CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

FACULTY OF ENGINEERING

TECHNOLOGY AND ENVIRONMENTAL ENGINEERING

DIPLOMA THESIS

(Air-conditioning in the cabins of motor vehicles)

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Abstract

The main aim of this diploma thesis is to analyze the current state of design and function of Air-conditioning system in motor vehicle cabins. The focus of the diploma thesis is on basic parameters especially the thermal state of the internal environment and the purity of the internal air from the point of view of the driver. Diploma thesis has two parts. The first part of the diploma thesis contains general information about Air-conditioning like structure etc. This part completely based on literature, professional publications, magazines, Internet articles, research papers and other professional material.

The second part of the diploma thesis contains information about the actual measurements those measured by different kind of measuring equipments. Second part of diploma thesis is an experimental part. The measurements made with different operational modes of the air-conditioning system (without, minimum, medium and maximum). RH%, CO_2%, Noise level L_A(dB), Cabin air temperature (t_i), Cabin globe temperature (t_g) and Particulate matters were measured inside the vehicle cabin.

Keywords: Clean air, drivers cabin, dust, microclimate, thermal state.

Abstrakt

Hlavním cílem této diplomové práce je provést analyzu současného stavu konstrukčního řešení a provozu klimatizačních zařízení v kabinách motorových vozidel. Zaměřit se na posouzení základních parametrů, zejména tepelného stavu prostředí a čistoty vnitřního vzduchu z hlediska řidiče. Diplomová práce má dvě části. První část diplomové práce obsahuje všeobecné informace o struktuře klimatizace apod. Tato část je kompletně založena na literatuře, odborných publikací, časopisů, internetových článků, výzkumných zpráv a dalších odborných materiálů.

Druhá část diplomové práce obsahuje informace o vlastním měření dané problematiky klimatizačních zařízení motorových vozidel. Druhá část diplomové práce je experimentální. Měření provedená s různými provozními režimy klimatizačního systému (bez, minimálního, středního a maximálního). RH%, CO_2%, hladina hluku L_A(dB), teplota vazduch kabiny (t_i), teplota globe kabiny (t_g) a PM byly měřeny uvnitř kabiny vozidla.

Klíčová slova: Čistota vzduchu, kabina, prach, mikroklima, tepelný stav.

Conclusion

The aim of the thesis was to analyze the current state of microclimate and operation of the air-conditioning system in the motor vehicle cabin. The focus of the diploma thesis was on basic parameters especially the thermal state of microclimate and cleanliness of the air from the point of view of the driver and passengers.

The first part of the diploma thesis is base on literature and other scientific publications related to the diploma thesis topic. In the first part of the thesis author described in detail all about the air-conditioning system, its working principle as well as the working principle of the individual components of the air-conditioning system. Every component of an air-conditioning system plays its unique role inside the air-conditioning system. The air-conditioning system is quite effective to create a suitable microclimate inside the vehicle cabin. The sensors of the air-conditioning system play a very big role to maintain suitable microclimate inside the cabin. Now, these days air-conditioning systems are very eco-friendly because of new refrigerant R1234yf.

The second part of the diploma thesis based on measurements. The measurements made with Kia Sportage car. The car was quite new, it had quite well functioning and sensor-based air-conditioning system. The type of the vehicle was SUV. Two identical routes were chosen for measurements. The first route was through villages and small towns (Prague Suchdol and via Unetice and Tursko to Kralup nad Vltavou and at last end up at Prague Suchdol). The second route was through Prague city (Prague Suchdol after passed through Hradčany, the North-South highway and at last end up at Prague Suchdol). The level of CO_2%, RH%, Noise (dB), Particulate matters (PM) and t_i (cabin temperature in℃) was measured during both measurements. The excess amount of CO_2, particulate matters (PM) inside the vehicle cabin have a very bad impact on drivers and passenger's health, and suitable t_i (cabin temperature) is necessary inside the cabin for relief from fatigue and stress.

Based on both parts of thesis it is quite confirmed that the air-conditioning system plays a big role to keep and maintain the suitable microclimate inside the vehicle cabin. Day by day technology is growing that is why in future the air-conditioning systems will be more reliable economically. The electric compressor is one of a suitable example of this. The electric compressor is very suitable with electric vehicles (EV) and hybrid vehicles (HV). Now these days because of the automatic air-conditioning system the driver of the vehicle can more

concentrate on driving, he/she does not need to perform manually to keep suitable microclimate inside the vehicle cabin.

According to the measurement part, we can say that the maximum operational condition of an air-conditioning system was very effective to keep the desired microclimate inside the vehicle cabin. The performance of the air-conditioning system depends on the ventilation rate. Solar radiations play a role to rise up cabin temperature t_i inside the cabin. The maximum operational condition of the A/C system showed best results during measurements. The noise level (dB) depends on the technical condition of the vehicle. The level of the dust inside the vehicle depends on the material and condition of accessories like mats, carpet and seat covers and take care of the vehicle.

At last, generalized conclusion is that the A/C system plays a very positive role to keep the desired microclimate inside the vehicle cabin.

References

[1] Air conditioner compressor. [Online]. 2008 – 2019. [Cit 5-11-2018]. Available from: https://www.airconditioning-systems.com/air-conditioner-compressor.html

[2] AUTO PARTS WAREHOUSE. A/C accumulator. [Online]. 1995-2019. [Cit 12-12-2018]. Available from: https://www.autopartswarehouse.com/ac-accumulator

[3] Daly, Steven. *Automotive air-conditioning and climate control systems*. Science Direct, 2006. ISBN: 978-0-7506-6955-9.

[4] Dahlan[a], Afiq Aiman., Zulkifli[a], Amirah Haziqah., Nasution[b,*], Henry., Aziz[b], Azhar Abdul., Perang[b], Mohd Rozi Mohd., Jamil[b], Hishamuddin Mohd., Zulkifli[a], Ahmad Ammar. 2014. Efficient and green vehicle air-conditioning system using electric compressor. *The 6th International conference on applied energy – ICAE 2014.*ScienceDirect.

[5] Datta, Santanu Prasad., Das, Prasanta kumar., Mukhopadhyay, Siddharth. 2014. Effect of refrigerant charge, compressor speed and air flow through the evaporator on the performance of an automotive air-conditioning systém. *International refrigeration and air-conditioning konference.*Paper 1470. [Online]. [Cit 10-1-2019]. Available from: https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2469&context=iracc.

[6] DENSO. *A/C compressors*. [Online]. 2018. [Cit 10-1-2019]. Available from: https://www.denso-am.eu/media/631294/deac13uk10mm_uk_thermal_ac-compressor_leaflet_web.pdf.

[7] EPCOS. *Sensors for Air-conditioning in automobiles.* [Online]. 2007. [Cit. 30-11-2018]. Availablr from: https://www.tdk-electronics.tdk.com/download/528068/647002b90bb6dbc8e9be4a0fe9242992/pdf-sensorsairconditioningautomotive-an1.pdf. (Sensors for air-conditioning in automobiles, 2007)

[8] GLOBAL DENSO. *Products for Electric and Hybrid vehicles*. [Online].2013. [Cit 25-12-2018] Available from: http://www.globaldenso.com/en/newsreleases/events/globalmotorshows/2013/iaa13/files/IAA13_evhv.pdf. (Products for Electric and Hybrid vehicles, 2013)

[9] Haynes, J. *Haynes Automotive Heating and Air Conditioning System Manual*. Haynes Manuals. ISBN: 978-1563929137.

[10] Hohls, S[a]., Becker, S[b]. *2018. Modeling of HVAC noise in a simplified car model*. SAE Techanical Papers. Scopus.

[11] Imam, Md Shahid., Basha, Dr. M. Shameer., Azizuddin, Dr. Md., Reddy, Dr. K. Vijaya Kumar. 2013. *Design of air-conditioning system in automobiles*. IJIRSET. ISSN: 2319-8753.

[12] Jadhav, S.M[a]., Arulprakasajothi, M[a]., Chandrasekhar, U[b]., Devarajan, X[a]. 2019. *Experimental investigation of vapour absorption refrigeration cycle for automobile cabin cooling*. Scopus, pp. 41 – 51.

[13] Kumar, S., Cerny, J., Kic, P. 2018. *Air conditioning in the cabins of passenger cars.* Agronomy Research 16, 2088-2096.

[14] Khurmi, R.S., Gupta, J.K. *A textbook of Refrigeration and Air-conditioning*. Publisher S. Chand & Company PVT. LTD. ISBN: 978-81-219-2781-9.

[15] Laukkonen, JD. What is Blower Motor? 2013. [Online]. [Cit 15-12-2018]. Available from: http://www.crankshift.com/blower-motor

[16] Munson, Cheryl. 2019. *Difference between Automatic air-conditioning vs. Manual*. Leaf Group Ltd. [Online]. [Cit 17-01-2019]. Available from: https://www.hunker.com/12591346/difference-between-automatic-air-conditioning-vs-manual

[17] MACS Worldwide. Three important functions of the receiver/drier in your cars A/C system. 2010. [Online]. [Cit 20-12-2018]. Available from: https://macsworldwide.wordpress.com/2010/07/13/three-important-functions-of-the-receiverdrier-in-your-cars-ac-system

[18] Miller, R., Miller, M.R. *Air conditioning and Refrigeration*. New York, McGraw-Hill, 2006, ISBN: 0-07-146788-2.

[19] Szekyova, M., K. & Novy, R. 2006. *Ventilation and air-conditions*. Jaga, Bratislava, 359 pp.

[20] Szczurek, A. & Maciejewska, M. 2015. Classification of air quality inside car cabin using sensor system. In: *International conference on sensor networks*, Sensor nets 2015, pp.211-219.

[21] THE LINDE GROUP. R1234 yf – Opteon. [Online]. 2018. [Cit 10-12-2018]. *Automotive Refrigerant with low global warming potential*. Available from: https://

/en/images/R1234yf%20-%20Opteon%20YF%20-%20brochure_tcm17-110818.pdf. (R1234yf-Opteon, 2018)

[22] Viegas, C., Monteiro, A., dos Santos M., Lacombe, N., Viegas, S. 2018. *Filters from taxis air-conditioning system: A tool to characterize driver's occupational exposure to bioburden?* Environmental Research 164, Scopus, pp. 522 – 529.

[23] Vevrka, Lukas. 6 interesting fact about air-conditioning system. 2012. [Online]. [Cit 2-12-2018]. Available from: http://www.auto.cz/klimatizace-69059

[24] Zhou, X[a] ., Lai, D[b] ., Chen, Q[c] . 2019. *Experimental investigation of thermal comfort in a passenger car under driving conditions.* Scopus, pp. 109 – 119.