Fractional cabin air recirculation: A simple and robust way to reduce PM exposure for passengers

Heejung Jung[1,2] and Michael Grady[1,2]

[1]Department of Mechanical Engineering, University of California, Riverside, CA 92521, U.S.A.
[2]College of Engineering-Center for Environmental Research and Technology (CE-CERT), University of California, Riverside, CA92507, U.S.A.
Keywords: vehicle cabin air quality
Presenting author email: heejung@engr.ucr.edu

A vehicle cabin provides a unique environment in which passengers are confined during their ride. Current vehicle HVAC systems are optimized to reduce the dust concentration and noise coming from roadway while maintaining comfortable temperature and humidity for passengers. On roadways, in-cabin exposures to ultrafine particles have been shown to be 10 times higher than ambient levels and contribute to approximately 50% of total daily ultrafine particle exposure among Los Angeles commuters (Zhu et al, 2007; Fruin et al. 2008). These results can apply to most of urban areas where high traffic volume exists. The high exposure at the above studies is because air on the roadway is entrained into the vehicle cabin. Scientists found cabin air-recirculation can reduce particle concentrations in the vehicle cabin significantly and effectively. However, their findings could not be applied to the cars in the market because of the simultaneous increase of CO_2 concentrations in the cabin.

This study (Jung 2013, Grady and Jung 2013) proposes continuous fractional recirculation of cabin air (as opposed to full recirculation and off/off control) to suppress increase of cabin CO_2 concentrations while taking advantages of air recirculation. The study showed cabin CO_2 concentration is determined by the balance between source strength and vehicle body leakage rate. This balance is influenced by multiple parameters: vehicle speed, cabin volume, fan speed and number of passengers. The study demonstrated to control cabin CO_2 concentrations at certain target level by adjusting opening of the recirculation door angle. This method is a cost effective way of maintaining clean air quality of the cabin and can be applicable to new cars.

Figure 1 shows comparison of CO_2 concentrations between mathematical model equations and experimental data during full recirculation mode at two different fan speeds while the vehicle is at constant speed of 21 km/h. The model predicts extremely well the time evolution of CO_2 concentrations.

Figure 2 shows a possible control strategy of cabin CO_2 concentration at a certain target concentration level. Upon the choice of recirculation mode the fraction of recirculation changes to control the cabin CO_2 concentration within the target range. For this example we chose rather high concentration (2000 ppm) as a target concentration to expect some energy saving from vehicle thermal management perspective as well.

Overall the presentation includes results and discussion from 1) feasibility test: proof-of-concept, 2) characterization of vehicle HVAC system, 3) influence of vehicle speed, 4) input parameters to control cabin CO_2 concentration, and 5) mathematical modelling.

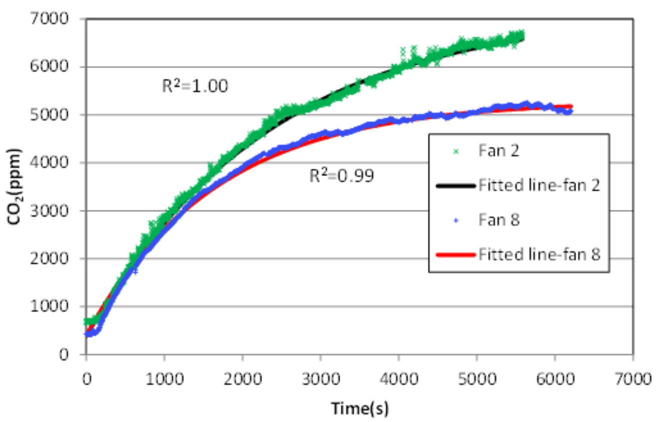

Figure 1 Evolution of cabin CO_2 concentration during full recirculation mode. The vehicle was at constant speed of 21 km/h. Green and blue markers show experimental data and black and red solid lines show fitted lines for fan speed 2 and 8, respectively

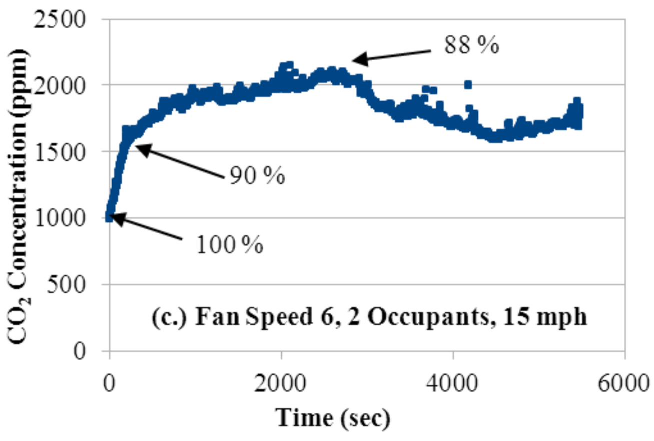

Figure 2 Feasibility test to control cabin CO_2 concentration at a certain target level, at 15 mph and fan speed 6 with two passengers. Percentage indicates degree of recirculation.

This work was supported by Hyundai-Kia motors.

Zhu, Y. F. et al., 2007, Environmental Science & Technology 41(7): 2138-2145.

Fruin, S. et al., 2008, Atmospheric Environment 42(2): 207-219.

Jung, H. (2013) SAE Technical Paper, 2013-01-1497.

Grady, M., Jung, H. (2013) SAE Technical Paper, 2013-01-1494.