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PERSPECTIVES FOR USING CLEAN AND ENERGY EFFICIENT ROAD VEHICLES

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ABSTRACT: *The development of the economy promotes the growth of the travel market, creating challenges and opportunities for the development of the transportation system. Increased income and personal demands are also conditions for people to buy and use vehicles. Habits and needs are one of the main leading causes of environmental pollution, especially air pollution. This article focuses on the pollution caused by vehicles. The process of checking the quality of a car before it is put into production is very complicated, combining many inspection steps. This article is about the PEMS method that meets Euro 6 standards, should be widely applied in the future not only for passenger cars but also for heavy vehicles and others. According to the measurements, Volkswagen Golf met the Euro 6b limits for the NEDC and PEMS test in lighter conditions. Detected values were well below the limit value. Skoda Octavia is well below the limit value for carbon monoxide in the RDE-PEMS test; however, NOx emissions were 2-3 times higher than in the NEDC test. Emissions of vehicles in the laboratory test are different from the actual environment, so the use of PEMS for vehicle testing is necessary.*

Keywords: *Perspectives, using clean energy, energy efficient, road vehicles, quality of a car*

INTRODUCTION

The transportation industry always comes with a range of problems such as air pollution, noise, congestion, accidents, etc. Currently, air pollution control is not only an urgent issue and a local top priority, but also has significant potential for controlling greenhouse gas emissions.[4] A massive percentage of urban air pollution is responsible for the transportation industry - as well as a primary greenhouse gas emission source. Increased greenhouse gases and the polluted air environment caused by transportation are increasingly severe, threatening the ecosystems and habitats of human life and creatures on Earth. According to the European Environment Agency (EEA), 36.48% NOx released to the air environment caused by road transport and 14.05% by commercial, institutional, and households. For PM2.5 related values are 10.67% and 55.49%, respectively. [1]
Based on WHO data from 2016, are attributed to ambient (outdoor) air pollution caused by about 4.2 million premature deaths. In general, higher urban air pollution levels cause an increased risk of cardiovascular and respiratory diseases, cancer and adverse birth outcomes, and also associated with a higher death rate.[2] Illnesses and deaths related to air pollution are most closely associated with exposure to small particles (Particulate Matter PM) less than 10 or 2.5 microns in diameter (PM_{10} and $PM_{2.5}$). Small particles bypass the body to defend against dust, penetrate deep into the respiratory system. They also carry on their surface a mixture of substances harmful to health, such as heavy metals, sulfurs, carbon compounds and carcinogens

including benzene derivatives.[2]
Transport is a significant and growing contribution to airborne particle pollution exposure. Road transport is estimated to account for up to 50% of PM emissions in the Organization for Economic Cooperation and Development (OECD) countries and up to 30% of PM emissions in European cities - mainly due to diesel engine transport. However, it can be very different between the total contribution of transport to particulate air pollution, from 12% to 70% of the overall pollution mix. Low- and middle-income countries suffer disproportionately due to traffic-related infections, especially in Africa, the Middle East, and Asia. In part, it is also due to the use of inefficient and old diesel engine vehicles and the lack of public and operational transport networks.[2]
Urban air pollutants are transport-related air pollutant that harms health. A mix of a critical factor in chronic respiratory (e.g., asthma), containing nitrogen oxides (NO_x), sulfur dioxide (SO_2), as ground-level ozone (O_3) precursors, carbon monoxide (CO) and volatile organic compounds (VOCs), poses a specific risk for vehicle drivers and passengers in closed spaces (e.g., garages); CO_2 and methane, which is a reliable greenhouse gas.[2]
Transport has been one of the standard policy areas within the European Union for more than 30 years. The harmonization of national laws, regulations and administrative provisions, and of the technological, social, and tax environment in which transport services provided, has steadily risen in importance. Moreover, the completion of the European single market, the abolition of internal borders, the drop in transport prices as a result of the opening-up and liberalization of transport markets, and changes in manufacturing and stock management systems have all led to an increase in goods and passenger volumes.[3]

Internal combustion engine (ICE)

For transport activities, emissions from vehicles are concentrated mainly on road traffic activities, and it depends on the type, quality, and fuel used by the vehicle. For example, diesel engines emit many times more black smoke than gasoline engines.
Diesel engines release a lot of suspended particles in the air. The air pollutants arising from road traffic activities are mainly CO, NO_x, SO_2, dust.
Not only emissions from diesel and gasoline but non-standard vehicles also create emissions that lead to air pollution. That is why the EU introduces a series of “Euro” standards, of which the “Euro 6” standard is the latest and most stringent. Diesel technology is also constantly developed with the aim of eliminating harmful gases. Clean diesel technology was created with a three-part system that is a highly efficient diesel engine, ultra-low sulfur diesel, and advanced emissions controls. Clean diesel complies with the “Euro 6” legislation on emissions. This standard requires test vehicles to meet standard conditions, including the Real-Driving Emissions (RDE) and the Portable Emissions Measurement System (PEMS). [4]

Clean and energy effective vehicles

A hybrid is a car that uses a combination of a traditional internal combustion engine and one or more electric motors to create traction. These two types of engines on hybrid vehicles combine to achieve different criteria, depending on the purpose of the manufacturer, i.e., to save fuel. [39] Range extender hybrid (REx) vehicle is an electric car that uses generators powered by gasoline installed on the vehicle. ICE does not drive the wheel; it is used to charge the car battery only. This setting allows the range extender system to continue running on electricity without having to stop to charge. [5] Plug-in hybrid vehicles (PHEV) are hybrid vehicles but have the ability to charge the battery with additional power from the outside. A PHEV has the characteristics of both a conventional hybrid electric vehicle (with an internal combustion engine and an electric motor); and of an all-electric vehicle with a plug to connect to the electrical grid. [6]
Electric cars with large battery (BEV) have a completely higher electric power range than plug-ins. Electric vehicles have many benefits over conventional vehicles. Although electric power plants can emit pollutants, the electric vehicle does not on the spot, emitted pollutants come from energy generation of plants. Black electricity origins from coal combustion grey electricity or/and from nuclear and thermal power plants. Green electricity supplied from solar, wind or hydropower plants, not to pollute the air, so we can say an electric vehicle is environmentally friendly. In addition, electric motors perform well and require less maintenance than ICE that provides performance benefits. [7]
Fuel-cell electric vehicles (FCEV) are powered by electrochemical “engines” that have the ability to

transform chemical energy directly into electrical energy through the redox process, usually hydrogen fuel and oxygen or air by an electrochemical reaction. The generation of electric power is carried out in fuel-cells by hydrogen gas. Electrical energy stored in batteries or supplied to electric motors. Small air channels are milled in bipolar plates, through which hydrogen gas is introduced on one side, and the other side is air or oxygen.

Benefits

The increase in vehicles has a lot of damage to the environment, especially the air. If we continue polluting, soon, we will destroy our own life and other creatures. That's why clean vehicles are researched and developed, which use electricity to operate. Unlike conventional vehicles, clean and effective energy vehicles bring great benefits to the environment and human life. If they are developed and widely used, the future environment will be improved, and our lives will be better. Here are some examples:

Health effects: Clean vehicles help improve the air environment and human health, reducing dust and smoke, which are harmful to humans when inhaled—thereby reducing diseases from air pollution such as pneumonia, rhinitis, CO poisoning, etc. Clean cars cause little or no noise due to running on electricity, and unlike diesel vehicles, noise pollution is also significantly improved. A clean and noise-free environment helps people live healthier lives.

Reduced exhaust emissions: Clean vehicles use the main source of electricity is electricity (batteries and electric motors). It reduces the number of toxic gases released into the environment when the vehicle is operating at all speeds and all types of weather. Therefore, the use of these environmentally friendly cars will help make the environment healthier and safer.

Slow down global warming: Ordinary vehicles emitting substances not only cause devastating effects on the environment but also contribute to global warming. Clean vehicles that need less fuel or use electricity, hence do not release toxic and global warming substances into the air on the spot.

Better gas mileage: Clean vehicles are designed using full electricity or a combination of electricity and gasoline. The other type is better than conventional vehicles because it only uses gasoline when the vehicle is running out of electricity. Therefore reduce the amount of gasoline consumed when using the car.

Less dependence on foreign oil: According to EIA, the United States imported about 9.10 MMb/d of petroleum from about 90 countries, exporting 8.57 MMb/d of petroleum to 140 countries and 4 US territories in 2019. Clean vehicles reduce the amount of gasoline consumed. This is an economic improvement for the United States and other countries. They will not have to depend on expensive foreign oil from the Middle East. Other countries can also improve financially and politically because they can use domestic gasoline rather than importing it from abroad. [8]

Saves drivers money: Clean vehicles have replaced that source in part with electric motors, fuel costs have been cut in half. For electric vehicle users, they will no longer have to go to a gas station and buy gasoline so that they can save even more.

Driving in safe: According to the WHO, more than 1.35 million people die each year in road traffic accidents. Distracted driving is one of the causes of traffic accidents. Statistics show that many drivers still send messages while driving, resulting in an increase in annual road accidents. To minimize the number of people injured by traffic accidents, a driver assistance system was created. The driver assistance system is an electronic system that helps the driver in the processes of driving and parking. Advanced driver assistance systems are known as systems developed to automate, adjust, and enhance vehicle systems to ensure better safety and driving. Automated systems provided by Advanced Driver-Assistance Systems (ADAS) can minimize human error, which has proven to reduce road deaths. [9]

Volkswagen emissions scandal

In September 2015, Volkswagen's emissions scandal occurred while the US Environmental Protection Agency issued a notice that violated the Clean Air Act against German automotive corporation. The agency found that during the emissions test in the laboratory, Volkswagen intentionally programmed the direct-injection turbocharged diesel engine to activate emissions control to help produce NOx emissions of vehicles that meet US standards during regulatory testing. But in fact, it emits 40 times more NOx when driving in the real world. [9]

Basic law ((EU) 2019/1161)

Directive (EU) 2019/1161 of the European Parliament and of the council of 20th June 2019 is used to amend Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles.[10] The law is intended to reduce greenhouse gas emissions further, to increase the rate of renewable energy consumption, save energy, reduce vehicle CO_2 emissions, and reduce air pollution and noise caused by road vehicles. Towards hiring, buying, and using green and clean transportation. Not just personal vehicles, but also public transportation, freight. The Directive sets out mandatory minimum procurement goals in each Member State for environmental protection vehicles, trucks, and buses in 2025 and 2030.
Because air quality varies mostly due to emissions from personal vehicles, laws like these are needed to improve the problem. For vehicles after the Directive and in the future, they will need to meet a certain standard to be produced and used on the world market. After applying this Directive, the atmosphere has been partially enhanced, reducing pollution and the danger of global warming.

RDE/PEMS

Real Driving Emission (RDE) As a result of the scandal, each vehicle form (passenger cars) due for initial emission certification will be tested as per the Worldwide Harmonized Light-Duty Vehicle Test Procedure (WLTP) beginning in September 2017. New European Driving Cycle (NEDC) usage values will continue to be calculated in parallel and will continue to be used in sales documentation as the legally necessary data as well as in all other publications. Additionally, all new models due for launch are tested in an on-road test, the so-called real driving emission test (RDE), to assess if Euro 6 limit values for nitrogen oxide and particulate concentrations are exceeded when taking into account the conformity factors. [11]
RDE measures contaminants, such as NOx emitted from cars when driving on the road and describes the vehicle's emissions test under actual road conditions. Exhaust gas analysis used to be carried out only at test stations for model sequence authorizations. RDE serves to confirm laboratory test results and will ensure cars provide low pollution emissions on the road.
Portable Emission Measurement System (PEMS) is a vehicle emission measuring tool for the calculation of nitrogen oxide (NOx), carbon monoxide (CO), carbon dioxide (CO2) emissions and particle number (PN).[11] PEMS is compact and light enough to be carried inside or shifted with a motor vehicle driven during measuring; the necessary pollution test projects are economically viable. PEMS applies directly from the vehicle in calculating and evaluating exhaust emissions while on an actual road trip; fuel consumption measurement; engine performance analysis and after-treatment exhaust; component examination. Simply put, further research can be performed quicker, with less staff; increasing significantly the amount of testing completed over a given period, decreasing the "cost per test" dramatically, but at the same time improves the overall accuracy expected in a real-world setting. [12]
PEMS measurements have increased in recent years and will continue to grow, not only because they form part of the EU regulation on type-approval and in-service monitoring, but also because they are useful and accurate instruments for vehicle market surveillance on the roads and assist vehicle manufacturers in the production of new vehicles. The Member States will be able to take steps against non-compliant vehicles sold in their national markets (including ordering vehicle recalls and revoking type-approval certificates). The new motor vehicle type-approval and market surveillance law were voted in favor of 19th April 2018 and replaced the Directive 2007/46/EC in September 2020. [13]
PEMS are placed outside the car, on a tow bar or frame, or in the back of the car. When in operation, the following factors are taken into account by PEMS: the location of the car, based on data given by a GPS, local weather conditions generated by a local weather station, and vehicle data from the control unit of the

engine. While monitoring these factors, PEMS (1) is used to assess the car's emission rates, including its gas mileage, while a valid driver drives the car on real roads. The test results are compared to those of other cars of the same family (based on many factors including the form of propulsion, method of fueling, or recirculation of exhaust gases). Changes to or disassembly of the tested vehicle such as exhaust drilling, removal of intake air system, need to be examined by both fleet managers and drivers, especially on passenger-carrying vehicles, for their acceptance. [13] [14]

Figure (1) PEMS is installed at the back of the car.

MEASUREMENT

The measurement was done by KTI Institute for Transport Sciences Non-Profit Ltd., Budapest, using PEMS equipment rented from the Austrian AVL company. After measured, KTI had to send the measurement data to the Austrian company, and they performed the calculation. The evaluation softver is CONCERTO[15], which calculation formulas do not public, approved by the TÜV. The softver functions as required in the (EU) 2016/427 regulation. The tests were performed on two brands of cars Volkswagen Golf and Skoda Octavia.
Test condition and test run requirements RDE emissions shall be verified by testing vehicles operating on the road under normal driving conditions, standard conditions, and usual payload. The RDE test must be representative of the operation of the vehicles on real routes and under average load, hence the measurement conditions and run requirements, determined by Directive EU 2017/1151 should be fulfilled.

Detailed measurement results

The following Figures (2 and 3) summarize the results of the measurements. During PEMS measurement, the data is recorded and stored by the system control. The sample is to be taken at least every 1 second. Effect of repeatability, highway (I) and urban (II) routes and cold/hot ignition (start) were investigated. The AVL PEMS samples every 0.1 seconds. Abbreviations are as follows: D: diesel, I/II: 1st or 2nd routes, C: cold start, H: hot start.

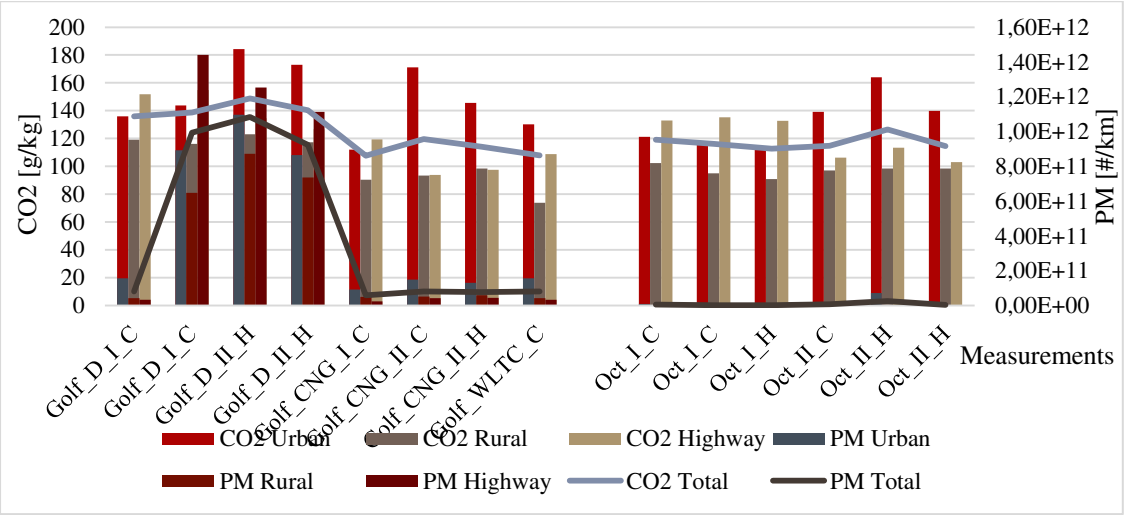

Figure (2) CO_2 and PM Emission of VW Golf and Skoda Octavia [g/kg]

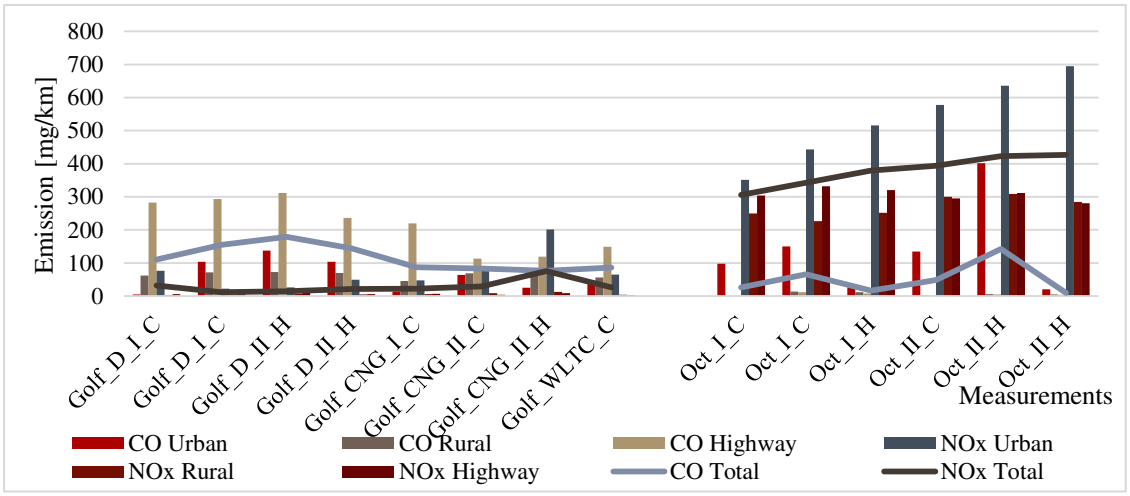

Figure (3) CO and NOx Emission of VW Golf and Skoda Octavia [g/kg]

Euro limits - type test values

The type of the approval limit and emission standard for Volkswagen Golf is Euro 6b class in petrol and CNG mode (no specific limits for gas operation), for comparability is also given below (Table 1). The values refer to the NEDC test performed on a laboratory roller dynamometer.

Table (1) Euro 6b and type certificate limits for the VW Golf (codes: engine CPWA, gear FD7) and Skoda Octavia tested

Limits	CO mg/km	THC mg/km	NMHC mg/km	NO_x mg/km	PM mg/km	PN #/km	CO_2 city g/km	CO_2 highway g/km	CO_2 mixed g/km
Euro 6b	100	100	68	60	4,5	6×10^{12}	--	--	--
VW Golf Petrol	287,9	35,0	30,4	12,6	0,54	$8{,}81\times10^{11}$	150	101	119
Golf CNG	41,5	49,8	6,0	17,2	--	--	120	77	92
Euro 5a	500			180		0,05			
Octavia WLTC	171,1	26,7	25,0	391,9	8		153,0	232,2	163,3

Comparison of measurement results with Euro limits

Volkswagen Golf In the more stringent RDE-PEMS test, the Volkswagen Golf met the Euro 6b limits for the NEDC test in lighter conditions. The measured values are well below the limit value. There is no specific limit for gas operation.

Skoda Octavia of the Euro 5a limits set for the NEDC test, Octavia is well below the limit value for carbon monoxide in the RDE-PEMS test. The absolute amount of particulate emissions cannot be assessed. NOx emissions in the RDE-PEMS test were 2-3 times higher than in the NEDC test. According to the literature, there is no such difference between the measurement procedures, i.e., Skoda would presumably not meet the level of the NOx emission requirement applicable to it.

Summary

Emissions from vehicles in the laboratory test are different from the actual environment, so the use of PEMS for vehicle testing is necessary. Vehicles are tested for their official emission values, and reference fuel consumption is regulated and relatively narrow laboratory conditions. On the road, however, atmospheric and driving conditions can differ across a wide range, often causing higher emissions than those measured in the lab. The compilation and definition of the route are clearly essential for CO_2 emissions, and the other components showed different tendencies. The repeatability of the measurements - taking into account the specifics of the RDE-PEMS measurement - is quite suitable for CO_2, generally good for the other components. For each fuel, vehicle, and part, the specific emissions in the urban phase are usually higher. That is, the air pollution effect is enhanced in the urban environment. The impact of a cold start in the urban period often results in increased emissions, but there is a difference from component to component. The CO_2 emissions of the gas mode are approximately 20% smaller than in gasoline mode. Particulate emissions are 1-2 orders of magnitude lower in gas mode, which is a very significant advantage. The carbon monoxide emissions of Euro 5, 6 cars are almost negligible. Built-in Skoda Octavia, the EA189 engine involved in the Volkswagen diesel scandal, emits exceptionally high levels of nitrogen oxides, especially in urban traffic. The effect of the recall correction was not seen on the NOx values.
It can be stated that the repeatability and accuracy of PEMS measurements are not as excellent as those of laboratory tests. New vehicles are expected to emit lower emissions. Thereby, the use of PEMS helps control vehicle quality better to reduce the number of harmful gases released into the air environment of the vehicles.

References

[1] Institute for Global Environment Strategies (IGES), Air Pollution Control in the Transportation Sector: Third Phase Research Report of the Urban Environmental Management Project. 2007. https://www.eea.europa.eu/data-and-maps/indicators/main-anthropogenic-air-pollutant-emissions/assessment-6
[2] https://www.who.int/sustainable-development/transport/health-risks/air-pollution/en/
[3] European Commission and Council of the European Union, “Commission Regulation (EU) 2016/427 of 10 March 2016 amending Regulation (EC) No 692/2008 as regards emissions from light passenger and commercial vehicles (Euro 6) (Text wit.h EEA relevance),” Off. J. Eur. Union, vol. 82, no. 31/03/2016, pp. 1–98, 2016.
[4] AECC, “Clean Diesel,” AECC. [Online]. Available: https://www.aecc.eu/key-topics
[5] T. Markel and A. Simpson, “Cost-benefit analysis of plug-in hybrid electric vehicle technology,” World Electr. Veh. J., vol. 1, no. 1, pp. 294–301, 2007, doi: 10.3390/wevj1010294
[6] https://www.mitsubishicars.com/outlander-phev/2020#meet-the-phev.
[7] https://www.damerowford.com/difference-between-hybrid-and-electric-cars.html
[8] https://www.eia.gov/tools/faqs/faq.php?id=727&t=6
[9] https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries.
[10 European Commission, “DIRECTIVE (EU) 2019/1161 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 20 June 2019, amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles,” Off. J. Eur. Union, vol. L 111, no. July, pp. 13–53, 2019.
[11] https://www.mercedes-benz.com.vn/en/passengercars/mercedes-benz-cars/wltp/wltp/overview/higher-measured-values.module.html.
[12] https://www.autoevolution.com/news/how-portable-emissions-measurement-systems-work-127086.html.
[13] C. Baldino, U. Tietge, R. Muncrief, Y. Bernard, and P. Mock, “Road Tested: Comparative Overview of Real-

World Versus Type-Approval NOx and CO2 Emissions From Diesel Cars in Europe," ICCT White Pap., no. X, p. 38, 2017.
[14] J. Merkisz, J. Pielecha, P. Bielaczyc, and J. Woodburn, "Analysis of Emission Factors in RDE Tests As Well as in NEDC and WLTC Chassis Dynamometer Tests." SAE International , 2016, doi: 10.4271/2016-01-0980.
[15] A. V. L. P. Description, D. Post-processing, H. Quality, D. Management, and D. P. Processing, "Avl Product Description Data Post-Processing Avl Concerto," pp. 1–8, 2012