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STUDY REGARDING THE AIR FLUX TEMPERATURES MEASUREMENT ON A CLIMATE CONTROL SYSTEM WITH AIR COURTAIN

BY

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Abstract. The heat, ventilation and air conditioning (HVAC) system is a very important component of the car since, beside the performances achieved from an energy point of view, it may also affect performance from the point of view of comfort. It is crucial for any manufacturer to be able to measure as accurately as possible the values related to the operation of the HVAC system. Thus, several technologies are used which involve direct measurement, by means of sensors of temperatures and speeds of the air fluxes or temperature measurement technologies, by means of infrared thermal imaging.

Key words: HVAC; sensors; infrared thermal imaging.

1. Introduction

The ventilation and air conditioning system is a key component of the modern vehicle with important implications, from several points of view. Thus, a vehicle which offers a higher thermal comfort is more attractive to customers than one with weaker performance. A high-performance ventilation and air conditioning system may be more economical from the point of view of the energy consumption, leading to a reduction of the fuel quantity and lower

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emissions. In addition, an air conditioning system may have powerful implications from the point of view of the safety due to the demisting and defrosting function. The methods used to measure and study the interaction of the air conditioned currents with the surfaces inside the vehicle or the human body should be therefore as varied as possible so as to provide a full picture.

2. Study Description

In the case of this study we shall analyze the way the human body and the vehicle interior interact with the air currents produced by a HVAC system with curtains of turbulent air conditioned jets. The system was designed and manufactured following a study which shows that in over 80% of the situations, only the driver is present in the vehicle and the main idea is to obtain a sensation of thermal comfort only for the area occupied by the driver and not for the entire volume of the car (Scottish Household, 2012).

In order to do this we divided the interior of the car into four distinct areas: front left, front right, rear left and rear right, separated by means of cold air curtains. The air conditioning system to be conceived should detect which places are being occupied in the vehicle, turn on the air curtains and be capable of producing the sensation of thermal comfort depending on the adjustment desired by the passenger, as in the Fig. 1:

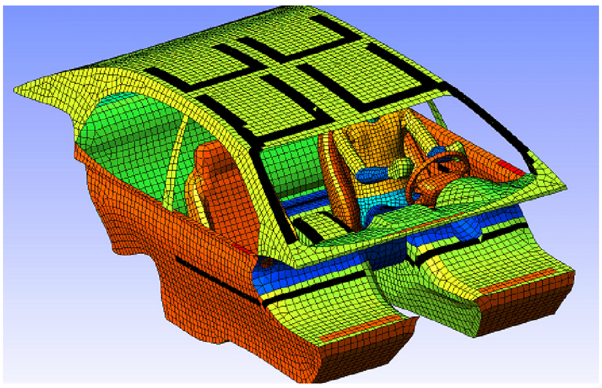

Fig. 1 – Position of the turbulent circular air conditioned jet curtains.

It was thus determined that:

− The flux of heat necessary for cooling a quarter of the car volume is much lower than the one necessary for the entire volume;

− The flux of heat necessary for cooling a half of the vehicle volume is much lower than the one necessary for the entire volume;

− The flux of heat necessary for cooling three quarters of the vehicle volume is much lower than the one necessary for the entire volume.

For this project we used a Mercedes Benz model E- Klasse 300D, with a modified and adapted ventilation and air conditioning system, in agreement with the study theme. Thus, for the driver's seat and the passenger's seat we adapted the system of turbulent circular air conditioned jet curtains.

The disposition of the air curtains is as follows: for the driver's and the passenger's seats we mounted an air tube-work which ascends on pillar "A" and the ceiling and has a U-shape above each occupant, Fig. 2; for the climate control of the feet area we mounted a U-shape tube-work at the level of the chair and above the feet, as in Fig. 3.

Fig. 2 – Tube-work for the turbulent circular air jets curtain mounted on the ceiling.

Fig. 3 – The turbulent circular air jets curtain tube-work mounted at the level of the seat

So far this system hasn't been implemented on any car and this paper is a comparative study between a classic HVAC system and a curtain based air conditioned implemented on the same car.

In this study we compared the advantages and disadvantages of a climate control system with air conditioning curtains which selectively activates on one or several seats inside the vehicle as compared to a classic one with nozzles installed on the test machine.

For the maximum accuracy in the measurement and evaluation of the project we left unchanged: the original installation of the air conditioning system; the air-blower fan; the electronic command and control unit of the air conditioning; the original sensors of the vehicle.

The study objectives were the following: a comparison between the HVAC system mounted on the car and the one adapted from the point of view of jets dispersion; the verification of the way the surfaces from the inside, including those of a dummy, are cooled; the verification of the air conditioned jets speed of the curtain to see whether the values range in the human thermal comfort interval; the verification of the jets dispersion for the two air conditioned systems.

In order to evidence the air jets, including those generated by the nozzles of the original system of the car and the curtains of air conditioned we used a Hurricane 1011 smoke generator positioned at the ventilation system and air conditioning intake, Fig. 4.

Fig. 4 – Hurricane 1101 smoke generator positioned at the ventilation and air conditioning system intake.

By injecting supersaturated liquid vapors we can evidence the form of the air jets from the dash nozzles for the original climate control system and for the one with turbulent circular air jets curtains. Thus, for the classic system we notice that the air jet has the form presented in Fig. 5 as incipient configuration, expanding gradually Fig. 6.

Fig. 5 – The air jet of the classic air conditioning system, incipient stage.

Fig. 6 – Air conditioning jet of the classic system.

One can notice that the jet has considerable dimensions and the area it touches is the chest and the head. At speeds over 0.4 m/s there can arise thermal discomfort, a dry eye sensation or the sensation of “draught”.

For the turbulent circular jets air conditioning systems we have the following interaction, Fig. 7.

Fig. 7 – The interaction between the turbulent air conditioning circular jets.

One can notice that the turbulent circular jets merge in the curtain and then it flows uniformly beside the driver, at low speed. The advantage is that the turbulent circular air conditioning jets curtains interact with the dummy in a friendly manner, without creating the sensation of “draught”, dry eyes or excessive cold which diminish the thermal comfort.

3. The Verification of the Way the Inside Surfaces are Cooled, Including those of a Human Dummy

The verification of the system and the distribution of temperatures inside the vehicle was conducted by using two thermal imagers, namely FLUKE TIS 10, (Info. Fluke) Fig. 8 and FLIR T660, (Info. Flir) Fig. 9.

Fig. 8 – Fluke TIS 10 Thermal imager.

Fig. 9 – FLIR T660 Thermal imager.

By means of the two thermal imagers we could visualize the interaction between the turbulent circular air conditioning jets curtain and the surfaces inside the vehicle, including those of the test dummy. We used two thermal vision systems, Fluke and Flir, because these provide software different functions and facilities, extremely useful for this study.

One can notice in Fig. 10, in the frame above, the classic HVAC system while in the figure below we have the turbulent circular air conditioning jets curtain system.

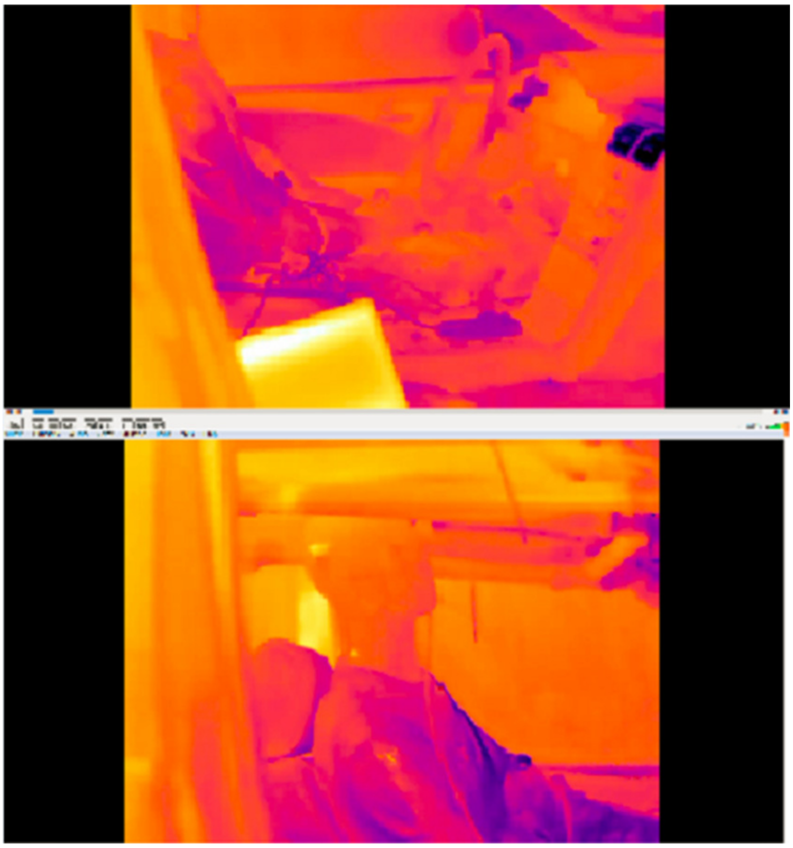

Fig. 10 – FLIR footage at 5 sec.

In the frames from Fig. 11 one can notice how the classic HVAC system cools non-uniformly the test dummy body and the air conditioning jets curtain system starts to cool uniformly

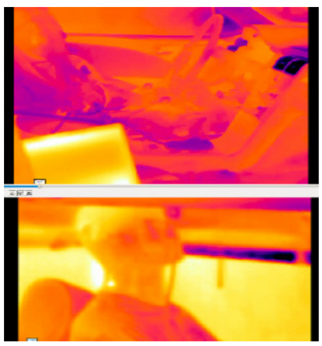

Fig. 11 – FLIR thermal imager footage at 35 sec.

In the image from Fig. 12 the classic HVAC system continues to cool non-uniformly the interior surfaces and the dummy body while the turbulent circular jets curtain system cools them uniformly.

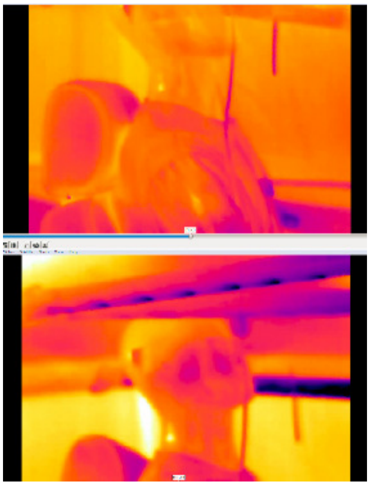

Fig. 12 – FLIR thermal imager footage at 1 min. 35 sec.

In Figs. 13, 14 and 15, one can notice the evolution of the two systems, clearly outlining the advantage of the turbulent circular air curtains as compared to the original classic HVAC system installed on the car.

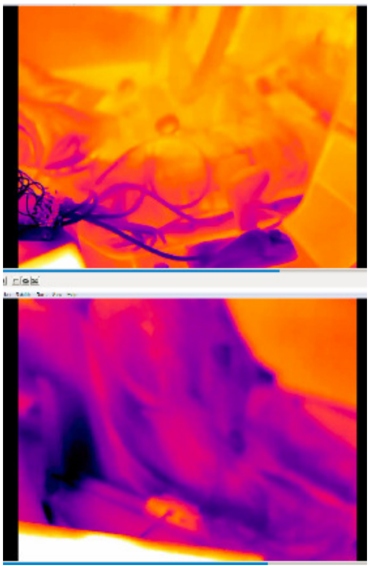

Fig. 13 – FLIR thermal imager footage at 2 min. 05 sec.

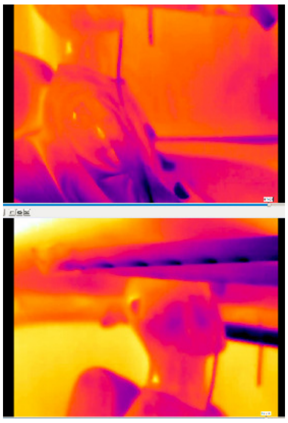

Fig. 14 – FLIR thermal imager footage at 2 min. 30 sec.

Fig. 15 – FLIR thermal imager footage at 2 min. 59 sec.

Thus, the classic system fails to cool uniformly the test dummy and the interior surfaces, while the air conditioning curtain system ensures a uniform temperature on all areas.

Another interesting aspect of the operation of the turbulent circular jets air conditioning curtains is the situation when a passenger wants a cold temperature and the other a hot one. The classic air conditioning system cannot ensure a clear separation area of temperatures in the central zone because the nozzles are close to one another and temperatures mix, resulting an average value. We can conclude that the occupant of a seat will receive the temperature of choice from the lateral nozzles and another temperature from the central nozzle.

After testing the turbulent circular jets air curtains, one can notice in Fig. 17 that the cross over area is well differentiated and thus, on an average distance of 0.15 m we have a difference of 16.7 degrees, the neighboring areas being well-delimited by the air conditioning curtains and each occupant being able to get a temperature close to the one of choice.

This result was evidenced with the help of the infrared Fluke TIS 10 thermal imager and the related SmartView software. These tools allowed us to evidence the operation of the turbulent circular air conditioning curtains and objectively analyze the evolution of temperatures inside the vehicle.

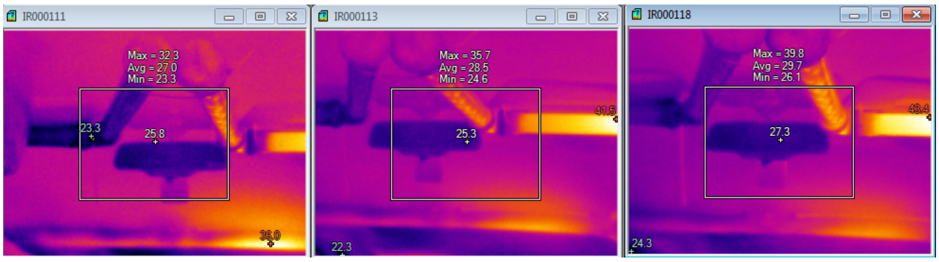

Fig. 17 – Photos of the cross-over areas with the help of Fluke TIS10 camera.

Another interesting aspect outlined by the two tools provided by FLUKE is that any joint on the tube-work behaves as a heat or cold accumulator. As noticed in Figure 18 where at the moment the turbulent circular air jets curtains were switched from hot to cold each joint area behaved as a heat accumulator.

There arises the need to design each HVAC system with as few joints as possible as they directly impact on the system performance.

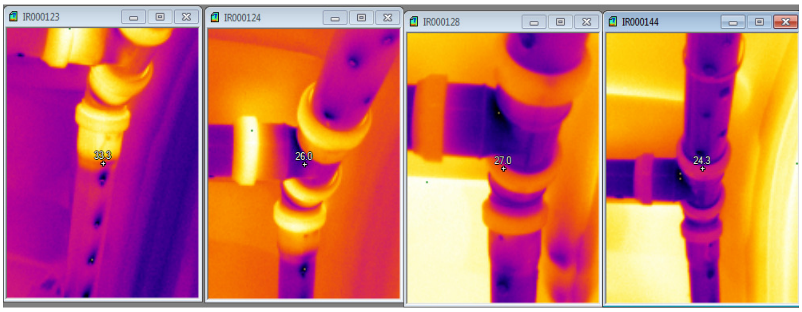

Fig. 18 – Cross over areas and the way heat accumulates when passing the cold air instead of the hot air in the tube-work.

Another aspect underlined in this study was the verification of the speed and temperatures along the curtain generated jet by means of DT 8880 hot wire anemometer and the related software at distances of 0.1 m, 0.2 m, 0.3 m and 0.4 m along the curtain jets Fig. 19.

The purpose of this data collection was to check whether for the upper and lower curtains the jet speeds ranges in the interval of 0.1 m/s and 0.4 m/s - the air conditioning speeds for the maximum thermal comfort area (Grossman 2010).

Fig. 19 – Anemometer positioned at the turbulent circular jets curtain at 0.4 m.

One can notice from Figs. 20 and 21 that the speed and temperature variations range in the desired interval and, for a more detailed analysis, we have the possibility of data collection under the form of a text file.

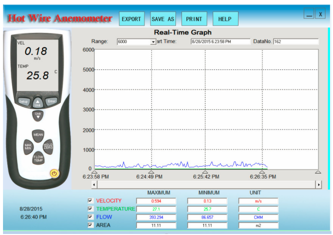

Fig. 20 – Speed variation for the upper curtain.

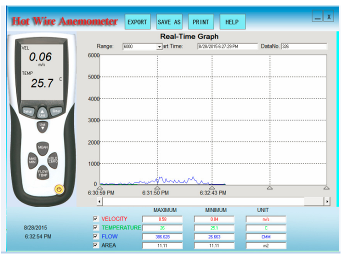

Fig. 21 – Speed variation for the lower curtain.

4. Conclusions

1. The HVAC system with turbulent circular air conditioning jets curtain ensures better performance from the point of view of: a uniform distribution of temperatures on the surface of the test dummy; the air speed

situated in the area of maximum thermal comfort; a uniform cooling of interior surfaces of the seat being taken.

2. The separation of temperatures depending on the passenger's desire is no longer an indefinite and full of compromises objective from the point of view of the thermal comfort and can be easily implemented by means of the curtains.

3. The turbulent circular air conditioning jets curtain system simplifies the piping of the system providing extra space since the nozzles on the central dashboard are no longer needed.

4. The technologies used in this study ensure an easier testing of the HVAC system, regardless of the configuration, providing a clearer vision on performances.

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STUDIU PRIVIND MĂSURAREA TEMPERATURILOR FLUXULUI DE AER LA UN SISTEM DE CLIMATIZARE CU CORTINE DE AER

(Rezumat)

Sistemul de ventilație şi aer condiționat (HVAC) este o componentă deosebit de importantă a autoturismului deoarece pe lângă performanțele din punct de vedere energetic, poate afecta şi performanțele din punct de vedere al confortului. Deosebit de important pentru orice constructor de autovehicule este să poată evalua şi măsura cât mai precis valorile legate de funcționarea sistemului HVAC. Pentru acest lucru sunt folosite mai multe tehnologii care implică măsurarea directă cu ajutorul senzorilor a temperaturilor şi vitezelor curenților de aer sau, tehnologii de măsurare a temperaturilor cu ajutorul termoviziunii în infraroşu. Rezultatele obținute în cadrul experimentelor arată că sistemul HVAC cu perdele de aer condiționat cu jeturi circulare turbulente oferă performanțe foarte bune din punct de vedere al distribuției uniforme a temperaturilor pe suprafața manechinului de teste, iar viteza aerului este situată în zona de confort termic maxim, oferind o răcire uniformă a suprafețelor interioare ale locului ocupat. Separația temperaturilor în funcție de dorința ocupantului nu mai este un obiectiv nedefinit şi plin de compromisuri din punct de vedere al confortului termic, fiind uşor de implementat cu ajutorul sistemului propus.