THE INFLUENCE OF GEAR CHANGE ON VEHICLE EXHAUST EMISSIONS. CALCULATIONS WITH THE VETESS EMISSION TOOL

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ABSTRACT

This study explores the influence of gear changing behaviour on vehicular exhaust emissions and fuel consumption using the emission simulation tool VeTESS (Vehicle Transient Emissions Simulation Software). VeTESS was used to assess the impact of (not) changing gear at certain vehicle speeds on the exhaust of vehicle air pollutants using theoretical drive cycles as input. The hypothesis formulated is that, by selecting a higher gear early, one will avoid high engine speeds and achieve a reduction of emissions and fuel consumption. Calculations to test this hypothesis were executed for two vehicles of the Belgian fleet: a Euro III diesel car and a EURO IV petrol car. The results for CO_2, CO and HC confirm the hypothesis and show that one can save fuel and decrease vehicle exhaust emissions by changing up gear. The results for NO_x and PM, on the other hand, differ slightly.

1. INTRODUCTION

Large reductions in vehicle emissions can be achieved by improvements in vehicle technology. These enhancements have a relatively large implementation time and considerable costs. Furthermore, these measures are often regulated at a high policy level, limiting the contribution of the local authorities to this regard. On the other hand, policy measures to improve fuel economy can also be taken at a lower policy level, like actions focusing on a change in driver behaviour to promote environmentally friendly driving (De Vlieger et al, 2000). An environmentally friendly driving style includes different behavioural aspects to obtain a more fuel-efficient driving, one of them implying a selective use of gears (Beckx et al, 2006). By shifting gear early one can avoid high engine speeds and therefore achieve a reduction of emissions and fuel consumption. Before implementing aiming this kind of measures, it is important to assess the potential benefits of these actions in advance.

This paper presents the methodology that was used to assess the impact of an improved gear change behaviour on vehicle exhaust. It will present the results of calculations that were made for gear changes with two different vehicle types, using the VeTESS emission model. Finally, the paper concludes and defines some interesting topics for further research.

2. METHODOLOGY

The methodology to calculate the emissions from vehicles driving at a certain speed in a certain gear consists of the two important steps:

- development of speed profiles, including information on gear selection
- calculation of emissions with the VeTESS emission tool

This procedure was suggested by the head of the team that originally developed VeTESS (De Bal, 2006 pers. comm.). In this section, we discuss these steps in more detail.

To estimate the impact of (not) changing gear at a certain vehicle speed, theoretical driving cycles were developed for two different vehicle types, a Euro III diesel car (Scoda Octavia) and a EURO IV petrol car (Volkswagen Polo). We believe these vehicles are representative for an important fraction of current passenger car sales in Belgium. First, for each vehicle type, the range of speeds that can be driven at a certain gear was defined, taking into account the minimum and maximum engine revolutions per minute (RPM) of the vehicle. Next, speed profiles were developed consisting of second-by-second vehicle speed data and information on gear selection. The first speed profile started with the lowest possible vehicle speed (taking into account the minimum engine RPM) in first gear. Every 30 seconds vehicle speed was raised with 2 kph, until the maximum engine RPM was reached. Next, this procedure was repeated for the range of speeds that can be driven in second gear, third gear, etc. As a result, for every vehicle type, 5 speed profiles were developed.

These speed profiles were used as input for the VeTESS emission model. VeTESS (VEhicle Transient Emissions Simulation Software) was developed within the EU 5th framework project DECADE (2001-2003) as a vehicle level simulation tool for the simulation of fuel consumption and emissions. The calculations in this vehicle simulation tool are based on a detailed calculation of the engine power required to drive a given vehicle over any particular route. It calculates emissions and fuel consumption on a second-by-second basis for a specific vehicle on a given speed profile, based on the required engine power. We refer to Pelkmans et al. (2004) for a detailed technical description of the VeTESS-model. For the moment detailed engine maps are only available for a few types of vehicles. Simulations in this study were performed on a Euro III diesel car (Scoda Octavia) and a EURO IV petrol car (Volkswagen Polo), as described in Beevers and Carslaw (2005). As a result of this procedure, detailed emission estimates were available for every vehicle speed and gear choice of the two selected vehicle types.

3. RESULTS AND DISCUSSION

According to the methodology described in the previous section, calculations were performed on two different vehicle types. Following graphs each represent the emission factors for a certain pollutant in function of the vehicle speed and gear selection. The emission factor was calculated as the average emission value during a few seconds of a certain speed profile, taking into account the distance that was covered. Figure 1 presents the emission factors as a function of vehicle speed and gear selection for the EURO III diesel car Scoda Octavia. In figure 2 the emission factors for the EURO IV petrol car are presented.

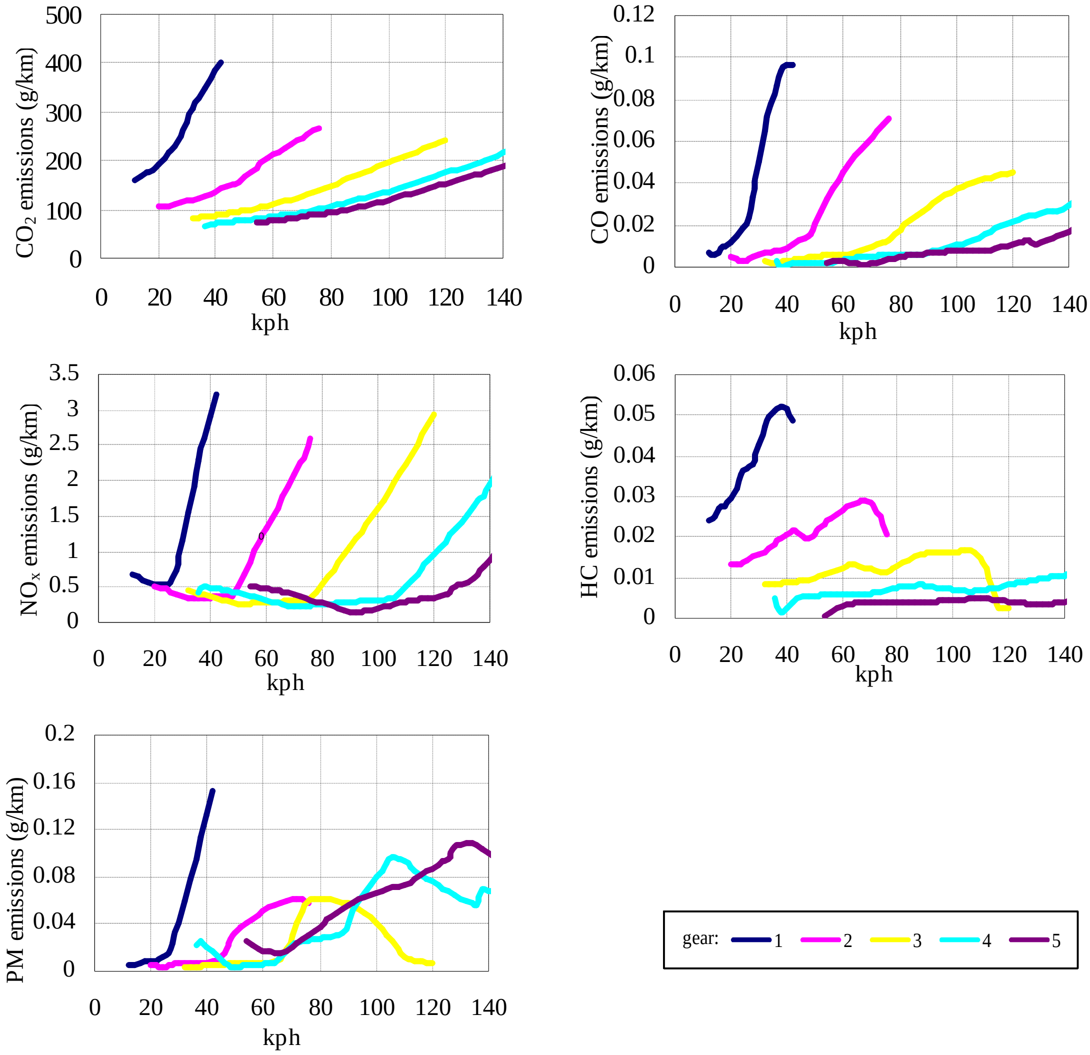

Figure 1. The emission factors as a function of vehicle speed and gear selection for the Euro III diesel car Scoda Octavia.

In figure 1 the influence of gear selection on emissions for the diesel car is clearly demonstrated for CO_2, CO and HC. When changing up gear early, the emission of these pollutants will be reduced. When driving for example 20 kph in first gear with this diesel car you will emit significantly more CO_2 than when shifting up to second gear. These findings also apply for other gear changes. For NO_x this conclusion is not straightforward since the NO_x curve seems to display a small bend in the course. The graph for PM, on the other hand, shows larger variations in the course compared to the other pollutants. Reasons for these variations are not yet clear, but difficulties in the measurements of particulate matter and the ensuing large uncertainty for PM predictions need to be examined more thoroughly before real conclusions can be drawn for this pollutant.

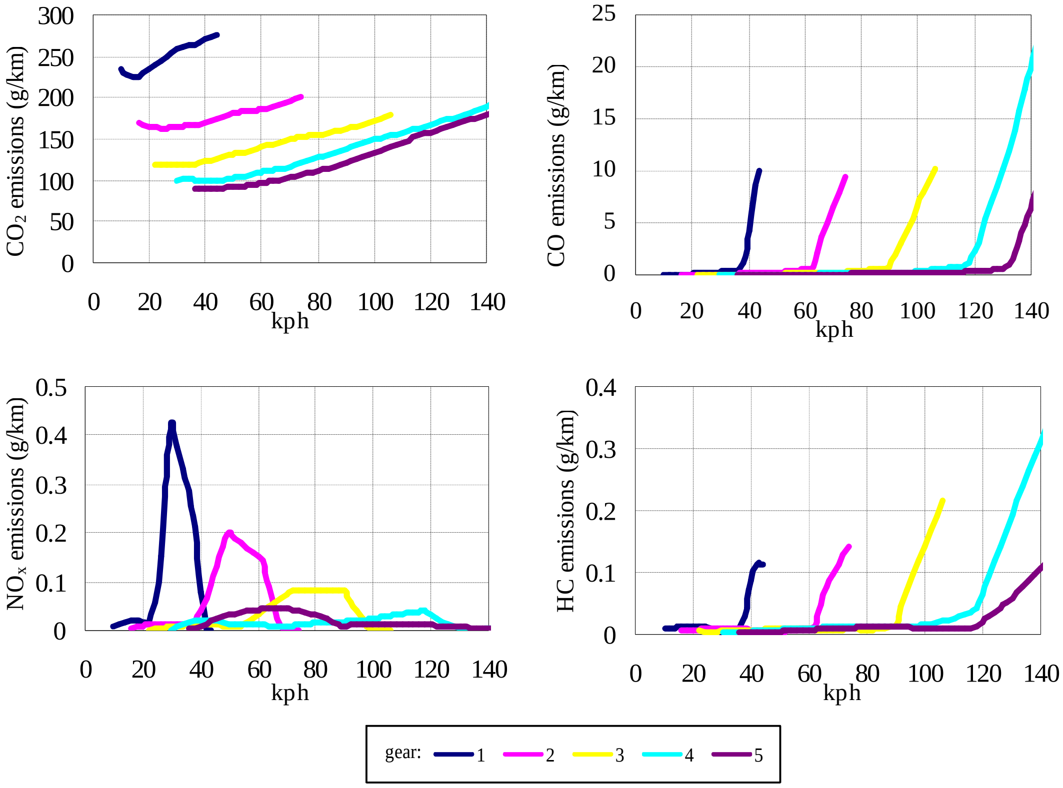

Figure 2. The emission factors as a function of vehicle speed and gear selection for the EURO IV petrol car Volkswagen Polo.

Figure 2 presents the emission results for the petrol car. Since PM emissions for petrol cars are not considered in the VeTESS model, no results are presented for this pollutant. The graph for CO_2 shows large resemblances to the CO_2 graph for the diesel car meaning that CO_2 emissions can be reduced when changing up gear early. The graph for CO resembles the one for HC, showing that driving in the ‘right’ gear will lead to very low emission estimates while remaining in a lower gear too long will cause a strong increase of emissions. The curves in the NO_x graph show a very different course with high NO_x peaks in first gear and lower peaks in higher gear selections.

4. CONCLUSIONS

Theoretical speed profiles were used to assess the impact of gear change on vehicle exhausts of two vehicle types by using the VeTESS emission tool. The results clearly show that both the Euro III diesel car and the EURO IV petrol car can reduce the emissions of CO_2 (and fuel consumption) when shifting up gear early. The same findings apply to CO and HC, but cannot be made for NO_x and PM. The large uncertainty ensuing from difficulties in the PM measurement can be the cause of these variations but needs to be studied thoroughly before drawing conclusions.

Since this study dealt with theoretical, non-realistic speed profiles the real impact of an improved gear changing behaviour on emissions could not be quantified. The use of real life driving cycles with information on gear choice will improve these assessments offering useful information to policy makers who aim at promoting an environmentally friendly driving behaviour. Future research should therefore include large scale monitoring programs to gain more insight into this matter. In 2007 a travel survey will be initiated in Flanders (Belgium) as a part of the research project "An activity based approach for surveying and modelling travel behaviour". The analysis of these data will hopefully provide more information on the problem of gear changing behaviour and emissions.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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