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Influence of passenger car auxiliaries on pollutant emission factors within the Artemis model

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ABSTRACT

The impact of the auxiliaries and particularly air conditioning on emissions (CO_2, CO, HC, NO_x and particles) is investigated. To this aim, various data from European laboratories are used and analysed. Parameters linked to technology and to climatic conditions are investigated. The main distinction is made between gasoline and diesel vehicles. A physical model is proposed to extrapolate the excess emissions at low temperature (below 28 °C) and with solar radiation, together with a statistical model.

1. Introduction

The Artemis (Assessment and Reliability of Transport Emission Models and Inventory Systems) study is aiming at developing a harmonised emission model for road, rail, air and ship transport to provide consistent emission estimates at the national, international and regional level. A workpackage is aiming at improving the exhaust emission factors for the passenger cars and light duty vehicles, by enlarging the emission factor database, especially for effects of auxiliaries.

A European Climate Change Programme working group estimated that the usage of air conditioning (AC) systems under average European conditions causes an increase of fuel consumption between 4% and 8% in 2020 (ECCP, 2003). A recent study valuated an increase of fuel consumption in 2025 below 1% (Hugrel and Joumard, 2004). That is why it is proposed to undertake a state-of-the-art review of this area, to include fleet characteristics and a collection of data on auxiliaries (Roujol, 2005). Studies about AC have been done in Europe focussed on the evaluation of individual passenger car emission due to AC (Barbusse et al., 1998; Gense, 2000; Pelkmans et al., 2003; Weilenmann et al., 2004), or on the improvement of AC (Benouali et al., 2003). A major study about AC impact has been carried out in the framework of Mobile 6 by the USEPA, focussed on the real use of AC in real conditions (Koupal, 2001) and on the effect of AC running at full load on regulated pollutants (Koupal and Kremer, 2001).

2. Excess fuel consumption and CO_2 emission data analysis

AC database is made up of experimental data from three European laboratories (Utac and Cenerg in France, Vito in Belgium), i.e. 27 vehicles and 146 tests. Driving cycle, number of vehicle tests, type of vehicle, experimental objectives vary with experimentation. The choice of vehicles covers the main types of vehicle (small and large vehicles), different propulsion systems (gasoline and diesel) and the emission standards (mainly Euro 1, but also Euro 3 and 4). The climatic conditions are specific to each laboratory, but have been chosen in order to represent

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severe climatic conditions. The small size of the database allows us to perform a simple statistical analysis. According to Mobile 6, emitter classes, vehicle type, driving cycle, emission AC off and mean speed have to be distinguished to estimate effect of AC. At this short list, we can add, as proposed by Benouali et al. (2003), the regulation type and the compressor technology type.

The excess emission of pollutants due to AC is the difference of emission with and without AC running in the same condition. We have first to decide the type of unit to express the excess fuel consumption due to AC: in volume per distance unit or in volume per time unit. For physical reason (no strong relation between cooling demand and vehicle speed), it seems that volume per time ($l\,h^{-1}$ for instance) is better.

According to Fig. 1, the mean speed has little impact on excess fuel consumption expressed in $l\,h^{-1}$ (with an average increasing from 0.65 to 0.95 $l\,h^{-1}$ between 19 and 120 $km\,h^{-1}$), but variance test indicates that the relation is statistically significant. The data can be divided in two parts: (i) standard driving cycles (UDC, NEDC and EUDC) with low average speed and low load, giving low excess fuel consumption independent of the speed, and (ii) 90 and 120 $km\,h^{-1}$ constant speed driving cycles with higher speed and load, giving higher excess fuel consumption. In the case of standard cycles, the effect of AC on fuel consumption is partially hidden by the improvement of engine efficiency, because the AC running increases the load and therefore the engine efficiency. But for real driving cycles and for the 90 and 120 $km\,h^{-1}$ constant speed, engine load is slightly higher and the AC running does not increase the engine efficiency. A similar conclusion is given in a recent experimental study on two vehicles in real driving conditions (Rouméqoux et al., 2004). Globally, for real driving cycle, fuel consumption due to AC expressed in $l\,h^{-1}$ should be quite independent of the speed or type of driving cycle.

Technological parameters analysed are parameters connected to the vehicle engine, to the AC system and to the body shape of the vehicle. The data are displayed according to the engine size, the fuel type, the vehicle size, the type of compressor and the type of regulation. In order to get enough data per class, only 4 types of vehicles are distinguished (see Table 1). The results show that the fuel consumptions are quite close with large standard deviations. Therefore we assume that the fuel consumption of AC does not depend on technical parameters.

The climatic conditions and set temperature have certainly a huge influence on AC running, and then on pollutants emissions. No experimentation is performed according to the solar radiation, although, according to Barbusse et al. (1998), solar load represents 45% of the total load of the AC. Theoretically, the relation between fuel consumption and outside temperature is quite linear because of convective heat gains linearly linked with the difference between outside and inside temperatures. According to the data, the variation of excess fuel consumption with the outside temperature is lower than expected: although the uncertainty of the measurements, the outside temperature at which there is no cooling or heating, obtained by linear extrapolation, seems to be below 0 °C. That seems to demonstrate that AC is running quite close to full load for the tests, i.e. for outside temperature higher than 28 °C. An extrapolation of these data is therefore non-applicable. In addition, as the experiments do not allow us to take into account solar heat radiation, a physical model is therefore developed.

3. Air conditioning physical modelling

The physical phenomena taken into account are the heat exchanges of the cabin with outdoor, the heat exchange on evaporator of air conditioner, the air conditioner and the engine running.

The passenger compartment modelling is based on a description of heat exchange as it is usually done in mono-zone thermal building modelling (Bolher et al., 2000). Air temperature and humidity in the cabin is assumed to be uniform. Heat exchanges governing temperature of cabin are due to the global heat exchange coefficient, UA ($W\,m^{-2}\,K^{-1}$), the untreated air flow rate due to permeability, m_p ($kg\,s^{-1}$), the internal heat gains due to occupants and electrical equipments, A_{int} (W), the solar gains, A_{sol} (W) and the treated air flow, m_t ($kg\,s^{-1}$).

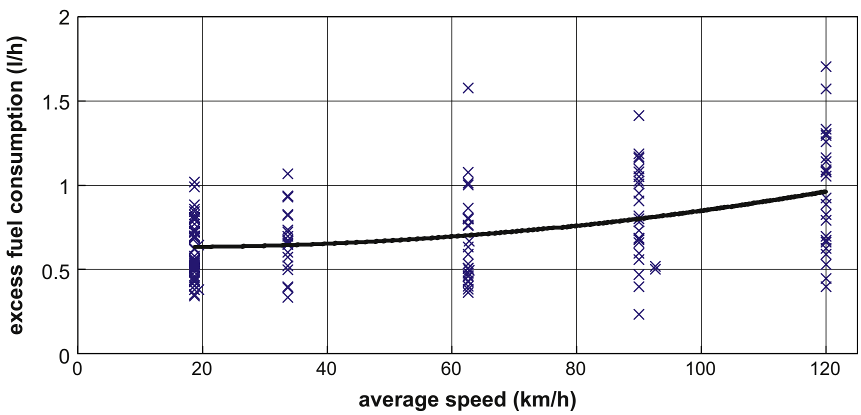

Fig. 1. Excess fuel consumption ($l\,h^{-1}$) due to AC versus average speed ($km\,h^{-1}$), with polynomial regression.