THE INFLUENCE OF INJECTION TIME'S DYNAMIC CHANGES ON PARTICULATE MATTERS PRODUCTION

P. Jindra, M. Kotek, T. Kotek, M. Hruška

Faculty of Engineering, Czech University of Life Sciences Prague, Czech Republic

Abstract

In last years the European Union has exhibited a significant interest in the reduction of crude oil usage. Biofuels can be used in conventional engines and they should reduce the emissions production. This article deals with analysis of particulate matters (PM) production in spark ignition combustion engine Skoda 1.2 HTP operating on E85 fuel.

The experiment searched optimum fuel injection time with respect to the capabilities of the original engine control unit (ECU) using special auxiliary control unit (ACU), which allowed the expansion of the adaptive range of the engine.

The conventional emission analysers are capable to detect gaseous emission components but they are not able to classify PM. Analysis of PM was performed with a TSI Engine Exhaust Particle Sizer 3090 (EEPS) which is able to classify particles from 5.6 nm to 560 nm.

The given size of PM can be taken as an impact on human organism's cells consequently human health. PM create an ideal medium for polyaromatic hydrocarbons (PAH), due to their composition and structure. Analysis of PM should become a standard component of every emission parameter assessment.

Key words: E85, bioethanol, emission, control unit.

INTRODUCTION

Currently has been issue of biofuels becoming more and more actual topic. All over the world we can see raising the usage of fossils fuels and growth of greenhouse gases (GHG) production. According to the assumptions 80 % of primary energy from fossil fuels is acquired and 60 % this energy is used for transport ESCOBAR ET AL. (2009). In the various parts of the world are introduced different legislative actions to reduce production of GHG.

One possible solution is using bio-ethanol as a high-percentage mixed biofuel in the E85 form. Potential problem is the lower energy density of ethanol compared to gasoline. To maintain similar performance parameters is needed to burn a higher amount of ethanol. This leads to increased fuel consumption. Advantage of ethanol is its higher octane number (ethanol 104, gasoline 95) and also quicker combustion ČEDÍK ET AL. (2014), ROBERTS (2007), PARK ET AL. (2010). Among its disadvantages are less able to start the engine at low temperatures and property through which binds water. This leads to corrosion ROVAI (2005).

For the operation of engines on a high-percentage alcohol fuel mixture is required small engine modifications. The stoichiometric ratio for a specific mixture of alcohol and gasoline must be respected. Mix ratio between air and fuel must be observed. Ethanol has mixing ration 9:1 and gasoline has 14.7:1. It is clear that compared to gasoline, it is necessary to create a richer mixture. Several different modifications are possible for solve this problem IRIMESCU (2012).

As the particulate matter (or solid particle) according to the laws of the USA is referred to any substance which is normally contained in the exhaust gas as solid particle (ash, soot) or as a liquid. They consist of elemental carbon forming particles and organic compounds (condensed water, sulphur compounds and nitrogen compounds). Solid particle itself is not toxic, but on the solid particles are adsorbed substances with high health hazards. LWEBUGA–MUKASA ET AL. (2004) found correlation between asthma and truck traffic volumes. Most of the emitted particles have a size from one to hundreds of nanometers (nano–particles) CHIEN (2009), VOJTISEK–LOM (2015).

This article deals with the issue of blended biofuels in terms of particulate matters production depending on the settings of the injection time. The measurement was aimed not only on the total production of solid particles but on their size distribution.

MATERIALS AND METHODS

The whole experiment was conducted on the test bed at the Department of Vehicles and Ground transport, CULS Prague.

The measurement was carried out with a four-stroke inline three-cylinder engine Skoda Fabia 1.2 HTP (see Tab. 1 for detailed parameters) with multipoint injection system with close-loop control mode at part engine loads to keep the engine operating near stoichiometric air–fuel ratio (AFR) and open-loop control mode at full engine loads to produce maximum power.

The tested engine was loaded using whirl dynamometer V125, the torque and engine speed were captured during measuring. Dynamometer reactions were captured with tensometric sensor with nominal load of 2 kN and with accuracy of 0.5 % of the nominal load.

Diagnostic system VAG-COM was used for communication with ECU. This system was primary used to read values from engine control unit as engine speed, engine load and to check errors.

The EEPS analyser was used for the measuring of particulate matters production. Detailed specifications of EEPS are shown in Tab. 2.

Tab. 1. – Technical parameters of tested engine

Engine code	AWY
Construction	3-cylinders, row, 6 valves
Volume	1198 cm^3
Compression ratio	10,3 : 1
Power	40 kW at 4750 rpm
Torque	106 Nm at 3000 rpm
ECU	Simos 3PD (multipoint injection)
Fuel	unleaded N95
Emission standard	EU4

Tab. 2. – Technical parameters of the TSI EEPS 3090

TSI EEPS 3090	
Particle size range	5.6 – 560 nm
Particle size resolution	16 channels per decade (32 total)
Electrometer channels	20
Time resolution	10 size distribution per second
Sample flow	10 l min^{-1}
Dilution accessories	Rotation Disk thermodilution
Charger mode of operation	Unipolar diffusion charger
Inlet cyclone 50% cutpoint	1 µm
Maximal time Resolution	10 size distributions/sec

The special dynamic driving cycle (Fig. 1) was used for engine testing under conditions close to real engine load in real traffic conditions.

The additional control unit (ACU) (Kotek et al, 2015) was used for the operative change of injection time extension. Two strategies were chosen: constant extension of 10 % and degressive extension when the basic 10 % extensions was set at the engine idle and with growing engine load the injection time was decreased to basic injection time (i.e. zero extension). Degressive calculation of injection time was realized by equation (1).

$$t_{inj} = t_{ECU} \cdot 0.87 \cdot (5 - p_{in}) \quad (1)$$

t_{inj} - calculated injection time (ms)

t_{ECU} - original injection time from ECU (ms)

p_{in} - intake air pressure (measured voltage analog value from MAF sensor - V)

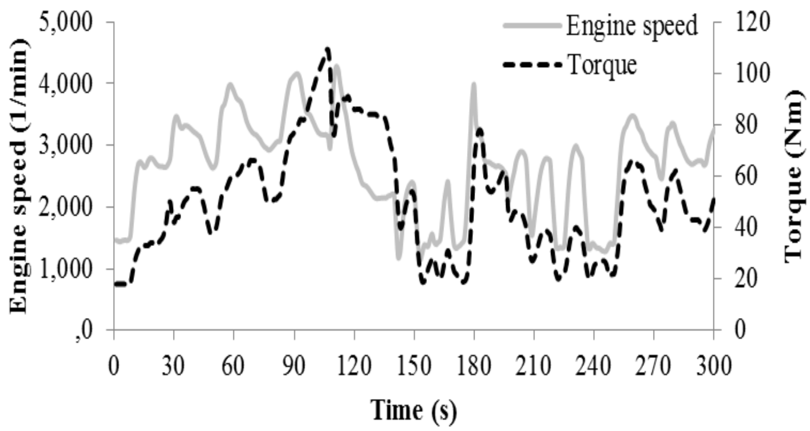

Fig. 1. – Dynamic driving cycle

RESULTS AND DISCUSSION

The production of PM in different size spectra for all researched fuels is shown in following figures. Analyzer EEPS has 32 channels for dimension of particulate matters. To simplify the graphs are showed only for particle sizes of 10, 60, 200, 400 nm.

The Fig. 2 shows the numbers of particles about 10 nm during driving cycle. In high engine load between 50 and 100 second is visible higher particles production for gasoline. Both setting for ethanol produce less volume of particles. These dimensions are considered to high dangerous.

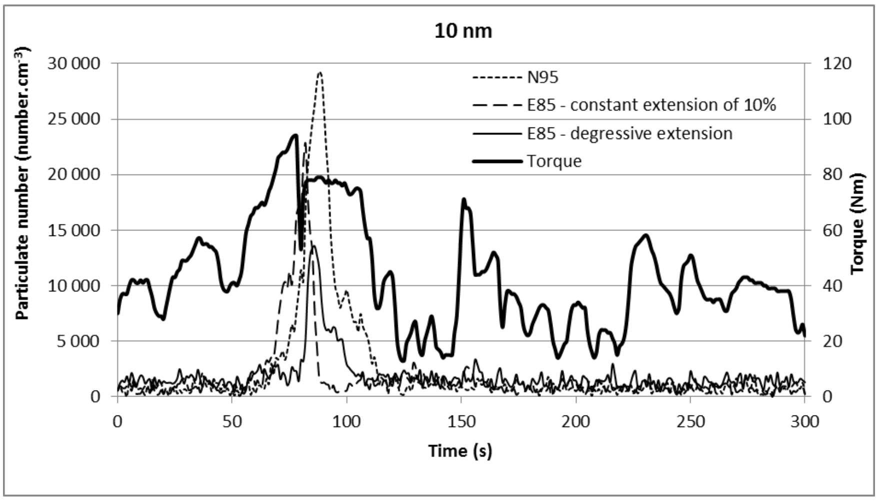

Fig. 2. – Numbers of particles of size up to 10 nm

Particles about 60 nm are shown in Fig. 3. There is visible bigger difference in settings of ACU. Higher production is in setting with constant extension. Degressive settings produce less volume of particles than constant extension.

Gasoline is situated in the middle between two settings of ethanol.

Course of the 200 nm particles production is shonw in Fig. 4. First time is visible higher production of PM when is used degressive setting. Most of time in driving cycle was produced more PM than others two measuring. Except when there was an increased demand at the engine load in time around 150 s and 255 s.

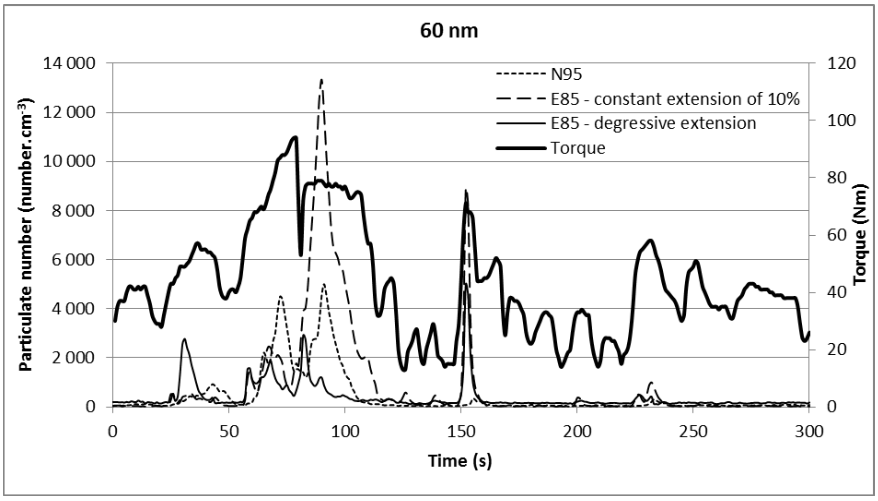

Fig. 3. – Numbers of particles of size up to 60 nm

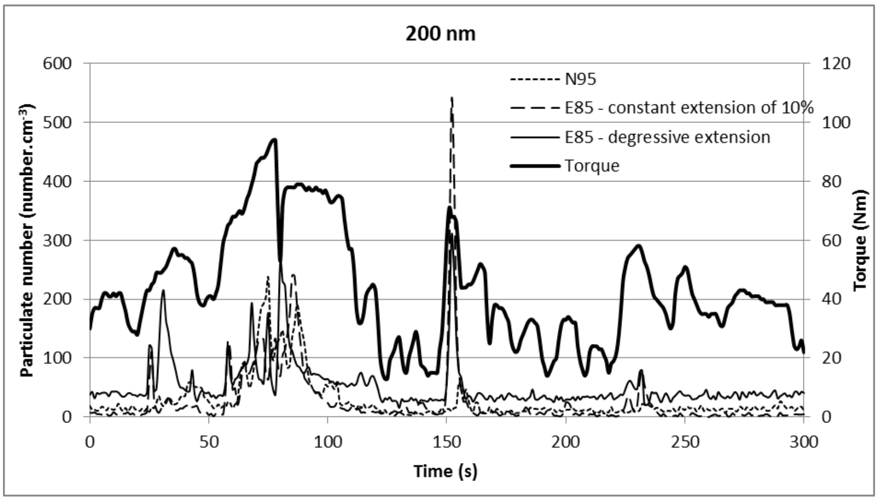

Fig. 4. – Numbers of particles of size up to 200 nm

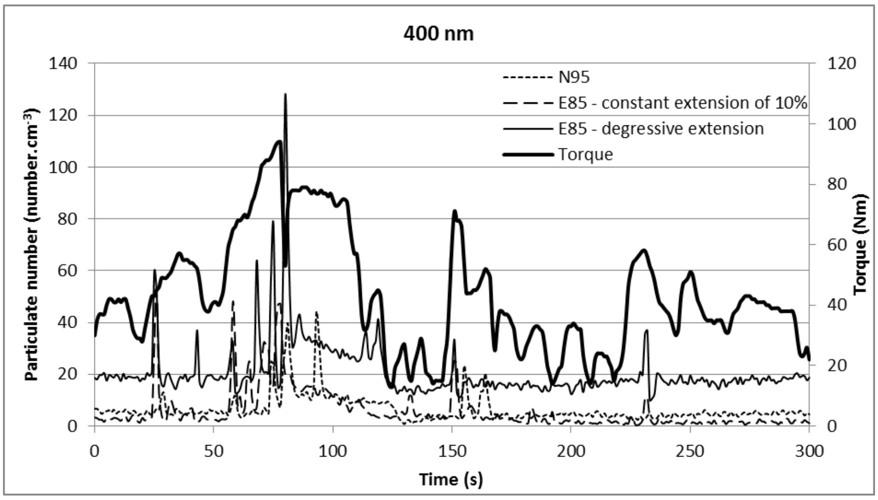

Fig. 5. – Numbers of particles of size up to 400 nm

In Fig. 5 is showed clear impact of degressive setting. In this settings is higher particles production about 400 nm. Standard settings for gasoline and setting for constant extension are very similar.

The following Fig. 6 shows the total quantity of particles produced for the entire duration of the measurement. The positive impact of degressive setting on the total production of particles is obvious.

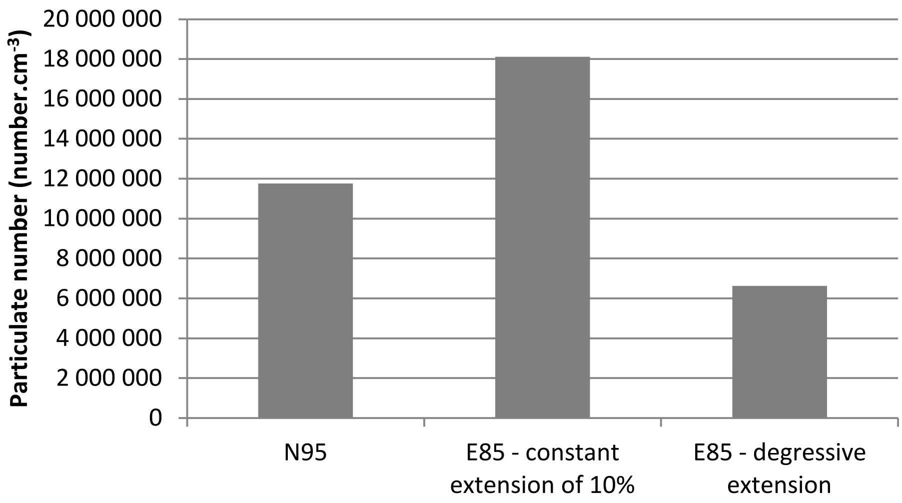

Fig. 6. – Total production of PM

Measuring confirmed that using ACU allows E85 in conventional engine. ACU expands adaptive ability of the original control unit.
Measuring spectra production particulate matters showed that the use of bioethanol causes changes in the distribution of particulate matters. For comparison are results compared with gasoline.
In settings with constant extension is distinct decrease produce very small particles and high increase production in all others situation. Very important is increase in the production of particles during high and fast engine load. Generally this situation occurs very rarely under real traffic condition.
In degressive settings is significantly higher production of particles larger than 100 nm. Compared with standart settings and settings with constant extension is increase 2 – 3 times higher. Total production of particulate matters is lowest at degressive settings.

CONCLUSIONS

Following the article Determination of the optimal injection time for adaptation SI engine on E85 fuel using self-designed auxiliary control unit KOTEK (2015) the depends of particullate matters production on settings of engine control units were determined. Generally engine operating on bioethanol reduces the production of small particles (less than 100 nm) and increases the production of large particles. In the case of high engine load is the production of large particles more pronounced.
Possible solutions to this problem is the assembly of the diesel particulate filter (DPF), which are capable very effectively removed particles larger than 100 nm. In the case of the use of bioethanol and DPF is possible reducing the particulate production in all size spectra.

ACKNOWLEDGEMENTS

This work has been realized with the contribution of Czech University of Life Sciences in Prague Internal Grant Agency, project 2016:31150/1312/3111 „Analysis of impact using biofuels on operating parameters of combustion engines.“.

REFERENCES

1. CHIEN, S. M., HUANG, Y. J., CHUANG, S. C., YANG, H. H.: Effects of biodiesel blending on particulate and polycyclic aromatic hydrocarbon emissions in nano/ultrafine/fine/coarse ranges from diesel engine. Aerosol and Air Quality Research 9, 2009: 18–31.
2. ČEDÍK, J., PEXA, M., KOTEK, M., HROMÁDKO, J.: Effect of E85 fuel on performance parameters, fuel consumption and engine efficiency – Škoda Fabia 1.2 HTP. Agronomy Research 12(2), 2014: 307–314.
3. ESCOBAR, J.C., LORA, E.S., VENTURINI, O.J., YANEZ, E.E., CASTILLO, E.F., ALMAZAN, O.: Biofuels: environment, technology and food security, Renew. Sustain. Energy Rev. 13, 2009: 1275–1287.

4. IRIMESCU, A.: Fuel conversion efficiency of a port injection engine fueled with gasoline-isobutanol blends, Energy 36, 2011: 3030-3035.
5. KOTEK, T., KOTEK, M., JINDRA, P., PEXA, M.: Determination of the optimal injection time for adaptation SI engine on E85 fuel using self-designed auxiliary control unit. Agronomy Research 13(2), 2025: 577–584.
6. LWEBUGA–MUKASA, J.S., OYANA, T., THENAPPAN, A., AYIROOKUZHI, S.J.: Association Between Traffic Volume and Health Care Use for Asthma Among Residents at a U.S.–Canadian Border Crossing Point. Journal of Asthma 41, 2004: 289–304.
7. PARK, C., CHOI, Y., KIM, CH., OH, S., LIM, G., MORIYOSHI, Y.: Performance and exhaust emission characteristics of a spark ignition engine using ethanol and ethanol-reformed gas, Fuel 89, 2010: 2118–2125.
8. ROBERTS, M. C.: E85 and fuel efficiency: An empirical analysis of 2007 EPA test data, Energy Policy 36, 2008: 1233–1235.
9. ROVAI, F., TANAKA D., SINATORA, A: Wear and corrosion evaluation of electric fuel pumps with ethanol/gasoline blends. SAE Technical Paper 2005-01-2196, 2005.
10. VOJTISEK–LOM, M., PECHOUT, M., DITTRICH, L., BERANEK, V., KOTEK, M., SCHWARZ, J., VODICKA, P., MILCOVA, A., ROSSNERVOA, A., AMBROZ, A., TOPINKA, J.: Polycyclic aromatic hydrocarbons (PAH) and their genotoxicity in exhaust emissions from a diesel engine during extended low–load operation on diesel and biodiesel fuels. Atmospheric Environment 109, 2015: 9–18.

Corresponding author:
Ing. Petr Jindra, Department of Vehicles and Ground Transport, Faculty of Engineering, Czech University of Life Sciences Prague, Kamýcká 129, Praha 6, Prague, 16521, Czech Republic, phone: +420 22438 3153, e-mail: jindra.petr@gmail.com