Emissions of Ultrafine Particles from an Euro-III Engine Running on Biodiesel

Yvonne Ruschel, Jürgen Krahl

In previous investigations higher emissions of particles in the nuclei mode were detected for rapeseed oil methyl ester (RME) compared to other fuels (Krahl et al., 2006; Munack et al., 2006). Therefore, at the example of an Euro-III heavy-duty engine a series of investigations began to obtain more detailed information to what extent RME induces the formation of ultrafine particles. As reference diesel fuel a ultra-low sulfur reference diesel fuel from Haltermann (< 1 ppm) was used (DF).

Particle size distributions – measured by SMPS – were accomplished after hot dilution to distinguish between solid soot and condensation particles.

Further investigations regarding the composition of particles in different size ranges were carried out. Therefore a Berner impactor was used to separate the particles according to their aerodynamic diameter in the size range from 15 nm up to 16 µm.

Each impactor stage was extracted separately with cyclohexane and the quota of unburned fuel and lubrication oil in the soluble organic fraction (SOF) were determined by gas chromatography (GC-FID).

The influence of the temperature on the particle size distribution was investigated in the range from 20 °C up to 300 °C. From 20 to 60 °C the size distribution was dominated by particles within the range of 10 to 20 nm. With an increase of the temperature up to 80 °C a decrease in number of nuclei particles to one tenth was observed. From 80 to 300 °C the number of particles remained almost constant. This suggests that particles of this size may consist mainly of volatile substances. By contrast no significant temperature influence on particle size distribution was noticed for DF. These results are supported by additional investigations of the particle composition. For RME higher quota of SOF and only small amounts of insoluble fraction (ISF) was found for all impactor stages with exception of the size range from 8 to 16 µm. This class mainly consists of ISF that can most probably be ascribed to carbon soot. Whereas particles in the size range from 15 to 30 nm solely consists of SOF, which is composed primarily of unburned fuel.

For DF lower quota of SOF were observed, whereas the amounts of WSF and ISF were higher in all size ranges compared to RME.

In course of investigations regarding the composition of particulate matter as well as investigations of the influence of dilution temperature it could be demonstrated that nuclei particles emitted for RME mainly results from emission of unburned fuel.

Emissions of Ultrafine Particles from a EURO-III Engine Running on Biodiesel

Yvonne Ruschel, Jürgen Krahl

Institute of Agricultural Technology and Biosystems Engineering, vTI - ✉ Bundesallee 50 - D-38116 Braunschweig
☎ +49 531 596-4219 - 🖷 +49 531 596-4299 - 💻 yvonne.ruschel@vti.bund.de - http://www.vti.bund.de

At the example of a Euro-III heavy-duty engine a series of investigations was carried out to obtain more detailed information to what extent rapeseed oil methyl ester (RME) induces the formation of ultrafine particles. As reference an ultra-low sulfur diesel fuel (< 1 ppm) was used (DF). Particle size distributions - measured by SMPS - were accomplished after hot dilution to distinguish between solid soot and condensation particles (figures 1 and 4).
Further investigations regarding the composition of particles in different size ranges were carried out by using a Berner impactor (figures 2 and 3).

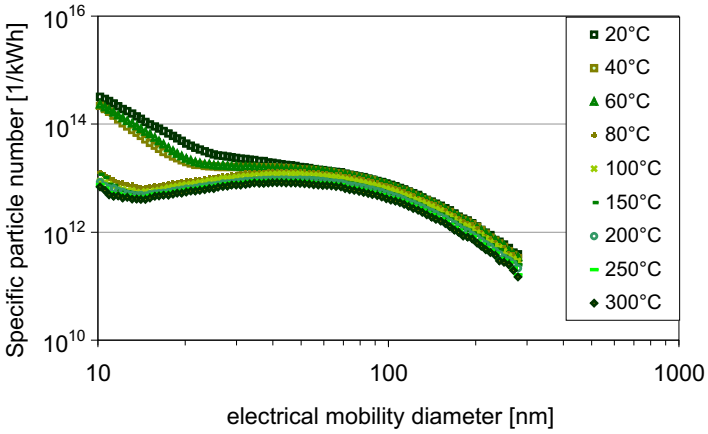

Figure 1: Particle size distribution of RME in mode 9 of the ESC test (1800 min^{-1}, 265 Nm).

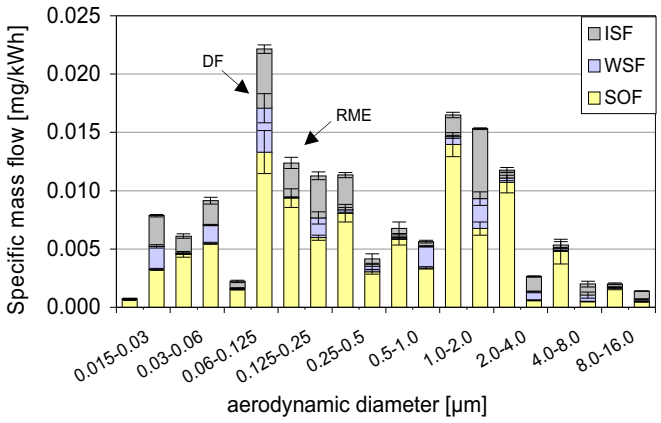

Figure 2: Composition of particulate matter.

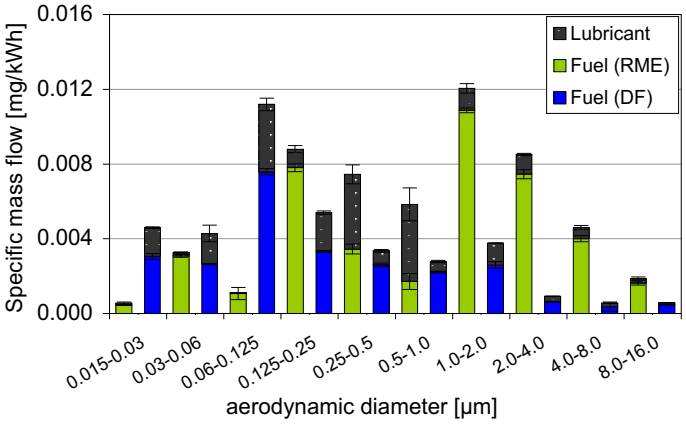

Figure 3: Composition of SOF.

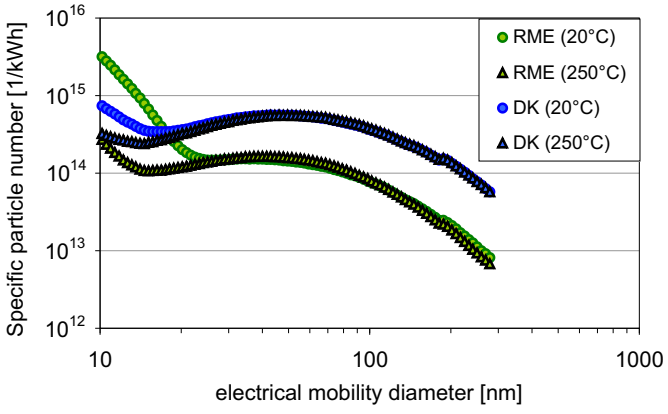

Figure 4: Particle size distribution in exhaust gas with and without hot dilution (ESC test).

For RME high quotas of soluble organic fraction (SOF) and only small amounts of insoluble fraction (ISF) were found for all impactor stages.
For DF lower quotas of SOF were observed, whereas the amounts of water soluble fraction (WSF) and ISF were higher in all size ranges compared to RME.
In course of investigations regarding the composition of particulate matter as well as investigations of the influence of dilution temperature it could be demonstrated that nuclei particles (< 30 nm) emitted for RME mainly result from emission of unburned fuel.

So harmful effects of RME due to higher numbers of carbon soot particles cannot compulsorily presumed.

References:

1. Krahl, J., Munack, A., Ruschel, Y., Schwarz, S., Bünger, J. (2006). Bestimmung der Emissionen und der Partikelgrößenverteilung (Feinstaub) im Abgas eines modernen Euro-4-Nutzfahrzeugmotors mit SCR-Abgasreinigung im Betrieb mit Biodiesel. Final report: Institute for Technology and Biosystems Engineering, German Federal Agricultural Research Centre (Hrsg.), 84 p., 2006.

2. Munack, A., Krahl, J., Herbst, L., Kaufmann, A., Ruschel, Y., Schröder, O., Bünger, J., (2006). Comparison of Shell middle destillate, premium diesel fuel and fossil Diesel fuel with rapeseed oil methyl ester. Final report: Institute for Technology and Biosystems Engineering, German Federal Agricultural Research Centre (Hrsg.), 43 p., 2006.