

DEPENDENCE OF THE TOXIC COMPONENTS EXHAUST EMISSION FROM THE CAR ENGINE STARTING TEMPERATURE

Zbigniew Kneba

Gdansk University of Technology
Department of Mechanical Engineering
Narutowicza Street 11/12, 80-233 Gdansk, Poland
tel.: +58 347-20-77, fax: (+58) 347-11-74
e-mail: zkneba@pg.gda.pl

Abstract

Toxic ingredients at cold start rise dramatically comparing to hot start. Car operation in urban area is characterized by short rides and different time stops. Engine cooling effect of change in both the combustion conditions, the preparation of combustible mixture and the change in engine control algorithm is presented. The aim of this study was to increase the experimental finding toxins in exhaust emissions when cold and warm start the engine. Measurements were conducted after natural cooled vehicle engine when parked car. Graphs of toxic emissions especially CO and HC at different temperatures start-up are presented. Work is aimed at designing algorithms for control of a preheating before and during the start-up. The significant impact of oxygen sensor delay time was proved experimentally. The biggest impact on reducing the toxic emissions in the exhaust when starting the engine is not warmed-up delay switching to the oxygen concentration sensor in the exhaust. This delay is caused by warm-up the sensor to a temperature of about 250 °C. To determine whether this delay is very short which would undermine the sense of indicating the effect of the heating fluid to the emission of toxins on the voltage sensor measured oxygen concentration after cold start. However, not only sensor is responsible for very high cold start toxic emissions. Equally important is the thermal state of the engine. The big increase in toxic gases emissions is especially in low range temperatures of engine parts and fluids.

Keywords: CO and HC emission, engine cold start

1. Cycles of warming up and cooling down of the passenger car engine

The way of car operation in urban agglomerations is characterized by short driving cycles and additionally by short stopovers with turning off engine in case of courier cars and delivery vans. Passenger car engine heating during driving lasts approx. 300-500 s. It corresponds to 2.1-3.4 km of travelled distance (in urban cycle). If you turn off the engine after travelling this distance the whole route runs in engine transient thermal state resulting in many adverse phenomena in comparison to warm start up, such as:

- increased mileage fuel consumption,
- increased toxic compounds emission to the atmosphere,
- greater noise emission,
- higher lubricating oil consumption,
- shorter mileage between repairs due to greater wear of parts,
- lack of thermal comfort inside the car at low ambient temperatures,
- worsen car dynamics.

Temperatures of engine parts and its liquids can not exceed permissible levels. In case of an engine with efficient cooling system the temperature, after engine heating, fluctuates only slightly. During engine heating the temperature changes from ambient or higher temperature to the temperature of thermally stabilized state. Typical stopover times during which phenomena of heat accumulation in engine oil coolers and construction materials are of an importance for car operation parameters are in a range of approx. 5 minutes to 1 hour. Shorter times do not cause any

significant change in the amount of accumulated thermal energy. Longer stopovers result in carrying away most of thermal energy accumulated during previous driving cycle. Cooling down of liquid in the stopped car engine cooling system depends on the temperature of engine parts and liquids before stopping, ambient temperature, air humidity, wind velocity and direction around the car. During one-hour stopover temperature of liquid near head decreases by 20 to 60 degrees depending on weather conditions. Also cooler's cooling runs were recorded during car stopover in various weather conditions. These are almost linear functions of 0.5-0.6 °C/min drop. Times of stopovers with engine turned off depend on car user.

Time of stopovers during passenger car travels is much diversified. In order to get to know a way of usage a car in which heat accumulation makes sense travel times and stopovers of taxicab in Gdansk were registered during 2 weeks. During 24 hours the taxicab realized on average 13 driving cycles and stopovers. Average travel time was 26 minutes and stopover time was 31 minutes.

The majority of stopovers last 20-40 min. Such a period of time results in engine partial cooling down. Thus, the use of accumulated thermal energy for preheating does not make sense. So the groups of users in which preheating makes sense is private users who tend to stop the car while they are at work in 6-8 hours.

2. Effect of thermal state on the emission of toxic components of exhaust gases and carbon dioxide

Currently, most attention focused designers to reduce carbon dioxide emissions, thereby indirectly fuel consumption. Other toxic gases emissions are very low. This results from the mastery of technology exhaust gas cleaning engines. The increase in weight of cars and their size causes higher fuel consumption. Effect of temperature on the starting of the engine mileage fuel consumption is mentioned in publications [1-3]. There is no comprehensive data as fuel consumption varies as a function of engine temperature start.

Attempt to answer this question were conducted by the author on a chassis dynamometer tests in the Daimler-Benz Werk Bremen. 10 cars were studied type of Mercedes C 200 Compressor with spark-ignition engines, 2 dm³ of displacement, mechanically supercharged. Tests related to toxic emissions at cold start-up coolant temperature – 20-24°C and a hot – 85-95°C. Averaged results are presented in graphs - Fig. 1.

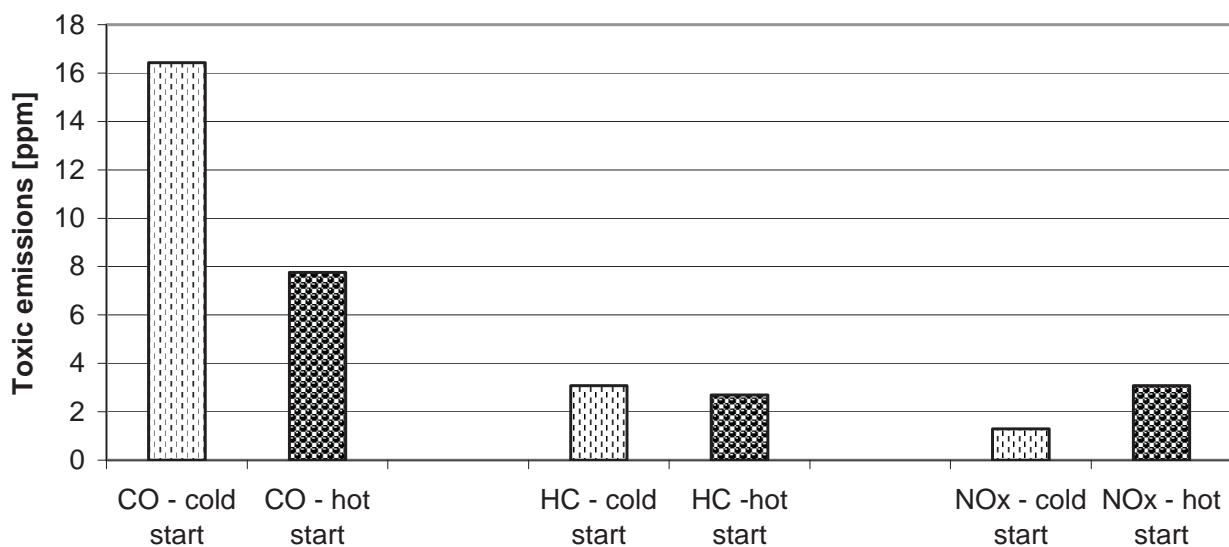


Fig. 1. Emission comparison of toxic exhaust components at start-up „cold” and „hot” car engine spark ignition - NEDC test [Courtesy of the plant of Daimler-Benz Werk Bremen - measurements author]

“Hot” engine start declining in relation to the „cold” start is more than twice the CO and HC emissions by over 12%. At the same time a 140% increase emissions of nitrogen oxides. The increase in emissions of nitrogen oxides is caused by an excess of oxygen when there is no enrichment of the mixture when cold start-up and higher temperatures in the combustion chamber at the beginning of the test. Fuel consumption, represented by CO₂ emission during test start-up to „hot”, is less than 14% of the „cold” start - Fig. 2.

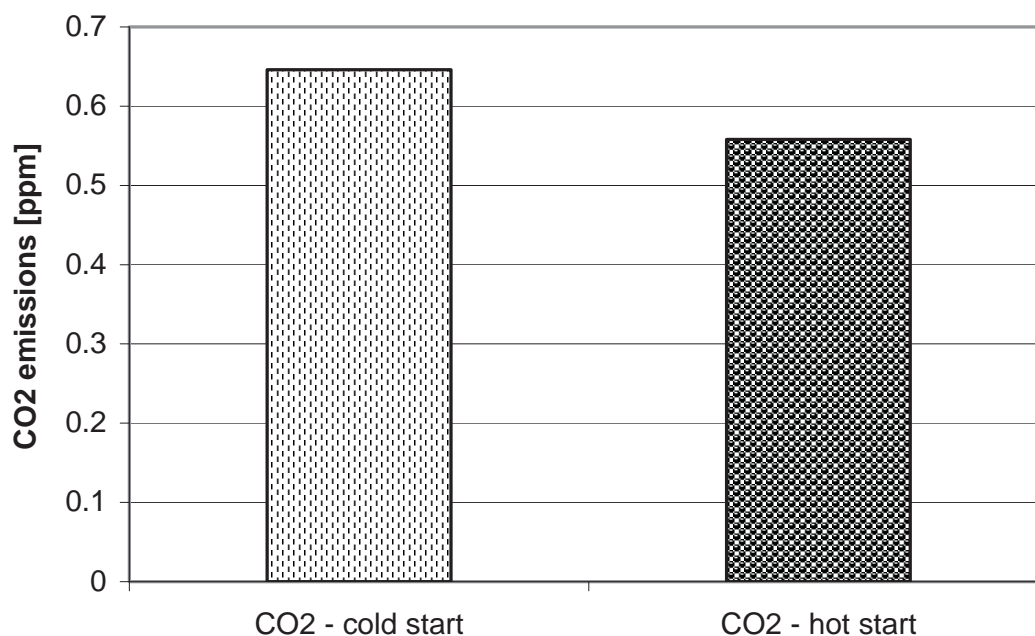


Fig. 2. Comparison of carbon dioxide emissions - indirect fuel consumption at start-up “cold” and “hot” car engine with spark ignition - NEDC test [Courtesy of the plant of Daimler-Benz Werk Bremen - measurements author]

To ask what are the levels of toxins in the exhaust emission car that runs on the stationary measurements of the composition of the gas after starting the engine cooled by stopping the car. Analysis of the exhaust gas analyzer was made the Leader type 8000th the analyzer was calibrated before measurements using calibrating gases. Current levels of toxins in the exhaust were recorded. Due to the length of the measurement system to be legible after about 10 seconds from the start. In the first second after starting the engine with a maximum observed in carbon monoxide emissions during the twelfth to the fifteenth second of hydrocarbons. Selected emission during the course of two studies of exhaust after start-up at different temperatures of the coolant is a graph in Fig. 3.

It may be noted that the emission maxims are spaced from each other and large emissions of hydrocarbons longer exist.

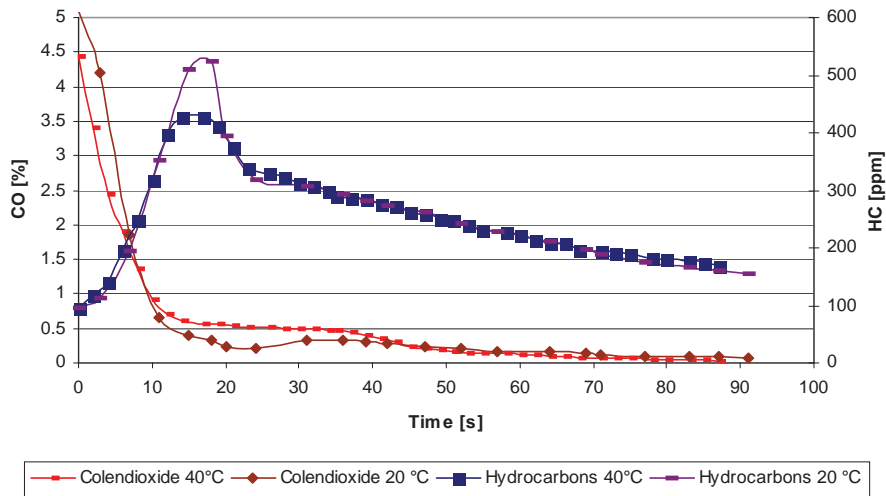
In subsequent tests recorded a maximum concentration of hydrocarbons and occurring at the same time the concentration of carbon monoxide (Fig. 4.).

The graph shows the approximated results of 25 trials starting with different coolant temperatures. Starting the engine of the liquid at temperatures from about 15 to about 60°C.

During the test concentrations of hydrocarbons and carbon monoxide decreased from 20 to 60 -that s the greatest impact on emissions of hydrocarbons and carbon monoxide is warming exhaust aftertreatment system. The Fiesta considered the full-hot after driving but the relatively cool engine aftertreatment system CO analyzer used was immeasurable and HC decreased during the first three minutes after the start resulting in consecutive minutes of 96, 81 and 52 ppm. After warming up the catalytic converter exhaust flow at high speed idle emissions of HC was 1 ppm when measured in ambient air of 5 ppm. HC measurement accuracy was + / - 0.4 ppm. With repeated trials calculated the average emissions from start-up to 40 seconds of engine idling by the formula (1).

$$HC_{\dot{s}r} = \int_0^{40} HC(t)dt, CO_{\dot{s}r} = \int_0^{40} CO(t)dt. \quad (1)$$

a)



b)

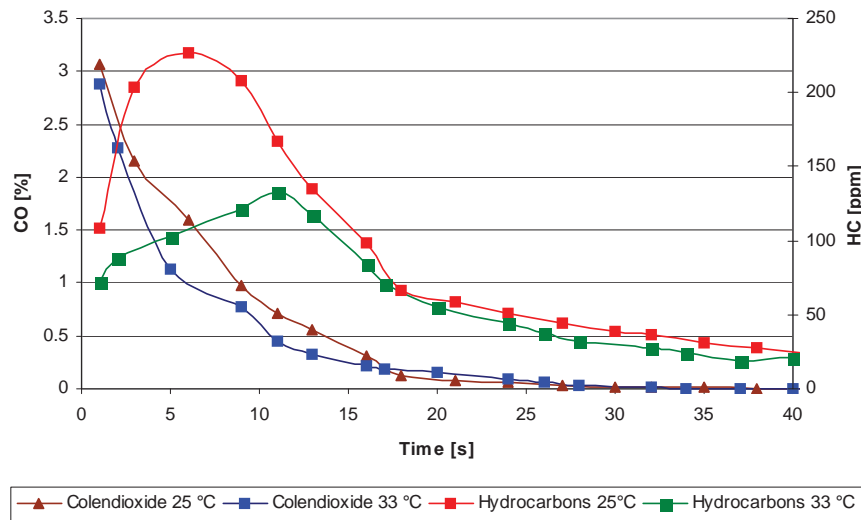


Fig. 3. Changes in emissions of toxic components in exhaust gases as a function of time after starting the engine: a) - Ford Fiesta 1.3, b) - Honda Accord 2.0

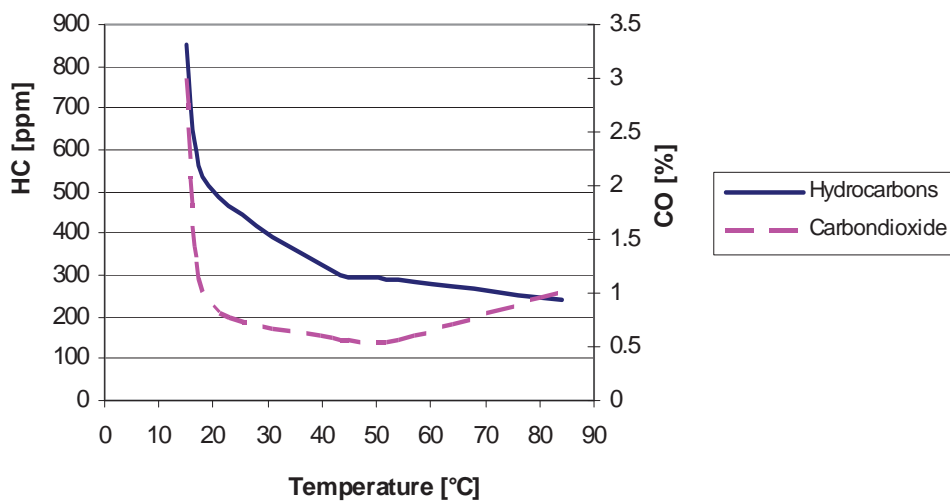


Fig. 4. Maximum hydrocarbon emissions and the emissions at the same time the carbon monoxide in 10-20 seconds after starting the engine as a function of coolant temperature Ford Fiesta 1.3

The average emission values shown in Fig. 5.

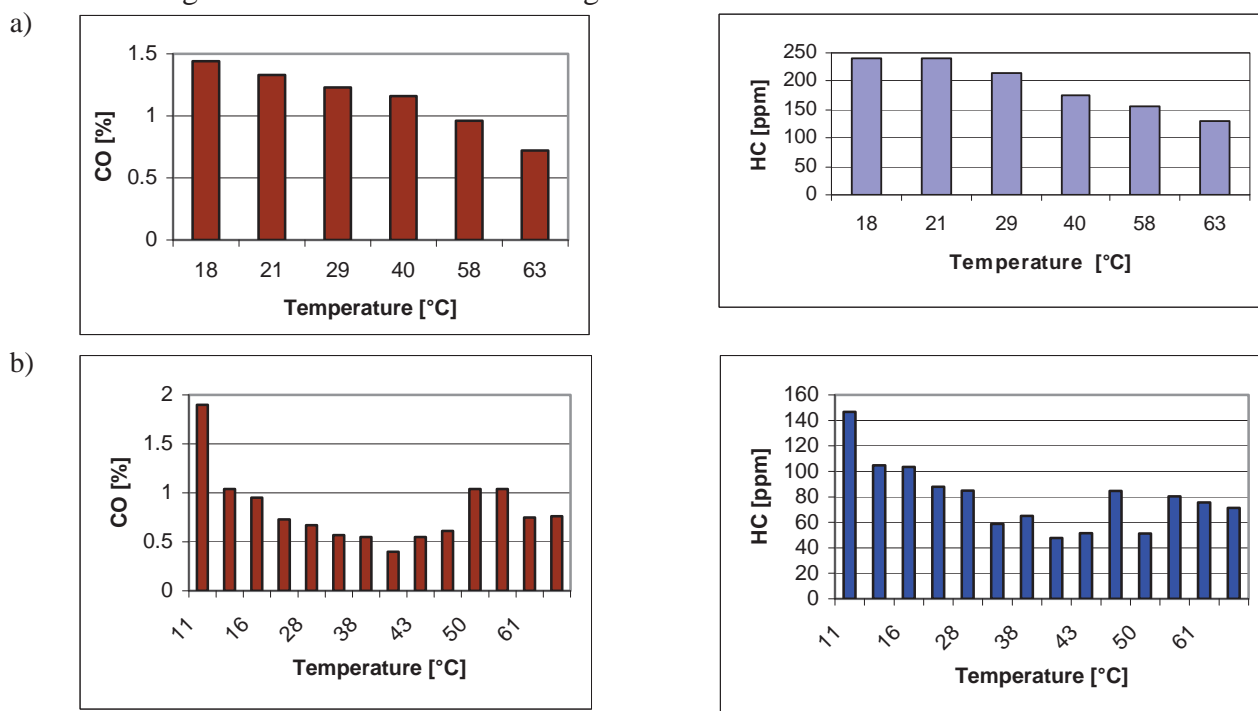


Fig. 5. Mean values of toxins in the exhaust emissions during the first 40 seconds of starting the engine at different temperatures of coolant) - The Ford Fiesta 1.3, b) - Honda Accord 2.0

The biggest impact on reducing the toxic emissions in the exhaust when starting the engine is not warmed-up delay switching to the oxygen concentration sensor in the exhaust. This delay is caused by warm-up the sensor to a temperature of about 250°C. To determine whether this delay is very short which would undermine the sense of indicating the effect of the heating fluid to the emission of toxins on the voltage sensor measured oxygen concentration after cold start. The measurement was carried out in a NEDC test on a chassis dynamometer in a Mercedes car type W203 (C 200 Compressor). The measurement result is illustrated in Fig. 6. Based on this, and repeated in other cars of this type of measurements it was found that the oxygen sensor starts working after 45-50 s of the start-up at 22-24°C NEDC test conditions. In this test, a train occurred in 10-13 s from the start. Oxygen sensor voltage change according to the composition of the gas at the beginning of the second phase of the municipal district of the test. It can be concluded that in the first test from 10 to 20 are the dominant influence on the composition of the gas has the same thermal state of the engine - its components and not the exhaust aftertreatment system. It should be noted that the exhaust gases, which could heat aftertreatment system transmit their warm to some cold engine parts and operating fluids. In terms of actual urban driving trips usually driving starts faster than in the NEDC test, and often greater acceleration resulting in quicker speed through heating aftertreatment system, especially oxygen sensor. But even in these circumstances, the closure of the control circuit composition of the mixture followed by about 5 s. Until then, emissions of toxic fumes are very large and temperature-dependent at the time of starting the engine.

3. Conclusions

- Cooling of the cooling liquid of stopped car engine occur with a speed of 0.5-0.6°C/min,
- The significant impact of oxygen sensor delay time was proved experimentally. However not only sensor is responsible for very high cold start toxic emissions. Equally important is the thermal state of the engine,

- In two measured cars dependence of toxic emissions from start-up temperature is different,
- The big increase in toxic gases emissions is especially in low range temperatures.

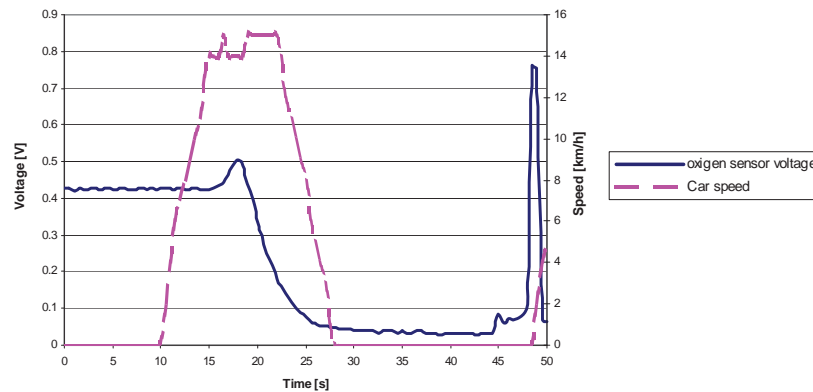


Fig. 6. Mileage oxygen sensor voltage as a function of time for the start NEDC test. Car test Mercedes W203 (C 200 Compressor). [Courtesy of the plant of Daimler-Benz Werk Bremen - measurements author]

References

- [1] Beichtbuchner, A., Jauk, T., Unterguggenberger, P., Wimmer, A., Eder, A., Richter, R., Winter, G., *Vorausberechnung des termischen Verhaltens und des Kraftstoffverbrauchs im Motorwarmlauf*, Wärmemanagement der Kraftfahrzeuge VI, Expertverlag, pp. 281-294, 2008.
- [2] Bielaczyc, P., Merkisz, J., Pielecha, J., *Stan cieplny silnika spalinowego a emisja związków szkodliwych*, Wyd. Politechniki Poznańskiej, Poznań 2001.
- [3] Bielaczyc, P., Merkisz, J., Szczotka, A., *An investigation of cold start and warm-ups phases with a SI engine for meeting new European emissions regulations*, Archiwum Motoryzacji, Nr 1/2, pp. 67-84, 1999.