AMOUNT OF TOXIC EXHAUST GASES EMITTED DURING ENGINE WARM UP

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Abstract. Almost everyone of us moves every day from point A to point B by using a car. But if this distance is small, then the car is being used not reaching the operating temperature, and emission gases neutralization systems are not fully functioning. Some people have no idea how harmful the automobile exhaust gases are, so the Cabinet of Ministers issued regulations on vehicle emission limits. However, these restrictions do not apply to cold engine operation. To determine the cold engine emission difference from when it has reached the operation temperature, an experiment was carried out on a car *Volkswagen Golf 4*, equipped with a spark-ignition engine. Petrol with 5 % bioethanol blend that complies with the Latvian laws was used in the experiment. The aim of the study was to determine the amount of exhaust gases emitted during automobile engine warm up in urban driving conditions. It was found during the experiments, that the amount of toxic gas CO for the car *Volkswagen Golf 4*, driving with a cold engine, is by 41 % more than using the automobile at the operating temperature, but the amount of HC is by 200 ppm more, and if the distance is less than 3 kilometres, then it would be preferable to find an alternative way to travel, because this travelled distance is where the toxic pollution from emission gases is the highest.

Keywords: exhaust gases, cold engine, toxic emissions.

Introduction

There are three main substances in emissions from an internal combustion engine, which are harmful to both the environment and human health: hydrocarbons (HC), carbon monoxide (CO) and nitrogen oxides (NO_x). CO is a poisonous, colourless, odourless gas that can cause cardiac arrest. HC is carcinogenic, mutagenic, and may cause reproductive disorders. NO_x is toxic, causes shortness of breath, restricts lung function and thus may reduce the ozone layer. In order to reduce the amount of these toxic exhaust gases, automobiles are equipped with catalysts; however, until the catalytic converter has not reached the operating temperature, the treatment process is remarkably limited. Thereby, depending on the outside temperature, automobiles can drive several kilometres before the catalyst reaches the required performance. Different investigations show that the engines of passenger cars in the first kilometres after cold start during winter conditions emit 90 % of the total amount of CO and HC.

In order to reduce the amount of toxic emissions in the exhaust gases until the reach of the operating temperature, there is built-in forced electric heating of catalysts in a few of the newest automobiles, yet the most of automobiles are still being warmed up either by running on the site, or driving right away after starting the car. Warming up the automobile on the site, in an urban area, usually taking place in courtyards of multi-storey buildings, while on idle mode, allows exhaust gasses to concentrate in a single place. Unfortunately, the environment suffers. A cold engine runs on enriched fuel mixture, thus remarkably increasing the emissions of CH and CO that are the basic harmful components in the combustion gas. It is not hard to make sure of that. If the engine of an automobile is being warmed up in a courtyard, the bad odour is going to be felt even on the top floor apartment.

If a car starts moving immediately after engaging, the amount of toxic emissions is scattered. On account of this warming up of the engine of automobile on idle mode is prohibited in several countries. For example, in Canada, Italy, France, Germany, and Holland a variety of automotive engine idle operations are regulated by law. In Hong Kong, Japan, and Singapore it is allowed to run a car on idle mode for three seconds in an hour, but in Holland it is allowed for the engine to be on idle mode only for 60 seconds. It is prohibited to run an automobile on idle mode for more than three minutes also in Taiwan [1].

From the technical point of view warming up of the engine on idle mode is required and necessary to reduce the wear and tear of the engine parts and thereby to increase the engine life and reduce the repair costs. The cost for such a saving is too high, because suffer both the environment and human health.

In the climatic conditions of Latvia the ambient temperature reaches -25 ºC during winter, thus it is not possible to warm up a car in five minutes, as established in the Latvian legislation. Thereby the choice of the warming process of engines depends on a driver, however, during summer it is possible to start movement immediately after starting the engine as the heat for window defrosting is not needed.

In order to save some time, as well as because of the growth of human welfare, movement from point A to point B by car takes place even over short distances. That is why the experiment was carried out in order to find out when the use of the vehicle causes more harm than benefits.

Materials and methods

As the object of the research the automobile *VW Golf 4* equipped with a gasoline engine with the capacity of 1.6 litres, and the engine maximum power of 66 kW was used.

For the research a gas analyser *OPUS 40-D* was used that can measure the amount of CO, HC, CO_2 and O_2 in exhaust gases, as well as control the coefficient of air excess λ.

Operation of the analyser requires the voltage of 220 V that is provided by a mobile electric generator during the motion of the car. For precise control of the engine parameters PC with a diagnostic program was connected to a control unit of the car engine via OBD2 connection (Fig. 1).

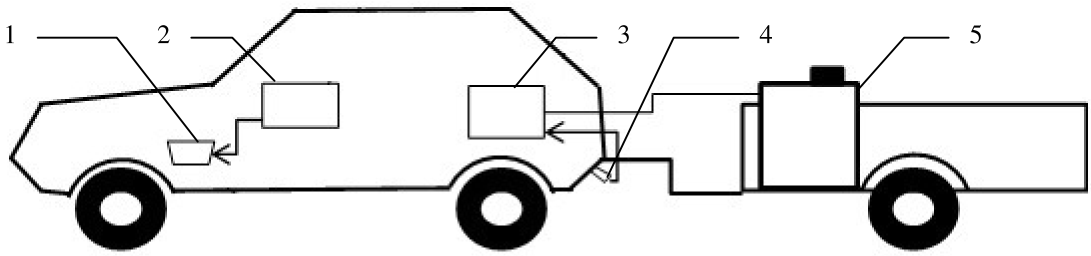

Fig. 1. **Interconnection scheme of the automobile and measuring equipment:** 1 – OBD; 2 – computer; 3 – analyser; 4 – exhaust gases; 5 – generator

In order to make the necessary measurements and install the equipment necessary for the experiment, a trailer for stationing the generator was connected to the vehicle and fuel level check in its fuel tank was carried out. After that cables were fixed between the trailer and the boot of the car in a way to leave a reserve needed for the cable during turning manoeuvres. The exhaust gas analyser device was placed in the cabin of the car and connected with a power transmission cable. The generator was set and voltage checked. The analyser was turned on and calibration was performed. The *VAG COM OBD2* cable was connected to the control unit of the car, testing of the system was carried out, the vehicle was engaged and the system restarted for the work, in order to make accurate temperature records. Measurements were made in every 5 degrees and readings of the analyser were printed out.

There are three employees involved in the experiment one of which fixes the readings of the temperature, the second operates the car, but the third works with the analyser of exhaust gases. Measurements were made after every 23 hours of idle standing. It was repeated three times during idle mode and three during the motion in urban conditions. Urban driving tests were conducted during normal working days at a variable driving speed and stopping at road crossings with and without the traffic lights.

After data collection the results were processed and average values obtained.

Results and discussion

Carrying out the warming up of the car the following emission components were determined: CO, CO_2, HC, O_2, lambda, coolant temperature and the time in which the engine of the vehicle reaches the operating temperature.

CO percentage depending on the operating temperature of the vehicle and the type of the movement is different. While the vehicle is on motion, CO increases to the maximum value of the engine temperature range 25-65 ºC. Then CO decreases and shows approximately constant values until reaching the operational temperature.

On idle mode the CO value reaches the maximum at 25 ºC, but when it has reached 30 ºC it decreases and is approximately constant throughout all temperature range (Fig. 2).

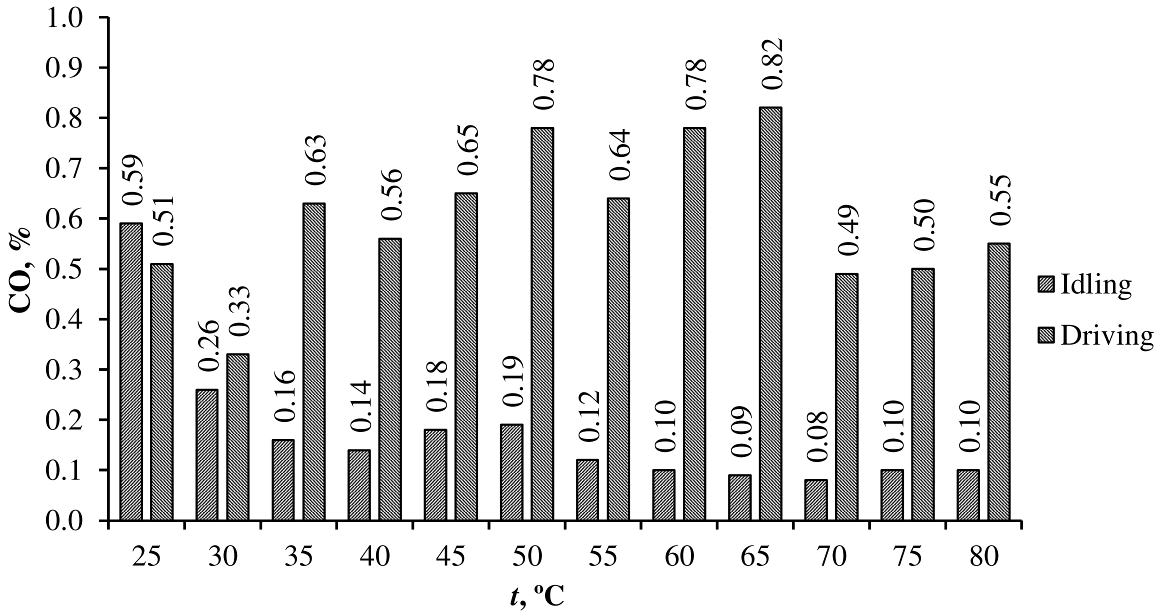

Fig. 2. **Changes of the amount of CO in exhaust gases**

While testing CO_2 it was observed that during the motion of the vehicle, CO_2 emissions for a cold engine are greater than during the idle mode, but in the temperature range of 30-80 ºC the CO_2 content in exhaust gases in both modes is similar (Fig. 3).

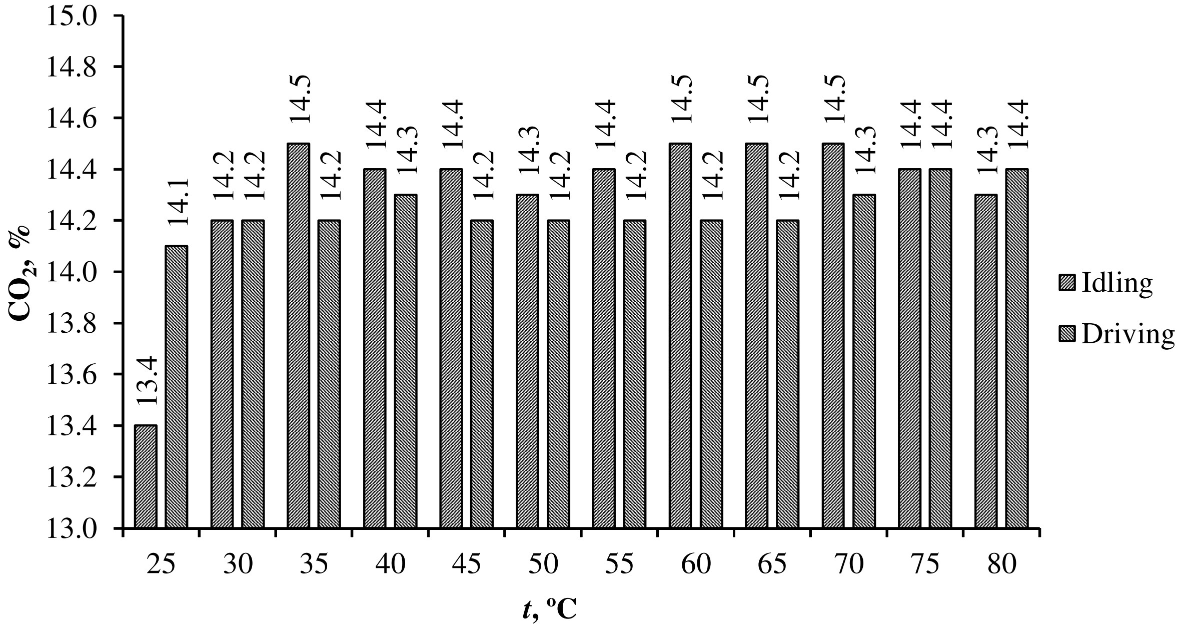

Fig. 3. **Changes of the amount of CO_2 in exhaust gases**

HC analysis is one of the most important, because exactly HC in exhaust gases causes the greatest harm to human health, as well as HC is explosive in higher concentrations.

While being in motion and on idle mode the values of HC are similar. Thus it may be said that exploitation of a cold engine in motion or idle is not determinant of a higher HC value, but the difference is whether the engine is warmed up or not. It is important to note that significant decrease of HC is observed starting from 40 ºC. (Fig. 4).

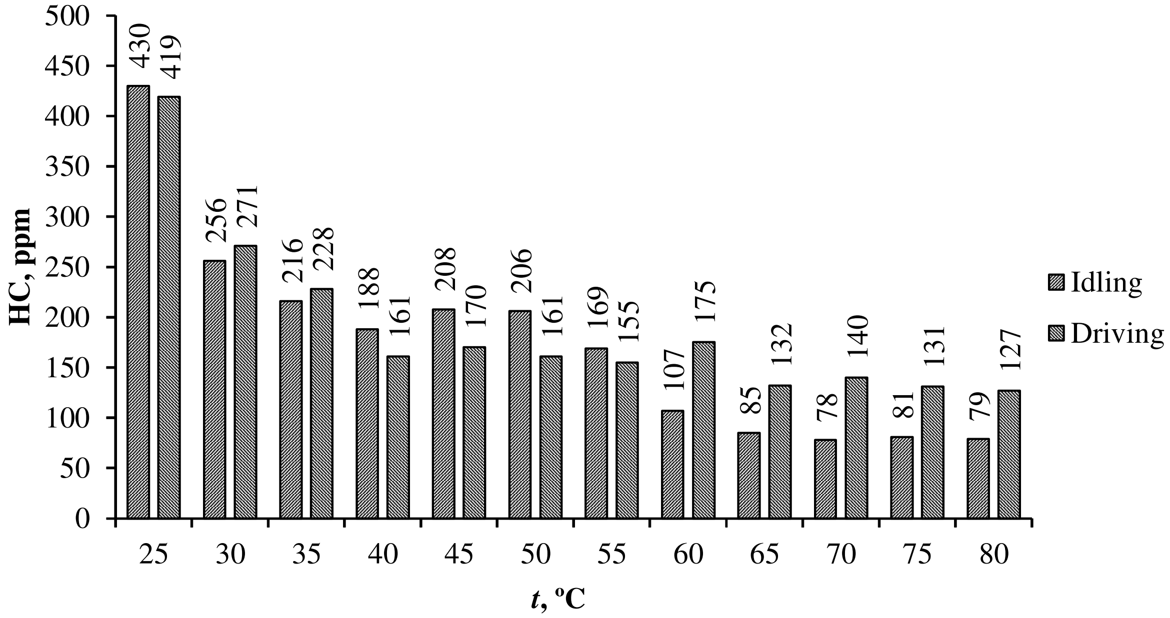

Fig. 4. **Changes of the amount of HC in exhaust gases**

While making observations of O_2 it can be found that during the idle mode O_2 concentration for a cold engine is higher in comparison with a cold engine in motion. Throughout all temperature range it is observed that while the vehicle is in motion the O_2 concentration is lower (Fig. 5).

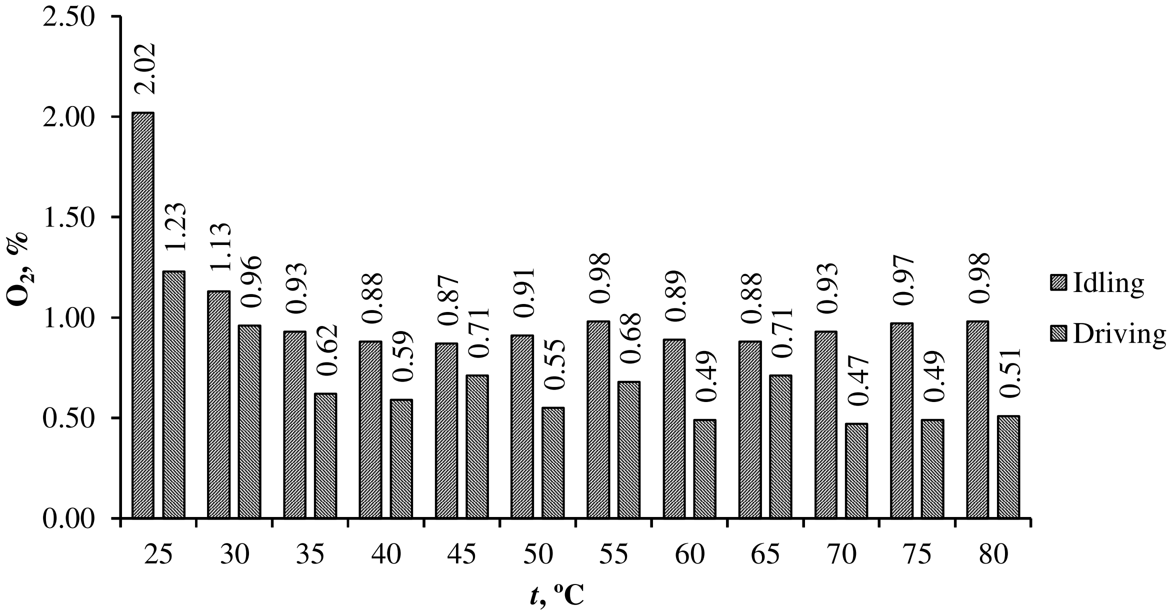

Fig. 5. **Changes of the amount of O_2 in exhaust gases**

The coefficient of air excess (Fig. 6) proves that the engine control unit of the car works without any errors and provides stoichiometric content of gas mixture throughout all temperature range.

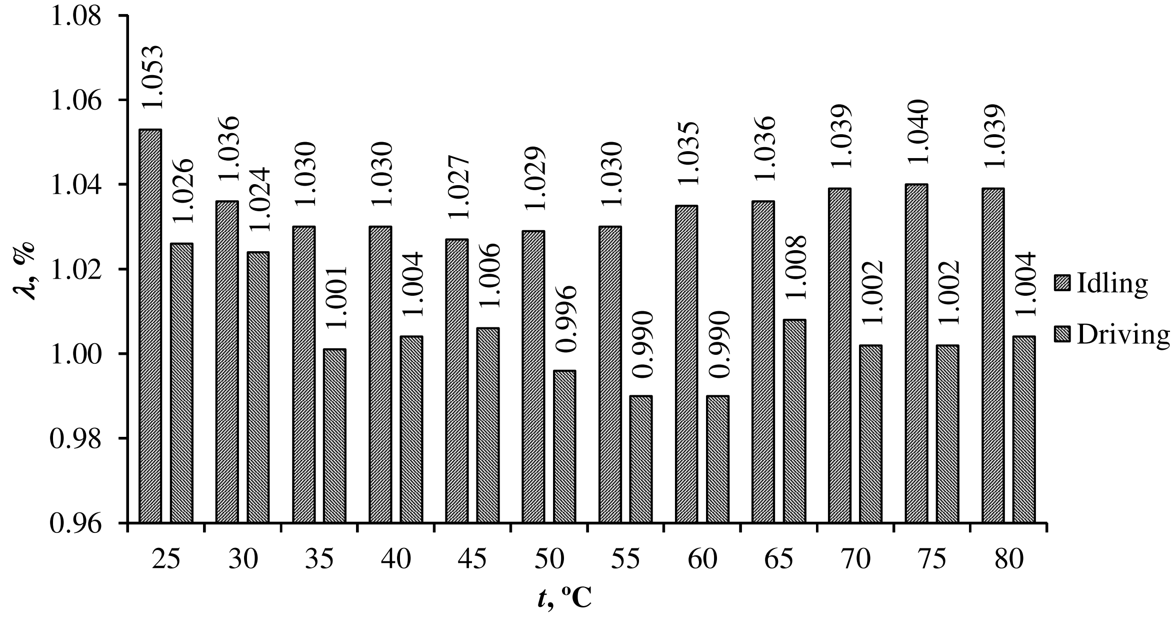

Fig 6. **λ changes in exhaust gases**

All repetitions during idle mode were carried out for 15 minutes, but in motion mode for 10 minutes at ambient temperature of 24 ºC.

Comparing the results with the data found by other researchers, they are similar. For example, Jean-Yves Favez et al. writes that testing 14 vehicles with gas engines, it was found that 5.2 km should be driven to establish CO, 6.6 km to reach the optimal amount of HC and 1.9 km for CO_2 to normalize [2]. Brett C. Singer et al. have studied the increase of exhaust gases for a cold engine at underground parking using 135 vehicles. It was found that after 200 seconds on average the emission of exhaust gases normalizes, but overall scientists recommend creating 'park&ride' parking lots to improve the air quality in a city [3]. While Yung-Chen Yao et al. have studied the cold exhaust gas emission of motorbikes and have come to the conclusion that engines of smaller volume (50 cm^3) emit more toxic emissions than gas engines with volume of 125 cm^3 [4].

Similarly in a number of investigations it is mentioned that during a cold day warming up of a gasoline car can take up to 10 km in motion mode in order to stabilize the decrease of toxic exhaust gases.

In several studies gasoline and diesel engines are compared and it is concluded that diesel automobiles emit less hydrocarbons, carbon monoxide and lead pollution than gasoline engines, but create more other harmful gases and solid particles. However, the main method of reducing the harmful impact of emission of exhaust gases on the environment is to use cleaner fuel or as an alternative for gasoline to use compressed natural gas (CNG), liquefied petroleum gas (LPG), hydrogen or alcoholic fuels or battery powered vehicles (electromobiles).

Conclusions

1. Complying with the law, both in Latvia and several other countries, it is not possible to warm up the engine of a car to the operating temperature while running it at idle. This factor slightly reduces the life of an engine, because cold oil cannot provide good lubrication quality of the engine parts.
2. Driving a with cold engine, the amount of CO in toxic exhaust gases in the engine of *Volkswagen Golf 4* is higher than 41 % than exploiting the vehicle at normal operating temperature. The highest amount of CO is in the temperature range 25-65 ºC of the engine.
3. The highest amount of CO_2 was observed in driving mode at 25 ºC, but in the temperature rate from 30-80 ºC the CO_2 content in exhaust gases during the both modes is similar.
4. The quantity of unburned hydrocarbons in exhaust gases does not depend on the engine warm-up mode, but it should be noted that it is significantly higher for a cold engine and reaches 430 ppm.

5. The study found that from a technical point of view, when driving through a city, it is preferable to warm up the vehicle before initiation of motion, however, the total waste of exhaust gases when warming up the engine at first and driving after is higher, because time is used for warming up the engine and then for the driving.
6. While evaluating the results of the experiment, it was found that if a section that is going to be carried out is shorter than 3 kilometres, it is preferable to search for alternative transport, because this section is too short for a vehicle to reach the operational temperature and toxic pollution from exhaust gases is at most.

References

1. Arnold P. Putting a Stop to Car Idling: Emissions Worsen Global Warming Conditions. Bright Hub Inc., 2012. [online] [cited 23.02.2016]. Available at: http://www.brighthub.com/environment/science-environmental/articles/64074.aspx
2. Favez J. Y., Weilenmann M., Stilli J. Cold start extra emissions as a function of engine stop time: evolution over the last 10 years. Atmospheric Environment, Volume 43, Issue 5, 2009, pp. 996-1007.
3. Singer B. C., Kirchstetter T. W., Harley R. A., Kendall G. R., Hesson J. M. A fuel-based approach to estimating motor vehicle cold-start emissions. Journal of the Air & Waste Management Association, Volume 49, Issue 2, 1999, pp. 125-135.
4. Yao Y. C., Tsai J. H., Ye H. F., Chiang H. L. Comparison of exhaust emissions resulting from cold-and hot-start motorcycle driving modes. Journal of the Air & Waste Management Association, Volume 59, Issue 11, 2009, pp. 1339-1346.