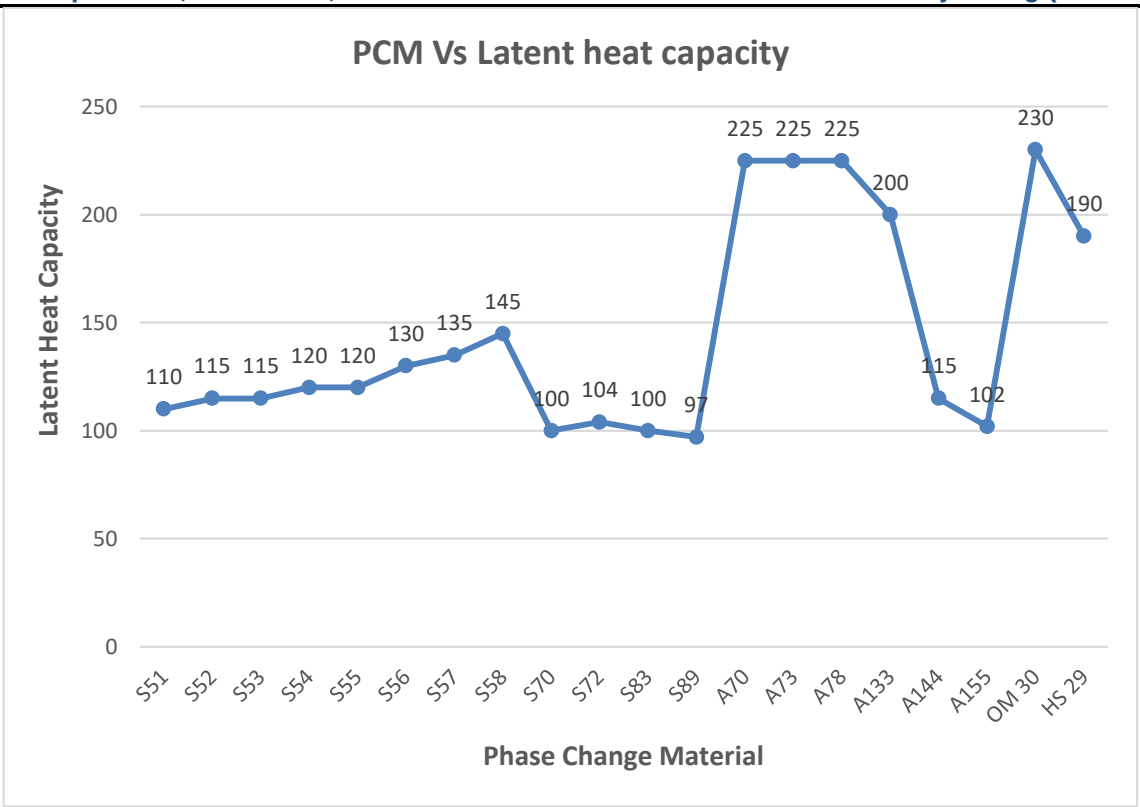

Figure 8: Graph of Phase change material Vs Latent heat capacity

The above graph shows that phase change material latent heat storage capacity. The total six material is having near about 200 KJ/Kg latent heat capacity. In these six materials five are the organic PCM and one is inorganic PCM. Here the material having highest latent heat capacity (OM30) is selected for experimental analysis

IV. Conceptual Design:

The selected phase change material is fitted in vehicle at two positions roof and door panel. The following figure shows configuration of PCM in roof.

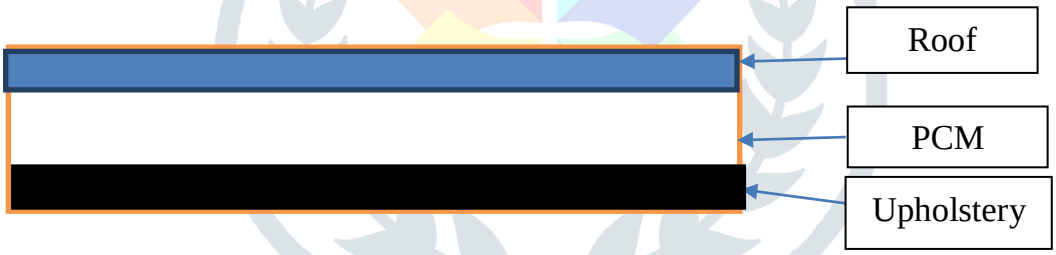

Figure 9: Configuration of PCM in roof

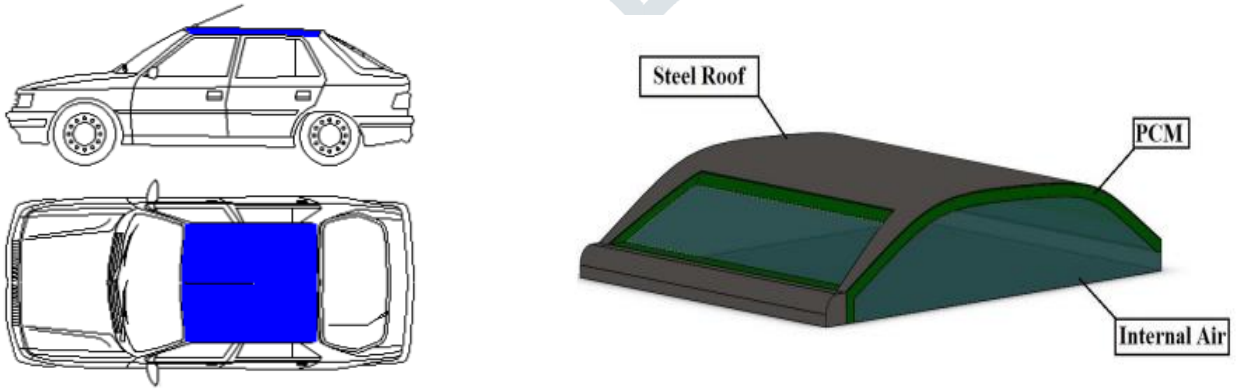

Fig. 10 PCM configuration in roof and CAD model

V. Conclusion

The above study shows that if vehicle is parked in hot sunny condition for long time, then inside temperature rises above 80^0 C. If the passengers, car owners are travelling through such hot vehicle then they fill suffocation until temperature come down. If any child or pet remain in such hot vehicle then they may die due to heat stroke. Now a days air conditioning is used when you seat inside the such hot vehicle but it will reduce the engine performance. A new technique to control the inside

temperature is incorporating the PCMs (Phase Change materials) in various parts of vehicle. The PCM absorb latent heat from heated surface and maintain the inside cabin temperature low. This phase change materials helps us to reduce the temperature rise inside the vehicle by 10^0C. This material will also reduce the load on engine by reducing the time of air conditioning system

References:

[1] Swanand Kirpekar, Suraj Mani Chourasiya and Avinash Arankalle 2014 Studies on Tropical conditions in hot sunny days in India and their effects on interior temperature rise in Truck Cabin in Innovative Design, Analysis and Development practices in Aerospace and Automotive Engineering, I-DAD, page 269 (Springer Publication)

[2] R. Farrington, J. Rugh Impact of Vehicle AirConditioning on Fuel Economy, Tailpipe Emissions, and Electric Vehicle Range Earth Technologies Forum Washington, D.C, National Renewable Energy Laboratory.

[3] Dharmesh Patel, Preyashi B. Manjrawala, Uttam B. Khunt , Dhyey R. Savaliya, 2021 Phase Change Material (PCM) in Automotive Climate Control System International Journal of Research in Engineering, Science and Management Volume 4, Issue 11.

[4] Gulnaz Fatima Siddiqui, Mukesh Vir Singh, Anubha Shrivastava, Manisha Maurya, Ambuj Tripathi, Shahid Akhtar Siddiqui Children Left Unattended in Parked Vehicles in India: An Analysis of 40 Fatalities from 2011 to 2020

[5] Croitoru C., Nastase I., Bode F., Meslem A., Dogeanu A., 2015 Thermal comfort models for indoor spaces and vehicles—Current capabilities and future perspectives, Renewable and Sustainable Energy Reviews, 44 304-318.

[6] Haller G., 2006 Thermal Comfort in rail vehicles,

[7] Mihaela Simiona, Lavinia Socaciua , Paula Unguresana, 2015 Factors which influence the thermal comfort inside of vehicles" Sustainable Solutions for Energy and Environment, EENVIRO - YRC, Bucharest, Romania.

[8] Hodder S. G., Parson K., 2008 The effects of solar radiation and black body re-radiation on thermal comfort, Ergonomics, 51 476-491

[9] Ružić D., Časnji F., Thermal Interaction Between a Human Body and a Vehicle Cabin in, Intech.

[10] Regnier C., 2012 Guide to Setting Thermal Comfort Criteria and Minimizing Energy Use in Delivering Thermal Comfort, in: E.O.L.B.N. Laboratory (Ed.).

[11] Catalin Neacsu, Mariana Ivanescu, Ion Tabacu, "The influence of the glass material on the car passenger thermal comfort"; Scientific bulletin automotive series year XV, no 19.

[12] Temming J., 1980 Comfort requirements for heating, ventilation and air conditioning in motor vehicles, Research and Development Division, Volkswagenwerk AG.

[13] Jovic J.J., Djoric V. D., 2009 Application of Transport Demand Modelling in Pollution Estimation of a Street Network, Thermal science, 13 229-243.

[14] Manojlovic A. V., Papic V. D., Filipovic S. M., 2011 Fleet Renewal: An Approach to Achieve Sustainable Road Transport, Thermal science, 15 1223-1236.

[15] Kilic M., Sevilgen G., 2009 Evaluation of Heat Transfer Characteristics in an Automobile Cabin with a Virtual Manikin during Heating Period, Numerical Heat Transfer, Part A: Applications, 56 515-539.

[16] Huang L., Han T., 2002 Validation of 3-D Passenger Compartment Hot Soak and Cool-Down Analysis for Virtual Thermal Comfort Engineering, SAE International Technical Paper.

[17] Sevilgen G., Kilic M., 2013 Investigation of transient cooling of an automobile cabin with a virtual manikin under solar radiation, Thermal science, 17 397-406.

[18] A. Jamekhorshid, S. M. Sadrameli; 2012 Application of Phase Change Materials (PCMs) in Maintaining Comfort Temperature inside an Automobile World Academy of Science, Engineering and Technology 61.

[19] Davis L, Ferraro R, and Grody R 5 "Solar thermal storage using phase change materials" in Fundamentals of heat & mass transfer, fourth edition.

[20] Adem Ugurlu, Chauhan Glycol 2012 A review on thermal energy storage systems with phase change materials in vehicles" Electronic journal of vocational colleges.

[21] A. Pasupathy a , L. Athanasius a , R. Velraj a,, R.V. Seeniraj b, 2008 Experimental investigation and numerical simulation analysis on the thermal performance of a building roof incorporating phase change material (PCM) for thermal management", Applied Thermal Engineering 28 556–565

[22]. Swanand Kirpekar, Dr. Padmayya Naik, 2022 Thermal Investigation inside the Vehicle in Standalone Condition During Severe Summer" , Dickensian journal, vol 22, issue 3.