OPERATION OF DIESEL ENGINES FOR COMMERCIAL VEHICLES USING ALTERNATIVE FUELS

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ABSRACT

Today the biggest challenging issues in vehicle industry are decreasing emission and application of different kinds of alternative fuels. In most of the European countries beside passenger vehicles commercial vehicles are also significant diesel engine players in road traffic. Those solutions are examined in the paper, which can provide alternatives in diesel operation like mixed, dual or single operation. In the following the gas as alternative fuel has been examined and gas fuelled vehicles will be categorized. In the paper the wide-spread energy sources are highlighted, that is why these are presented in more detailed in different states of matter.

1 GAS CATEGORIZATION AND GAS FUELLED VEHICLE CLASSIFICATION

1.1 LIQUEFIED GAS (PB, LPG)

Big advantage of liquid opposite to the compressed gas is that it claims smaller room, because gas molecules are much closer, which makes efficient transportation possible. The most wide-spread auto gas is LPG (Liquefied Petroleum Gas), because it can be liquefied at low pressure and environmental temperature. Nominal pressure in vehicle reservoir is 12 bar.

1.2 COMPRESSED NATURAL GAS (CNG)

Not only liquefied gas can be used for vehicle fuel, but compressed aeriform as well. National mark of compressed natural gas is CNG (Compressed Natural Gas). At fuel stations natural gas is compressed by compressors up to around 250 bar. Then compressed natural gas can be filled in a special pressure-tight reservoir in the vehicle, in which the usual nominal pressure is 200 bar.

1.3 OTHER GASES

Biogas or bio-CNG, which is methane made from biomass and practically it should be treated like compressed natural gas and its application in vehicles is also the same. Nevertheless it is a fully alternative energy source, which after production can be fed

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to national gas network and applicable as vehicle fuel for producing electricity and thermal energy.

Hydrogen (H_2) can be applied for vehicle fuelling. By reverse hydrolysis in fuel cells (compounding hydrogen and oxygen) electricity can be produced, which can drive a vehicle motor. In this case only water as by-product is produced, so it is a fully environmental friendly technology.

Engine features of the above mentioned fuels are presented in Table 1.

	Caloric value [MJ/kg]	Density (15°C; 1atm) [kg/m^3]	Lower and upper explosion limit [%(V/V)]	Inflammation temperature [°C]	Octane number (Cetane number)
LPG	46,3	533	1,8…9,5	490	89…115
Diesel	42,9	837	6…13,5	210	(48)
Petrol/Gasoline	44,2	741	1…6,5	225	95…100
Natural gas	45,9	0,768	4,4…15	595	120
Hydrogen	120	0,0838	4…77	560	130

Tab. 1.

Engine features of fuels

2 EXAMINATION ON DIESEL OPERATION IN CASE OF DIFFERENT FUELS

2.1 PURE DIESEL OPERATION

Diesel engines are compression-ignition and mostly four stroke engines. They operate by significant air excess. The air fuel ratio (λ) is the mass ratio of air to fuel present in a combustion process. If exactly enough air is provided to completely burn all of the fuel, the ratio is known as the stoichiometric mixture. In case of no-load run this ratio can be ten times higher, while usually at full load $\lambda = 1,2 \ldots 1,4$. Diesel ICEs (internal combustion engine) are wide-spread in commercial vehicles because in wide RPM (rotations per minute) interval big torque and low specific fuel consumption are provided. Emission especially nitrogen-dioxide and soot emission is a very important issue. In Figure 1 a fuel based distribution of commercial vehicles put into circulation in Hungary is presented.

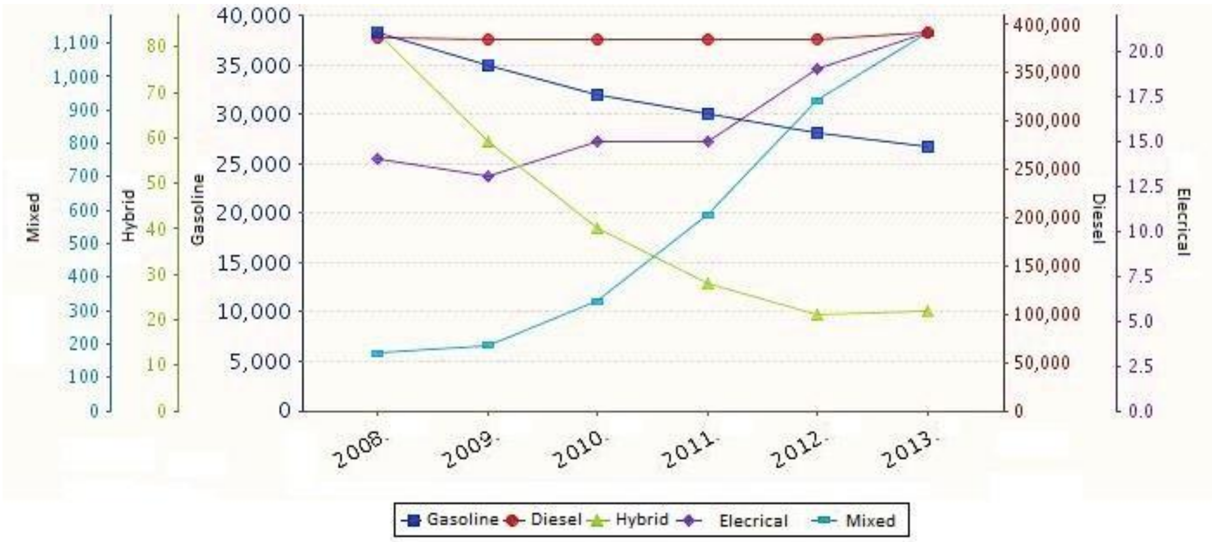

Fig. 1.

Fuel based distribution of commercial vehicles put into circulation in Hungary[1]

2.2. GAS-POWERED RUN

2.1.1 CNG-powered run

First regarding natural gas features it can be applied as "forced ignition" petrol engine fuel. Adjustment means a device, by which Diesel cycle can be approximated to Otto cycle and ensure natural gas ignition. Late modification on diesel to CNG engine claims significant change in construction. In order to decrease the compression ratio the piston or cylinder head must be modified and ignition and ignition distribution system should be constructed. CNG supply system has also to be designed, which suit technical and operational requirements. This process is usually not reasonable because of demanding many working hours and high costs.

The medium and heavy gas engines are constructed on the basis of manufactured diesel engines series. More and more engine manufacturers extend their product range to original CNG engines. Recently there has been a CNG-boom on roads. While at turn of the millennium there were one million registered CNG vehicles on Earth, in 2011 this number increased to 14 million. This means 27% expansion annually, which significantly oversoars the whole vehicle stock increase.

Since 2007 in 27 member states of Europe CNG vehicle number has been intensively growing, during four years registration has been growing by more than one and a half times.

In case of late modification of diesel engines additional external ignition energy is needed, because CNG has higher inflammation temperature. However, in case of

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[1] Online statistics of Hungarian Central Statistical Office

combined run the diesel fuel supply system is applied for flame generation. That is why these systems can also operate in CNG/diesel and pure diesel run as well.

Advantages of CNG

Lower operational costs

- Environmental friendly
- Product variety of more manufacturers
- Renewable energy source combined with biogas
- Longer engine lifetime
- Supported by EU applications.

Disadvantages of CNG:

- More expensive vehicle purchase (fewer pieces than Otto or Diesel vehicles)
- Modified engine construction
- Time consuming fuel supply
- Maintenance in special workshop
- Regular reservoir inspection by authority
- Limited fuel stations, expensive own fuel station

2.1.2 Direct injection LPG-diesel run

Combined fuel vehicles cannot be operated only by LPG like in dual operation. Dual operation means that after engine start the driver can change between diesel or gas fuel by a switch. In this case exclusively only one of these fuels is applied. In case of combination the four-stroke engine is started only by diesel then by a switch in the passenger compartment combined run can be activated. This construction does not affect the diesel injection system, since gas can be fed by a separately controlled supply system.

Because of safety reasons the control unit does not pump gas into the supply tube at no-load run, because too high air excess can cause engine overheat. In case of full load there is also no gas in intake air, because of low air excess diesel oxidation would not be appropriate. During engine braking there are no diesel and gas in the chamber. If there is no more gas or malfunction the operation is switched back to diesel run automatically. The significance of the system is that diesel combustion is better by the intake LPG-air mixture. In the cylinder the amount of intake air is decreased than in pure diesel operation, because it is now substituted by gas. In a given service by lower air excess the amount of nitrogen-oxide can be decreased. Moreover, the oxidation of vaporized diesel oil particles is carried out appropriately in the cylinder, because by the flame front of diesel combustion gas is inflamed, which has higher caloric value than diesel has. Beyond emission reduction combined operation has favour effect on power and torque as well.

If combustion temperature decreases in cylinder and there is lean oxygen, then nitrogen-oxide is also decreased. Growing coal hydrogen (CH) concentration is caused by non-combusted fuel drops, which the consequence of the inhomogeneous mixture.

At every load level exhaust gas temperature is decreased by 10%, if the intake air from chamber is mixed by gas. Temperature decrease also means nitrogen-dioxide decrease as well (Figure 2).

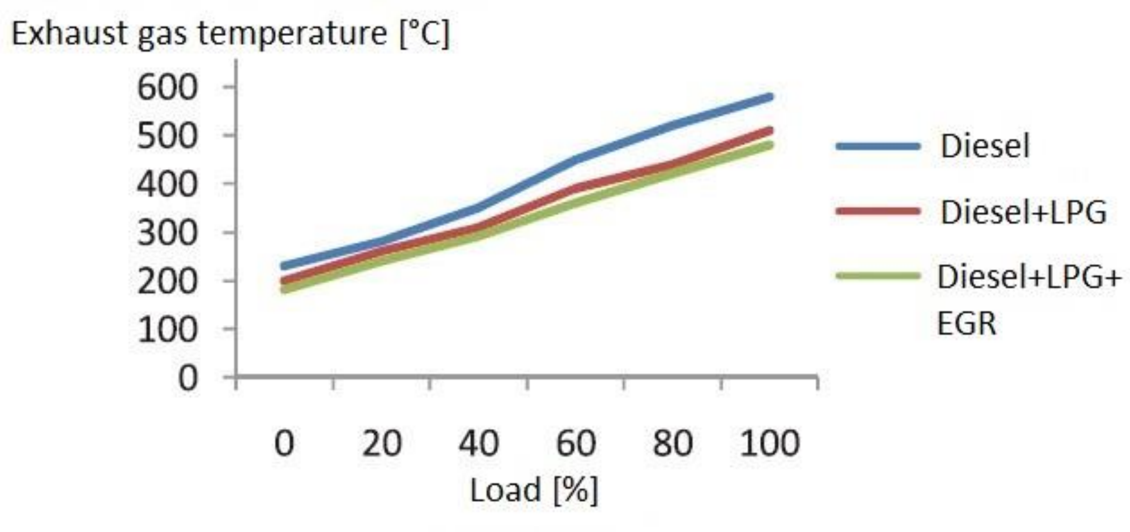

Fig. 2.

Exhaust gas temperature change in combined operation[2]

By increasing engine load nitrogen-oxide (NOx) emission is not increased, but decreased. In Figure 3 load dependent NOx emission can be seen based on unitary work. By combined operation the amount of toxic gas can be reduced and at low engine load NOx emission can be decreased about more than 50%. All this phenomena can be derived from long last combustion process and lean oxygen, since intake PB gas-air mixture contains more gas at higher load.

[2] http://www.sciencedirect.com/science/article/pii/S1877705812022394

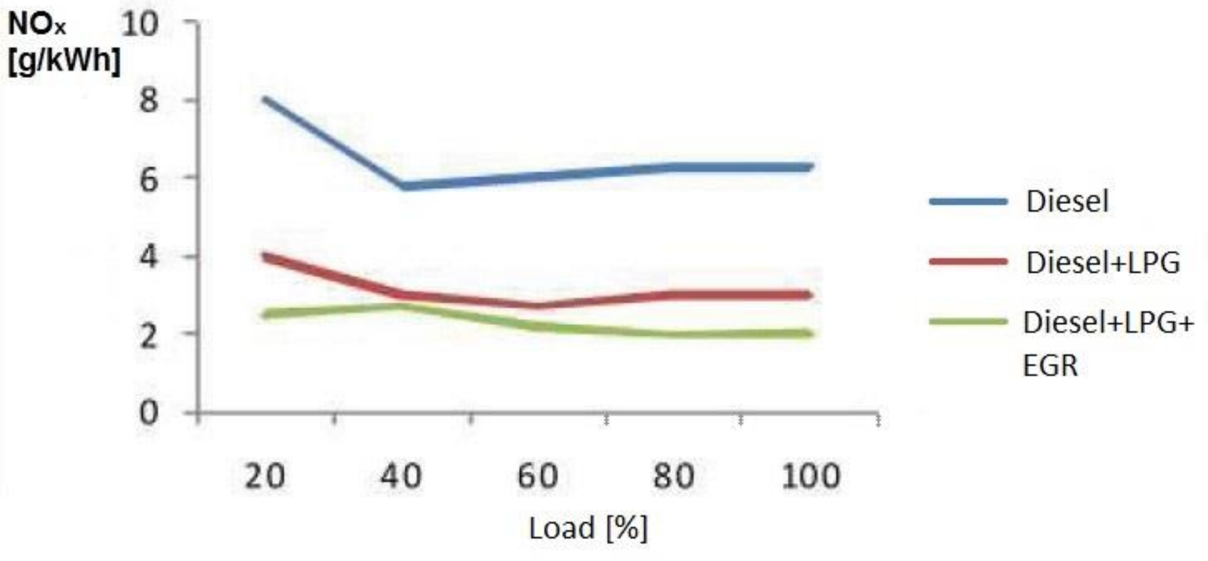

Fig. 3.

NOx emission in combined operation[3]

Smoke emission in combined operation at low vehicle load can be decreased by half and in case of pure diesel operation by two third. By the application of exhaust gas recirculation (EGR) at high vehicle load this value is more favorable, which is presented in Figure 4. Data are defined by Bosch scale, which means that a certain amount of exhaust gas is drawn through a given permeability filter paper and the rest particles are evaluated by its reflecting feature.

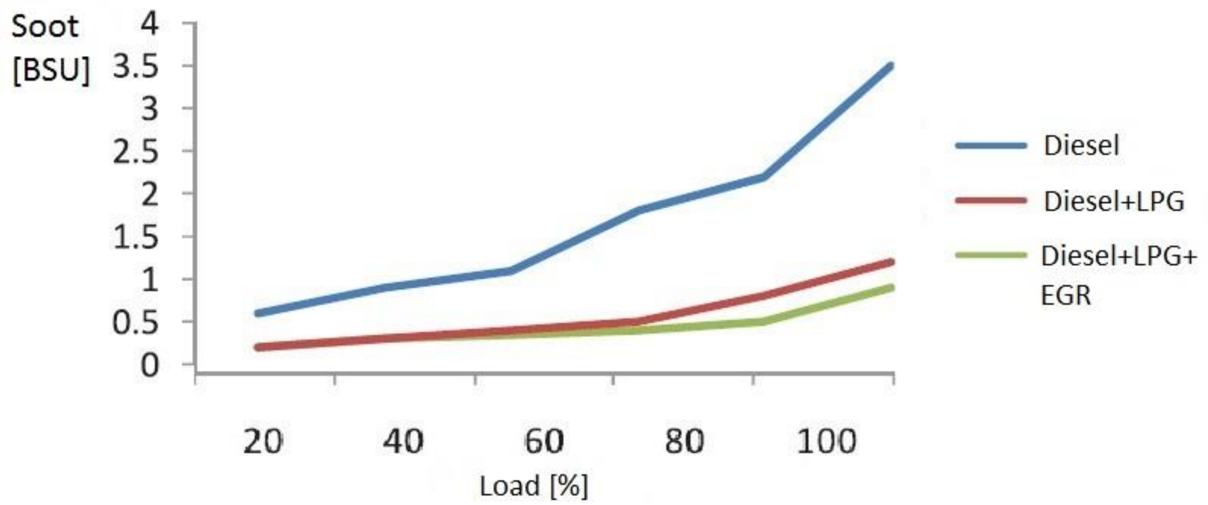

Fig. 4.

Particle emission in combined operation[4]

Main goal of emission components of diesel engine is to decrease NOx and soot particles. This can be realized well in diesel-LPG operation.

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[3] http://www.sciencedirect.com/science/article/pii/S1877705812022394
[4] http://www.sciencedirect.com/science/article/pii/S1877705812022394

Nevertheless, in case of low vehicle load coal hydrogen emission increases and this is caused by non-combusted fuel particles (Figure 5). At medium and high load this is decreased by combined operation, but in pure diesel run two times bigger amount can be measured.

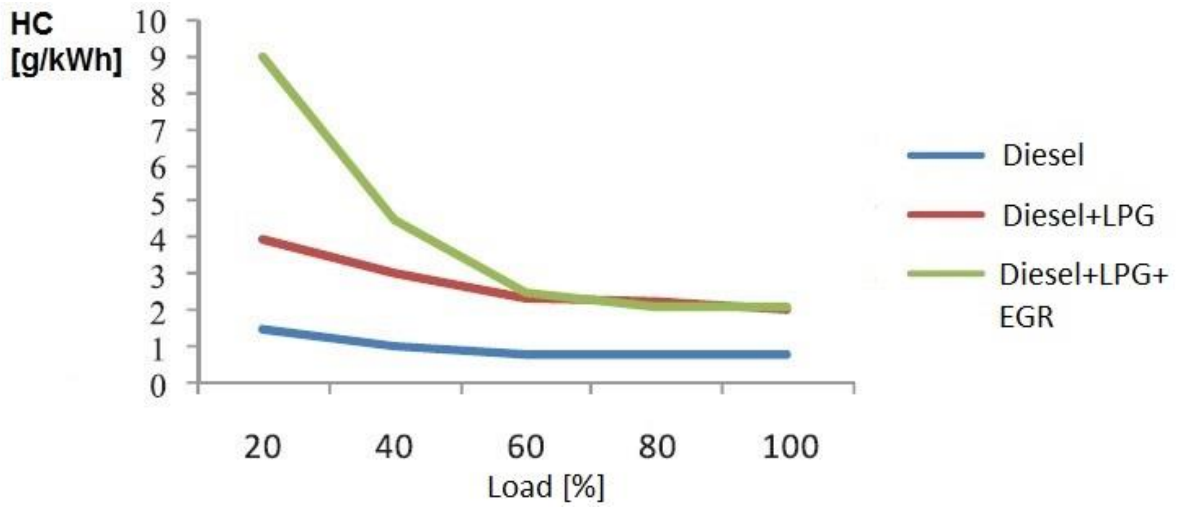

Fig. 5.

Coal hydrogen emission in combined operation[5]

In case of combined operation not only the amount of CH, but also of coal monoxide is higher in the outflow combustion product mainly at low engine load on lower load levels (Figure 5).

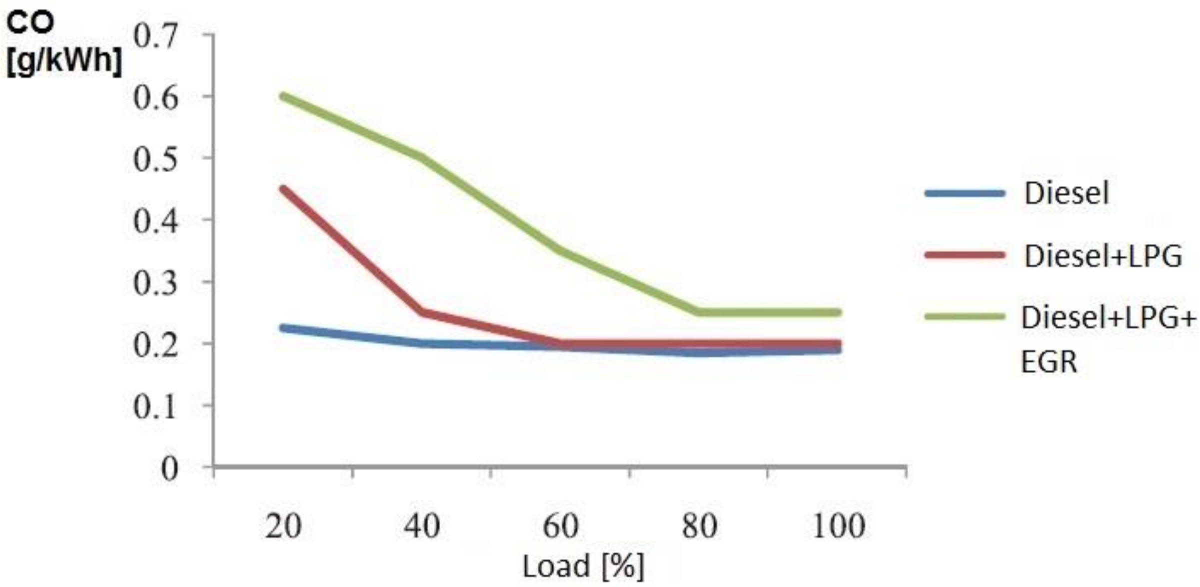

Fig. 6.

Coal monoxide emission in combined operation[6]

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[5] http://www.sciencedirect.com/science/article/pii/S1877705812022394

[6] http://www.sciencedirect.com/science/article/pii/S1877705812022394

3 EMISSION EXAMINATION ON DIESEL-LPG COMBINED OPERATION

Tests have been carried out on simply constructed commercial vehicle of EURO 0 emission category. In this case EGR does not influence the measurements, thus raw emission can be examined.

In the following diagram the work points are presented to be measured.

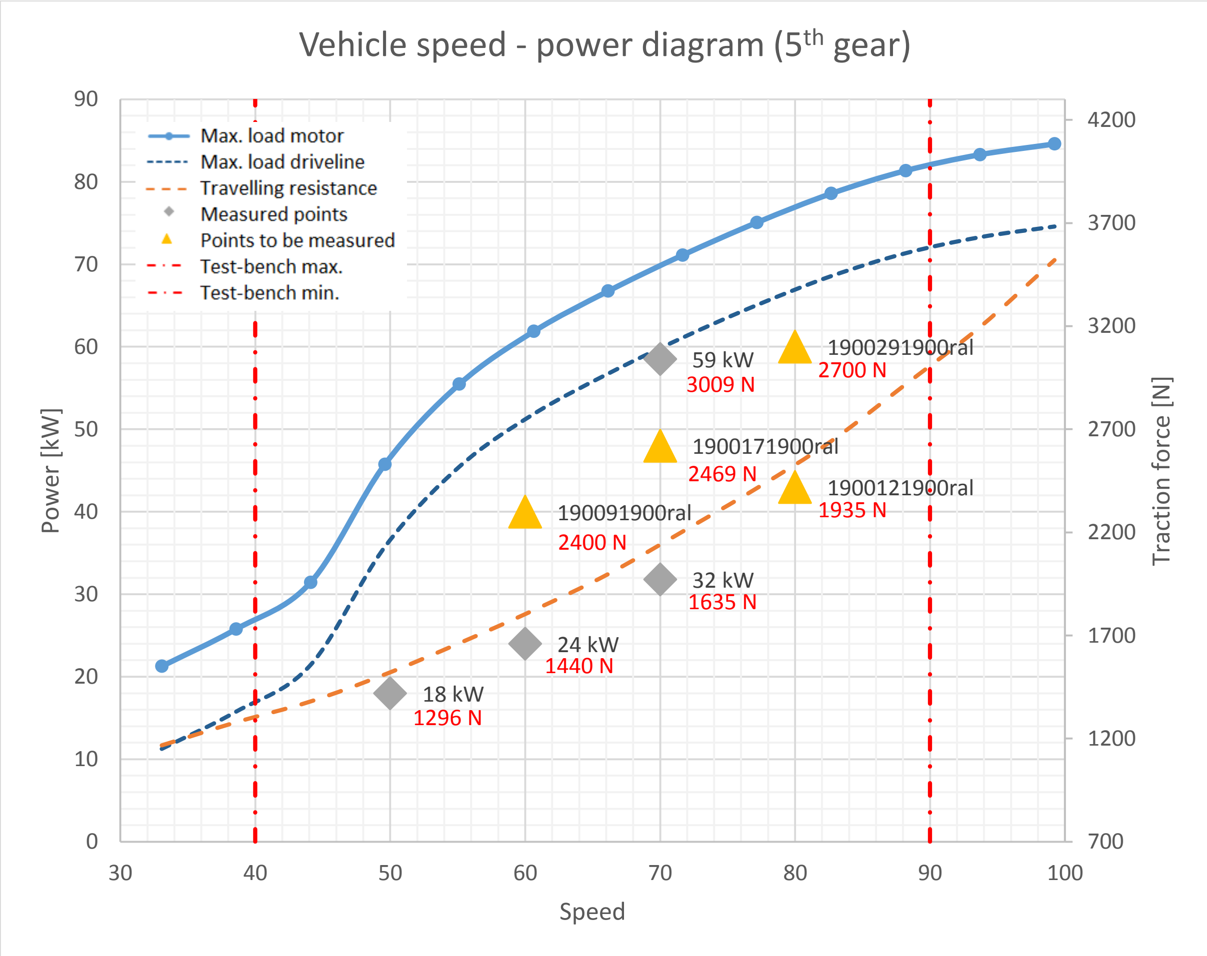

Fig 6.

Examined work points

In the following comparison of pure diesel and diesel-LPG emission has been elaborated.

In Figure 7 and Figure 8 two work points show the emission values. In case of NOx and smoke significant improvement can be realized, which is also valid for CO_2 referring to decreased consumption. CH and CO emission increase can be decreased by simple technology, e.g. oxidation catalyst.

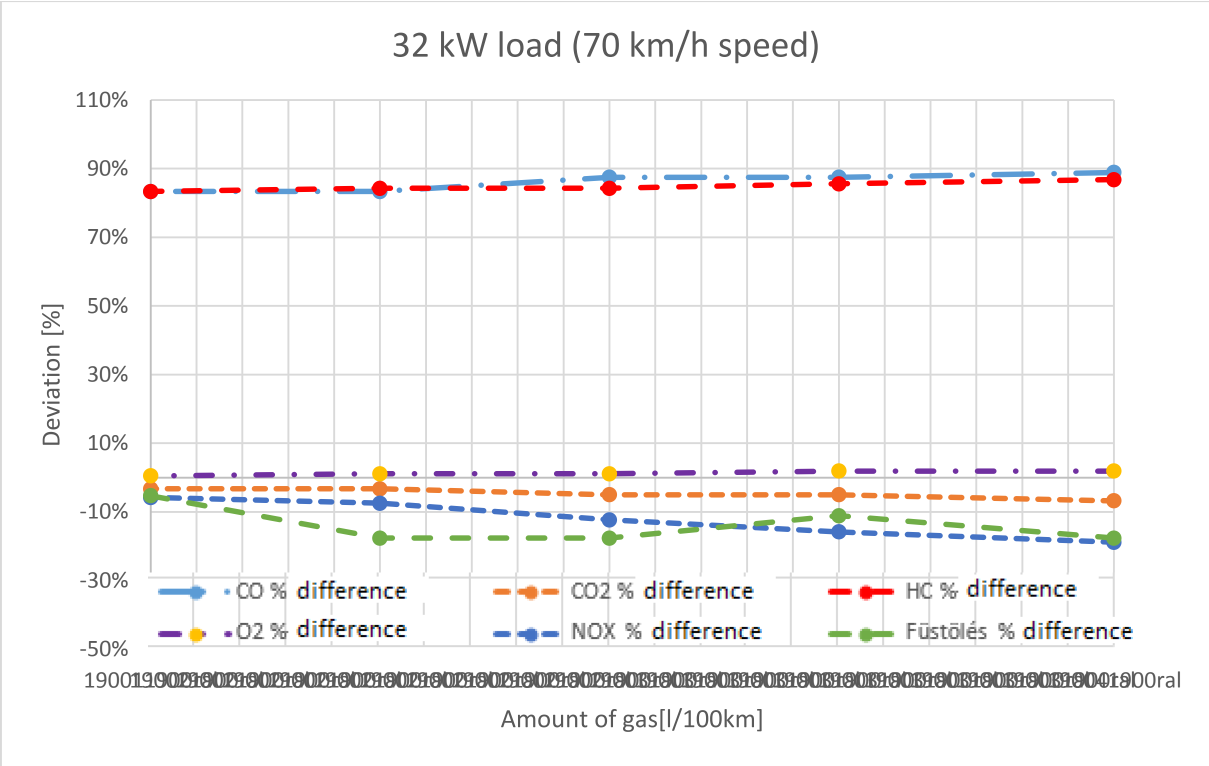

Fig. 7.

Deviation of emission values from diesel operation(70 km/h - 32 kW)

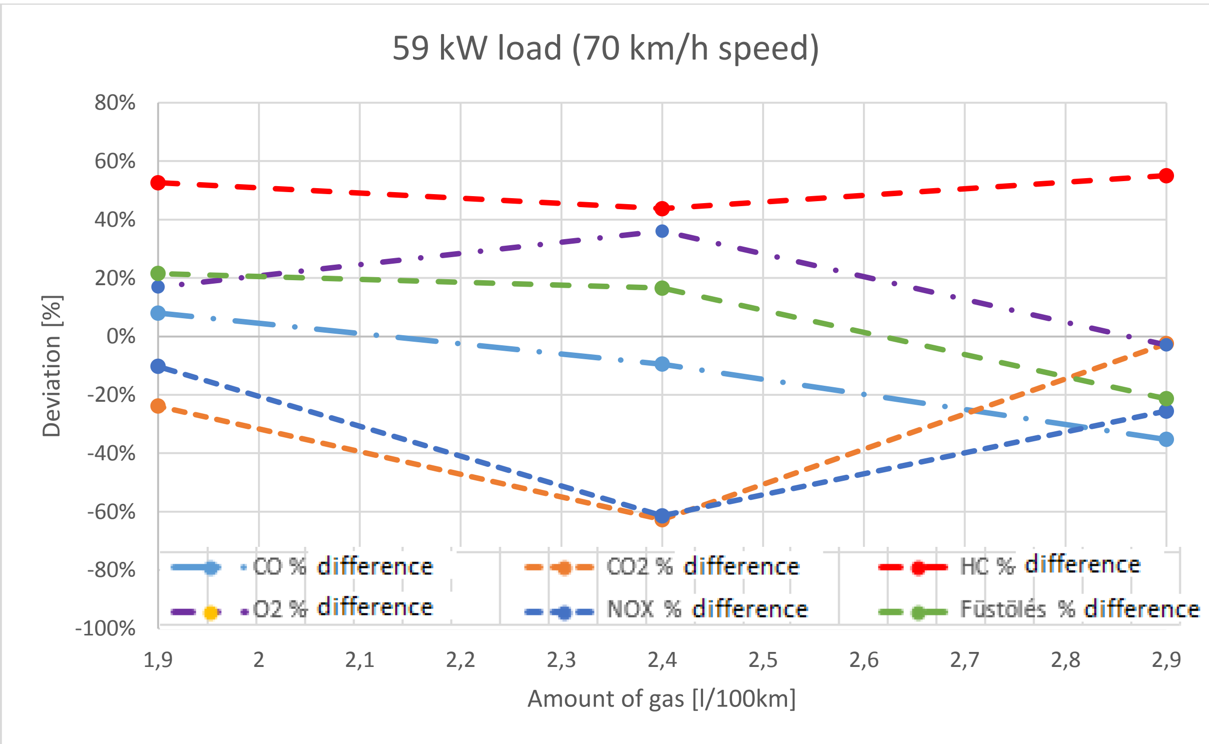

Fig. 8.

Deviation of emission values from diesel operation(70 km/h - 59 kW)

4 SUMMARY

Concerning the comparison of pure diesel and diesel-LPG run in the latter case more favourable emission can be realized, wich is also valid for CO_2 referring to decreased consumption. CH and CO emission increase can be decreased by simple technology, e.g. oxidation catalyst.

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