



Contents of Work Package - HVAC for Optimal Comfort in Vehicles

2-WP08:HVAC for Optimal Comfort in Vehicles

Coordinator of the WP

Brno University of Technology, responsible person: Jan Fišer

Participants of the WP

Sobriety s.r.o., responsible person: Martin Kožušník, František Dospíšil

Main Goal of the WP

2-WP08-001 (ZV) System of air distribution devices for flexible HVAC - Gfunk
(BUT FSI + SOBRI) Project deadline: 10.2020

The workpackage is focused on the methodical coverage of research and development of HVAC systems for vehicle cabins. The topic is very up-to-date in terms of the impact of HVAC systems on the energy consumption and range of EV vehicles.

Partial Goals for the Current Period

2-WP08-004 (O) Methodology for the prediction and evaluation of thermal management in vehicle cabins - O
(BUT FSI + SOBRI) Project deadline: 12.2020



Contents of Work Package DP 2 WP08 - HVAC for Optimal Comfort in Vehicles

Main Goal of the WP

2 – WP08 - 001 (ZV) - System of air distribution devices for flexible HVAC in the vehicle cabins capable of responding to various / ongoing changes to the interior design (flexi interior) and capable of reflecting operational and power flexibility requirements, which is closely linked to the autonomous vehicles and energy-optimized HVAC systems.

2 – WP08 - 004 (O) – The methodology integrates tools for computational prediction of thermal load and thermal comfort in vehicle cabins with measuring by using state-of-the-art measuring technologies such as thermal manikin or local smart sensors. For the methodology the simulation tools such as CFD and models of the human thermophysiology/comfort are incorporated. Whole methodology is parametric to be used for comparative study in wide range of different cabin (road, off-road, autonomous and rail vehicles as well) and can evaluate an impact of different HVAC technology on cabin thermal management.

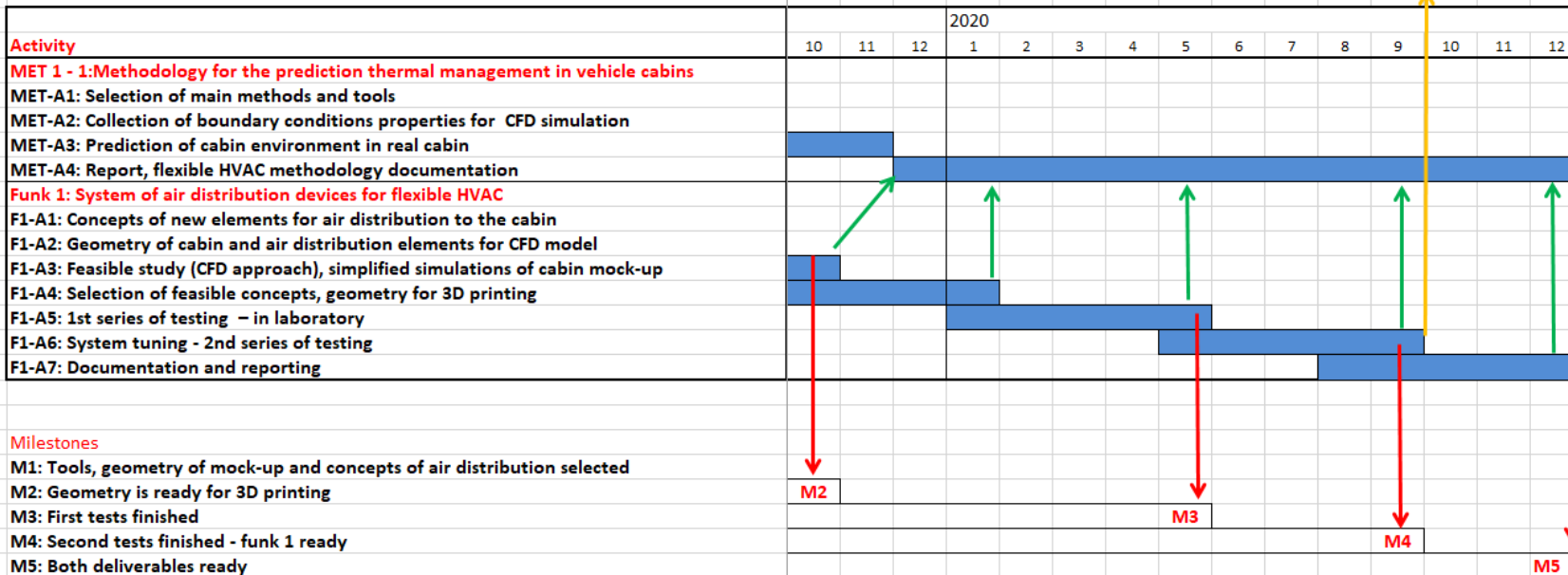


Contents of Work Package DP 2 WP08 - HVAC for Optimal Comfort in Vehicles

Partial Goals for the Current Period

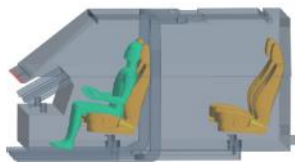
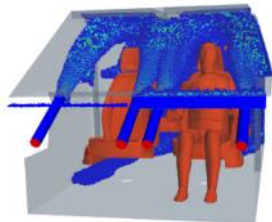
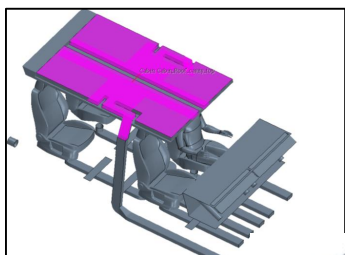
TAČR NCK - 2WP08 - schedule

HVAC for optimal Comfort in Vehicles

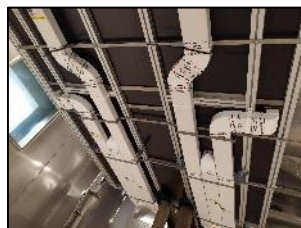
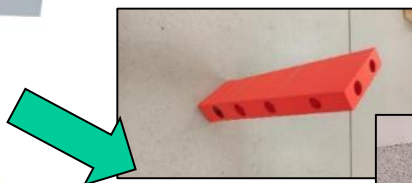


WP08 - HVAC for Optimal Comfort in Vehicles - Teaser

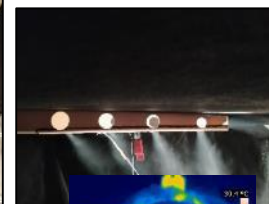
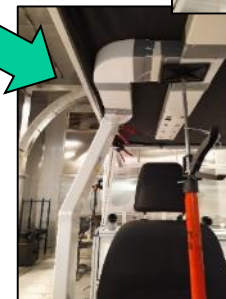
Development of HVAC air distribution devices - design, prototyping, 3D printing, testing



Design: CAD + CFD



**Manufacturing: prototyping
and 3D printing**

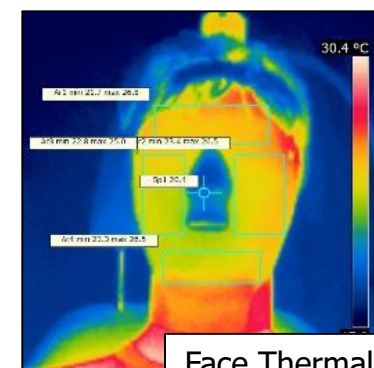


Testing of performance

WP08 - HVAC for Optimal Comfort in Vehicles - Teaser

HVAC, cabin environment and thermal comfort applied research and methods

Ceiling ventilation device developed in WP08 (low mixing air distribution concept) is optimal for flexible cabins, thermal comfort and to **prevent spreading of aerosol and pathogens (flu, COVID19) across cabin.**



Face Thermal comfort
based on heat-flux





Contents of Work Package DP 2 WP08 - HVAC for Optimal Comfort in Vehicles

The workpackage is focused on the methodical coverage of research and development of HVAC systems for vehicle cabins to provide optimal travelling comfort. These systems have to be flexible not only in the power capacity (rapid cooling / heating up) but also in the possibility of providing comfort for different layout of cabin interior, which may be flexibly changed (flexible interiors).

Simulations, CFD and thermophysiology

- 1) CFD in cabin interior
- 2) Sensation and comfort prediction

BUT + Sobri

MET 1: Methodology for the prediction and evaluation of thermal management in vehicle cabins

2-WP08 - HVAC

HVAC technology R&D

- 1) Air distribution elements

BUT + Sobri

FUNK 1: System of air distribution devices for flexible HVAC

Cabin environ. measurement

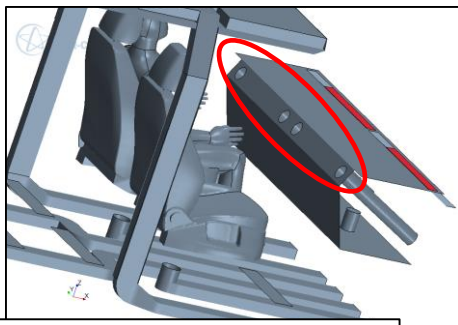
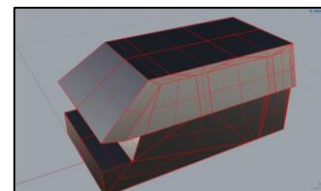
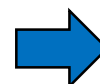
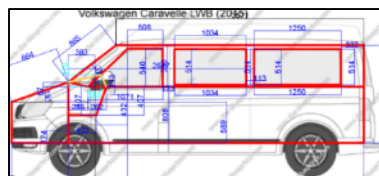
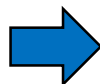
- 1) Thermal manikin + models
- 2) Teq sensors

BUT

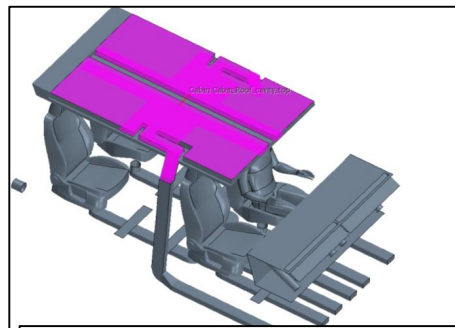
Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 001 - System of air distribution devices for flexible HVAC

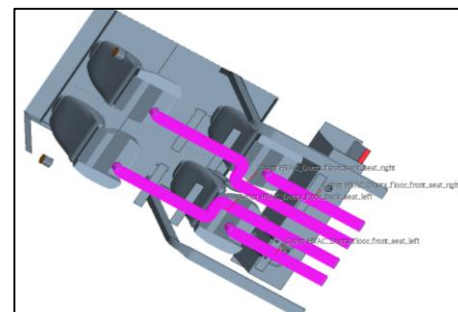
A2: Geometry of cabin and air distribution elements for CFD model



Typical mixing ventilation



Ceiling-based displacement ventilation

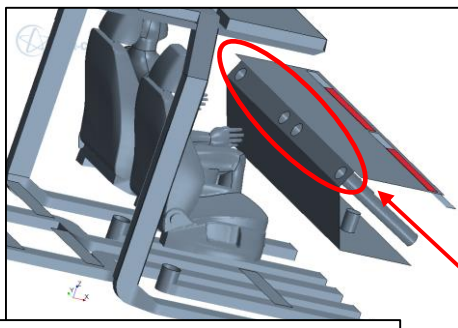


Local air distribution under seat

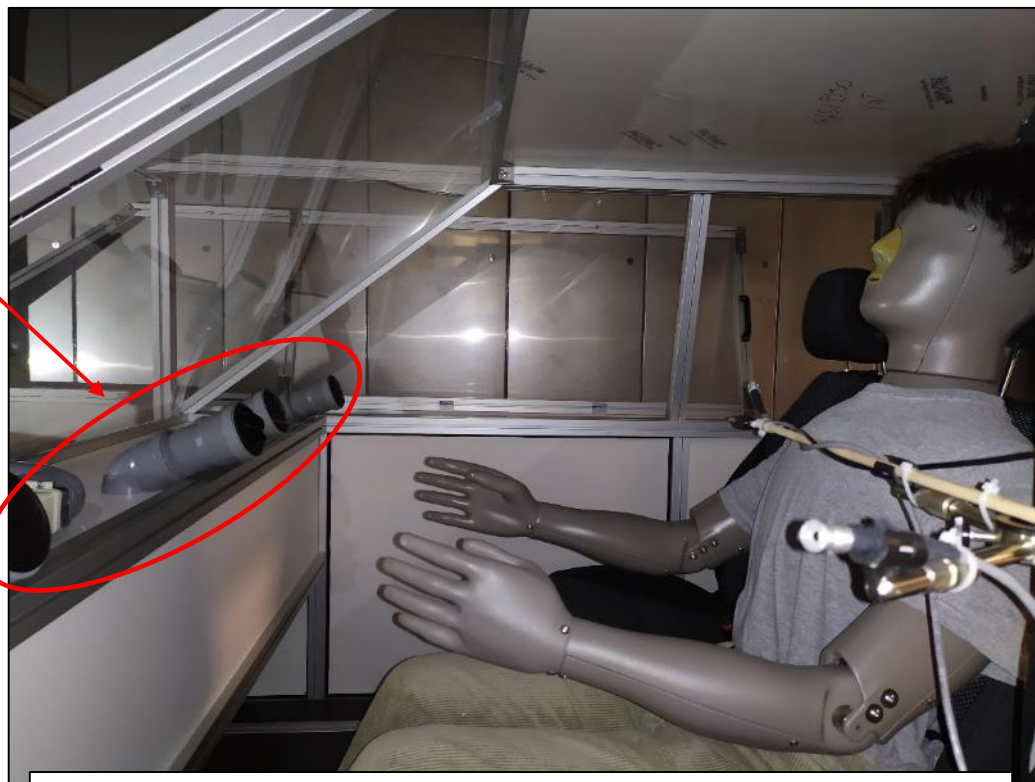
Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 001 - System of air distribution devices for flexible HVAC

A4: Geometry for 3D printing, Gfunk realization



Typical mixing ventilation

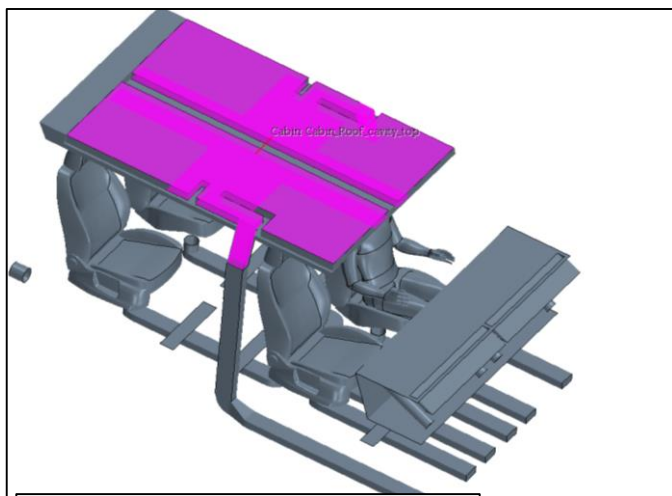


Mixing air distribution system – realization in cabin mock-up

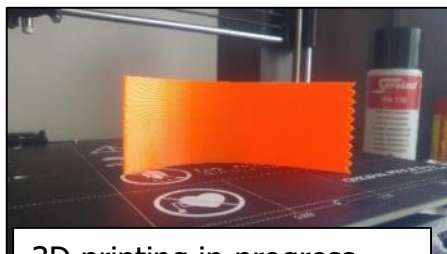
Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 001 - System of air distribution devices for flexible HVAC

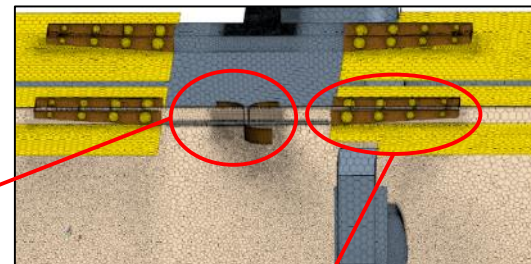
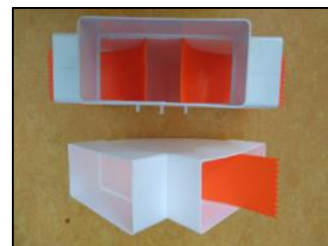
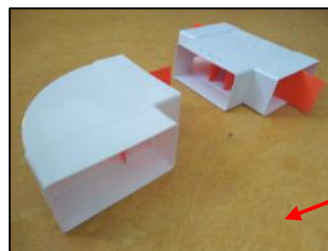
A4: Geometry for 3D printing, Gfunk realization



Ceiling-based displacement ventilation



3D printing in progress



1st version of air distributor

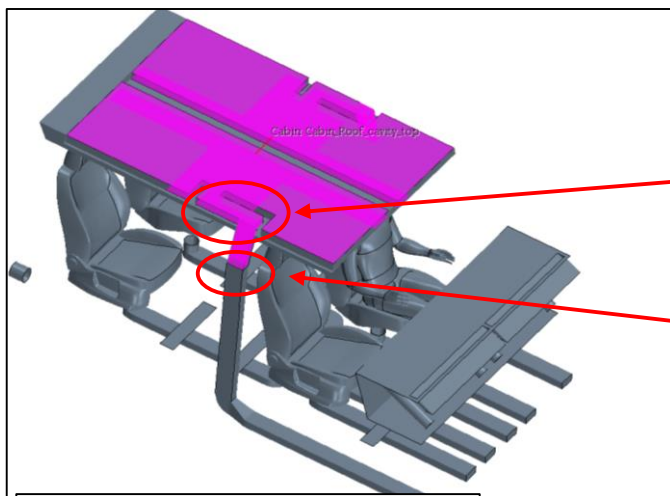


2nd printed version of air distributor

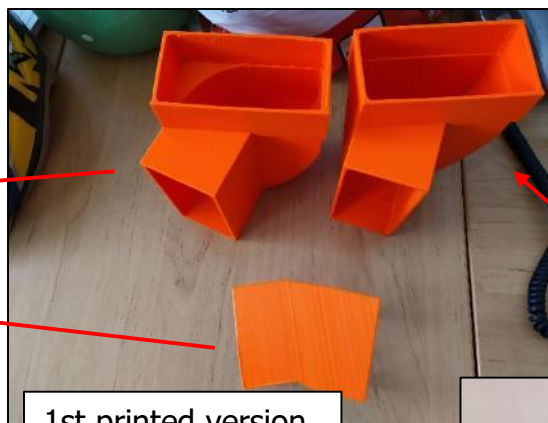
Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 001 - System of air distribution devices for flexible HVAC

A4: Geometry for 3D printing, Gfunk realization



Ceiling-based displacement ventilation



1st printed version

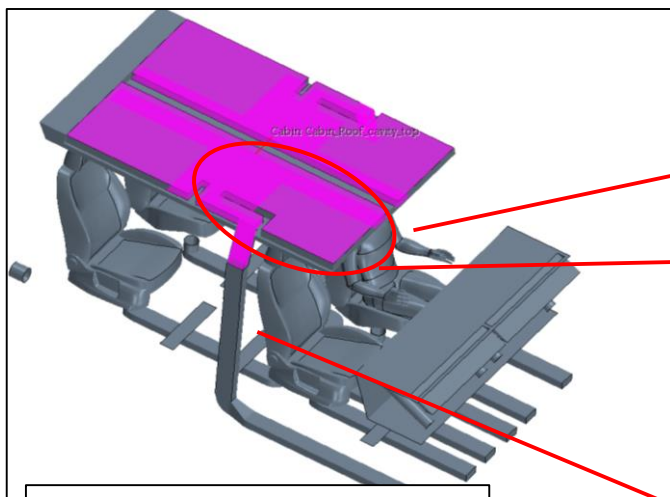


2nd printed version

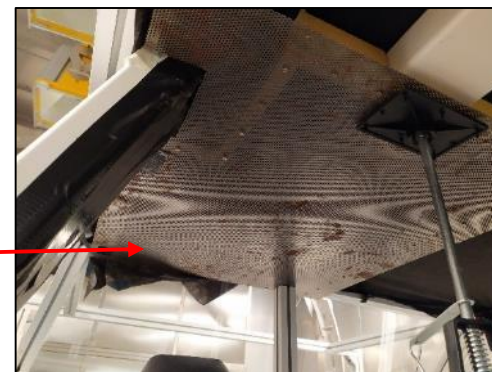
Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 001 - System of air distribution devices for flexible HVAC

A4: Geometry for 3D printing, Gfunk realization



Ceiling-based displacement ventilation

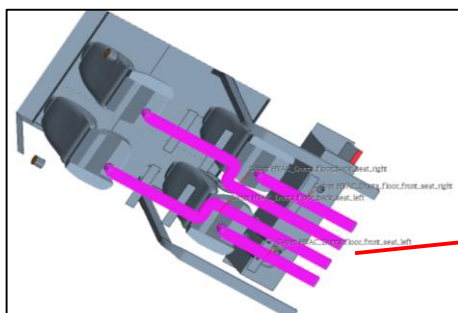


Realization of Ceiling-based displacement ventilation system in cabin mock-up

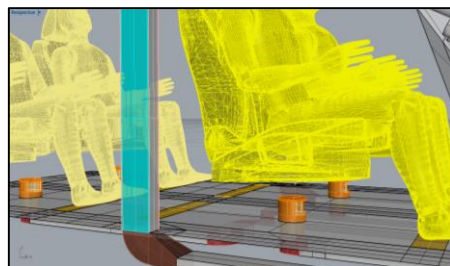
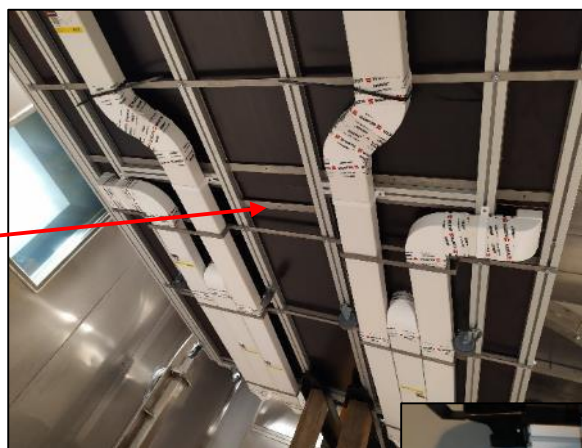
Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 001 - System of air distribution devices for flexible HVAC

A4: Geometry for 3D printing, Gfunk realization



Local air distribution under seat



Realization of Local air
distribution under seats



Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 001 - System of air distribution devices for flexible HVAC

A5/6 : 1st and 2nd series of testing in laboratory

1st series of tests – mixing ventilation – smoke visualisation



1st series of tests – mixing ventilation – infrared camera imaging



Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 001 - System of air distribution devices for flexible HVAC

A5/6 : 1st and 2nd series of testing in laboratory

1st series of tests –
mixing ventilation –
direction to face



1st series of tests –
mixing ventilation –
direction to chest

Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 001 - System of air distribution devices for flexible HVAC

A5/6 : 1st and 2nd series of testing in laboratory

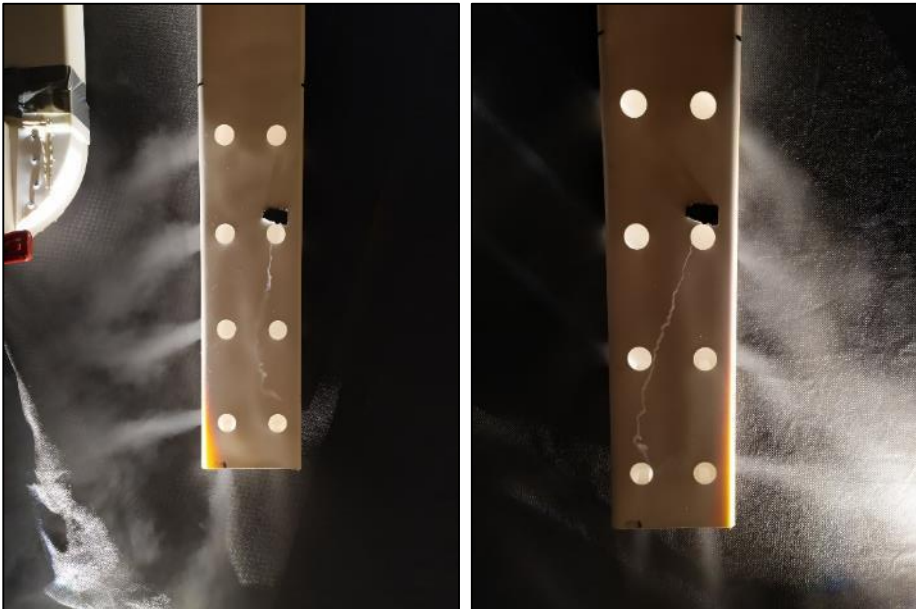
2nd series of tests – Ceiling-based displacement ventilation – smoke visualisation



Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 001 - System of air distribution devices for flexible HVAC

A5/6 : 1st and 2nd series of testing in laboratory



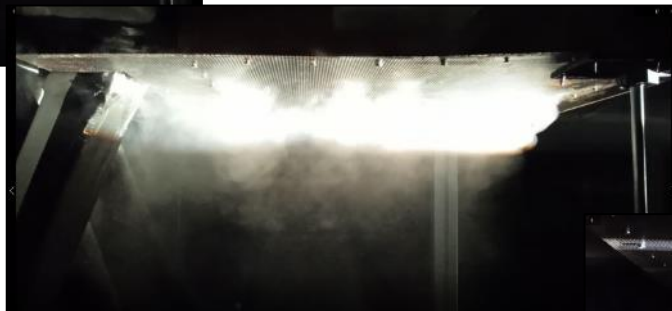
2nd series of tests – Ceiling-based displacement ventilation –
air distributor test (1st version of air distributor)



Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 001 - System of air distribution devices for flexible HVAC

A5/6 : 1st and 2nd series of testing in laboratory



2nd series of tests – Ceiling-based displacement ventilation –
Air Terminal Device test (1st version of air distributor)

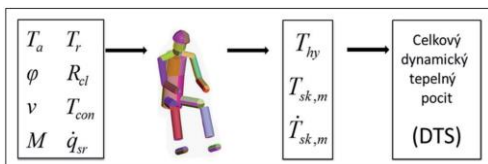
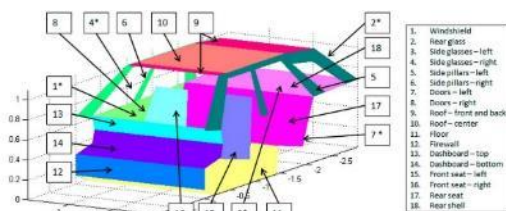
Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 004 - Methodology for prediction and eval. of thermal management in vehicle cabins

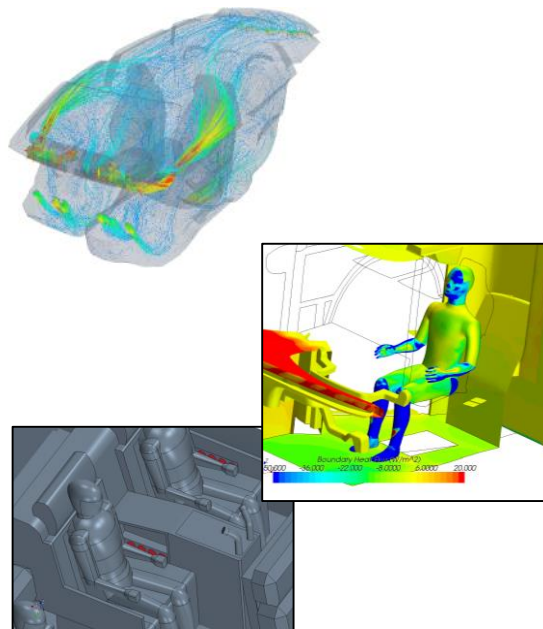
A3/4: Prediction of cabin environment, Report, HVAC methodology documentation

Models and tools for methodology

1D simulations



CFD simulation



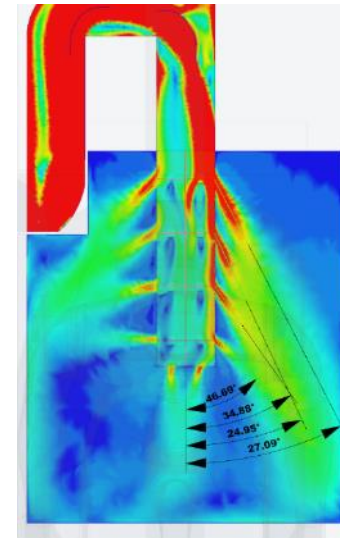
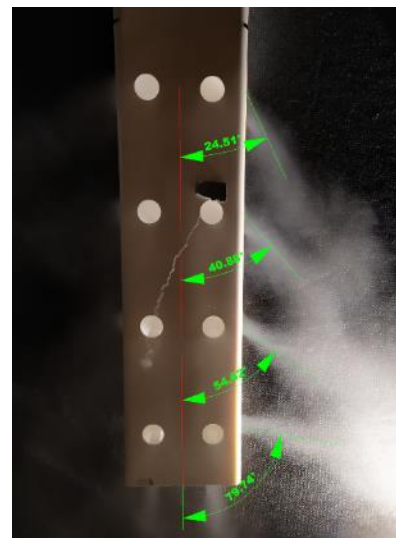
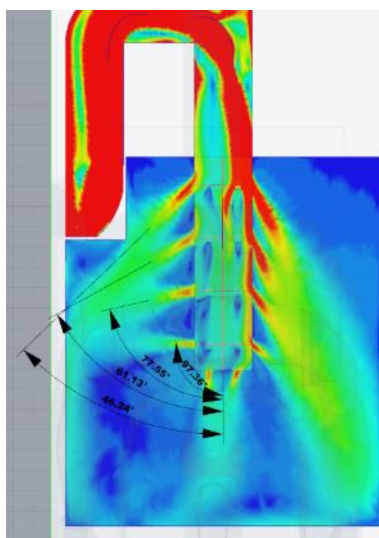
Measurement and testing



Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 004 - Methodology for prediction and eval. of thermal management in vehicle cabins

A3/4: Prediction of cabin environment, Report, HVAC methodology documentation

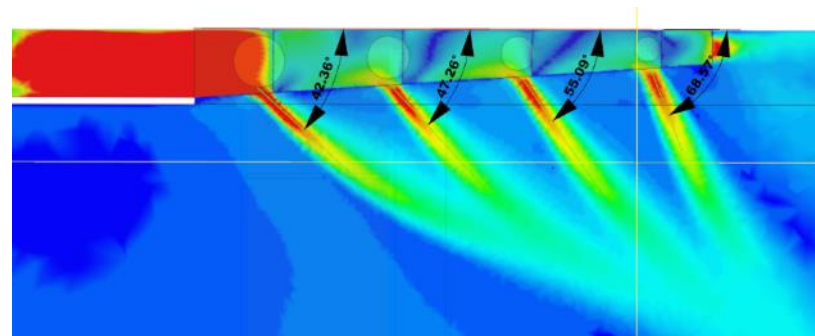
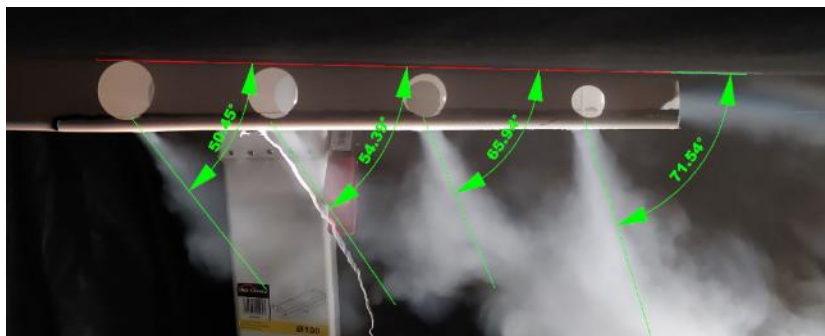


Lab and CFD results comparison – horizontal plane
Ceiling-based displacement ventilation system – Air distributor

Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 004 - Methodology for prediction and eval. of thermal management in vehicle cabins

A3/4: Prediction of cabin environment, Report, HVAC methodology documentation



Lab and CFD results comparison – vertical plane
Ceiling-based displacement ventilation system – Air distributor



Activities in WP08 - HVAC for Optimal Comfort in Vehicles

2 – WP08 - 004 - Methodology for prediction and eval. of thermal management in vehicle cabins

A3/4: Prediction of cabin environment, Report, HVAC methodology documentation

<p>T A Č R T</p>	<p>TECHNOLOGICKÁ AGENTURA ČESKÉ REPUBLIKY</p>	<p>TNO1000026</p>	<p>T A Č R</p>
<p>VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ</p>	<p>SOBRIETY S.R.O.</p>	<p>OBSAH</p>	
<p>METODIKA PREDIKCE A HODNOCENÍ TEPELNÉHO MANAGEMENTU V KABINÁCH POZEMNÍCH VOZIDEL</p>	<p>VÝSTUP DÍLČÍHO PROJEKTU DP2, PRACOVNÍ BALÍČEK WP08 - HVAC PRO OPTIMÁLNÍ KOMFORT VE VOZIDLECH</p>	<p>1 ÚVOD A ZAMĚŘENÍ METODIKY 3 1.1 Postup řešení 3 2 METODIKA A JEJÍ SOUČÁSTI 4 2.1 Simulační nástroje a modely 4 2.1.1 1D modely pro výpočtovou predikci tepelného zatížení 5 2.1.2 CFD model kabiny s virtuálním modelem tepelného manekýna 6 2.1.3 Metoda ekvivalentní teploty a Diagram komfortních zón 7 2.1.4 Termofizilogické modely lidského komfortu + indexy 8 2.2 Experimentální technika 9 2.2.1 Tepelný manekýn 9 2.2.2 Smart senzory ekvivalentní teploty 10 2.2.3 Klimatická komora 11 3 PŘÍPADOVÁ STUDIE - VĚTRÁNÍ KABINY S FLEXIBILNÍM INTERIÉREM 12 3.1 Parametrizovaná geometrie skutečné kabiny 12 3.2 Model pro CFD a jeho nastavení 13 3.3 Simulované případy 13 3.4 Výsledky simulací 14 3.5 Experimentální měření reálného větracího systému 16 3.6 Porovnání výsledků měření a CFD simulací 17 4 MOŽNÉ OBLASTI VYUŽITÍ METODIKY 18 5 ZÁVĚR 20</p>	
<p>PŘÍLOHY Vysoké učení technické v Brně</p>	<p>DALEŠÍ ÚČASTNÍCI PROJEKTU Sobriety s.r.o.</p>	<p>Technologická agentura České republiky Evropská unie +20 254 68 00 www.nca.cz</p>	<p>2</p>
<p>V Brně xx. 12. 2020</p>			

Report draft



Fulfillment of goals and deliverables of DP 2 WP08 - HVAC for Optimal Comfort in Vehicles

In December 2020 - altogether 1 technical deliverables and 1 additional (milestone) ones.

Current State of Deliverables, Milestones and Fulfilment of Goals

All tasks leading to the fulfilment of the main project objectives in 2020, is one functional samples (Gfunk) and one other (O) deliverable were elaborated. In 2020, the design works, manufacturing of parts and applied research focused on 1st and 2nd laboratory tests series of Gfunk were made. The simulation of cabin environment and air distribution system to optimise flow fields in air channels were processed as well and the results were compared with lab tests. The report Methodology for the prediction and evaluation of thermal management in vehicle cabins is in progress.

List of Due Deliverables and Their Added Value

2 – WP08 - 001 (ZV) – System of air distribution devices for flexible HVAC

2 – WP08 - 004 (O) – Methodology for the prediction and evaluation of thermal management in vehicle cabins

Solving the tasks of the project enabled young PhD students to be employed and to strengthen scientific cooperation between BUT and Sobriety. The knowledge gained contributes to increasing competitiveness and the possibility of further development and cooperation between FME BUT, Sobriety and other project participant.



Current contribution of DP 2 WP08 - HVAC for Optimal Comfort in Vehicles

Assessment of the Contribution of Deliverables

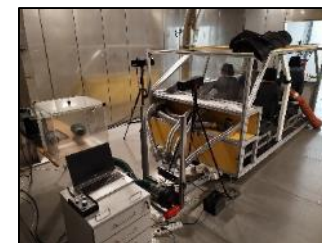
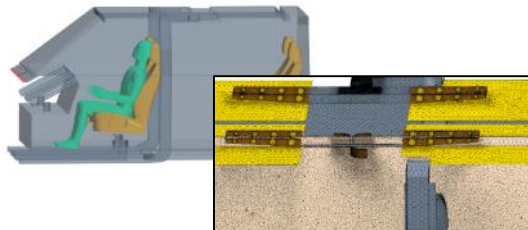
In 2020, the applied research focused on the simulation of cabin environment and new types of air distribution system by means of CFD simulation were processed. Also 1st and 2nd laboratory tests series Gfunk were made. Presented research activities should contribute to improve the cabin environment in new types of cabins (EV vehicles, flexible interiors). The main contribution of 2-WP08 is to provide HVAC air distribution systems which is suitable for flexible cabin interior and new types of vehicle services (e.g. Transportation as a service).

The quality of air distribution is crucial for protection against spreading of aerosols and pathogens (flu, COVID19) across vehicle cabin. Ceiling based air distribution system, developed in WP08, perfectly match to this demands, because each person has „air cell“ around seat and no typical air mixing (=lower pathogen transport) in a cabin is present.

Acknowledgement

This research has been realized using the support of Technological Agency, Czech Republic, program National Competence Centers, project # TN01000026 Josef Božek National Center of Competence for Surface Transport Vehicles. This support is gratefully acknowledged.

Výťah z prací 2019-2020, DP 2 WP08 - HVAC systémy pro optimální komfort ve vozidlech



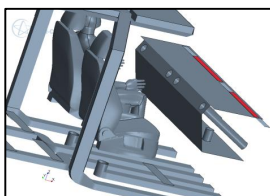
Vybrané typy distribuce vzduchu CFD optimalizace



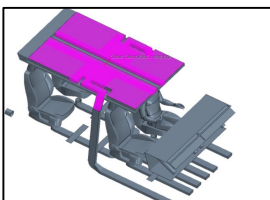
Realizace systému



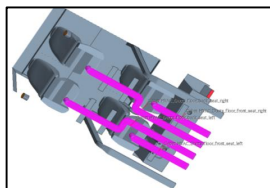
Experimenty, Porovnání, Metodika



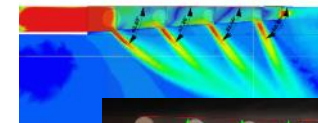
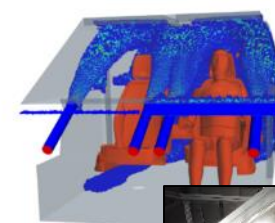
Typické
směšovací
větrání
Srovnávací případ



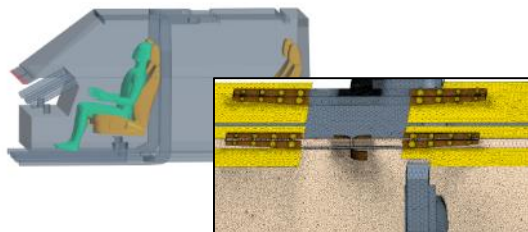
Zaplavovací
větrání



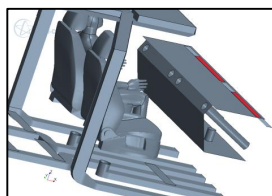
Lokální
větrání s
přívodem pod
sedačkami



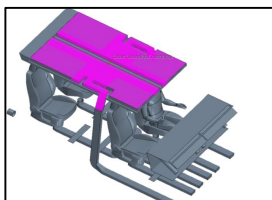
Results of DP 2 WP08 - HVAC for Optimal Comfort in Vehicles – Achieved 2019-2020



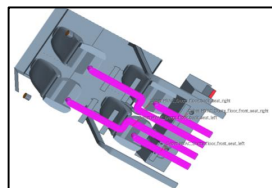
**Selected types of air distribution
CFD optimization**



Typical mixing
ventilation
Control case



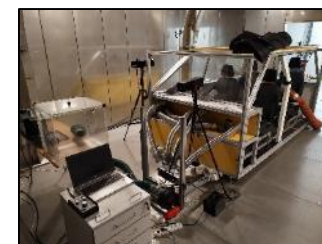
Displacement
ventilation



Local
ventilation
under seats



System realization



**Experiments, Comparison,
Methodology**

