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FACT promotes the development and use of bio-fuels in developing countries for local people

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Supposed carcinogenity of emissions from biofuels

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Introduction

Recently some discussion arose about the supposed carcinogenity of the tailpipe emissions from engines that are fed with biofuels. In this case mainly vegetable oil based fuels, like PPO (pure plant oil) and biodiesel (fatty acid methyl ester) are meant.
In this paper some technical background is given about this discussion. The experiments done in Sweden and Germany are discussed and some suggestions for further research are done.

Motive

The most recent wave of discussion was caused by an edition of the German TV program "Panorama", broadcasted at June, 29th, 2006 [1]. The program suggested that research, currently being done for the FAL (the German federal agricultural research centre), showed more harmful emissions from diesel engines fed with biofuel, compared to fossil diesel.
It was said that rapeseed oil led to more harmful emissions than diesel fuel, and that the risk of cancer from [the emissions of] rapeseed oil would be ten times higher than [those of] currently available diesel.
The documentary makers even referred to a Swedish study from 1999 that would show the risk of lung cancer for the emissions from rapeseed oil combustion.

Swedish study not relevant

The referred Swedish study is from Pedersen, Ingemarsson and Olsson [3] and is called "Oxidation of rapeseed oil, rapeseed methyl ester (RME) and diesel fuel studied with GC/MS".
Summary: Small samples (5 µl) of rapeseed oil, rapeseed oil methyl ester (RME) and a superior quality diesel oil according to the Swedish environmentally class 1 (SEC1) were oxidised at 550 °C in a reactor. The compounds produced were analysed using a gas chromatographic (GC) method: direct gas injection with GC/MS. Rapeseed oil and RME produced factor 10 more 1-alkenes, dienes, and benzene in comparison with diesel SEC1. Rapeseed oil produced high amounts of acrolein and other aldehydes. Oxidation of RME produced significant amounts of methyl acrylate (2-propenoic acid, methyl ester).

As it is shown from the abstract, no engine research is carried out whatsoever. The samples of fuel have been placed in a heated oven and were burnt slowly at a low pressure and relatively low temperature. This process is totally different from the instantaneous combustion at high pressure and temperature as it happens in an engine. Hence no conclusions about biofuel engine emissions can be drawn based on this report [8]. This same conclusion had already been drawn by Niels Ansø, former Danish Folkecenter, back in 2001 [4].

German research on test bed engine emissions with PPO

The research that is currently in progress for the German FAL consists of tail pipe emission measurements in an engine laboratory [2]. These measurements are done on a stock truck diesel engine that has not been converted but is yet fuelled with 100% PPO. The engine used is the Mercedes-Benz OM 906 LA, a modern 205 kW high speed six cylinder truck diesel engine with PLD (Pumpe-Leitung-Düse, unit injector) direct injection (DI) and three valves per cylinder. The engine fulfils the requirements of the Euro III emission norm.

Among other things, the researchers found an increase in fuel consumption from 22 to 25 kg/h, whereas the maximum shaft power from the engine increased from 205 kW to 216 kW. This indicates an increase in specific fuel consumption of 10%. Furthermore an increase in specific HC emissions from 0,006 to 0,027 g/kWh was measured, nearly a factor of five increase. The limiting value for Euro III is 0,66 g/kWh. In specific CO emission a decrease was found from 0,55 to 0,45 g/kWh (about 20%) whereas the norm is set on 2,1 g/kWh. The specific NOx emissions rose from 4,8 g/kWh with diesel to 6,3 g/kWh, thereby exceeding the limit of 5 g/kWh with about 26%. Finally the specific PM emission increased from 0,07 to 0,09 g/kWh, approaching the limiting value of 0,1 g/kWh set by Euro III. All numbers mentioned above relate the emission with PPO to the emission with diesel as fuel.

Table 1 – unconverted test bed engine emissions summarized

	HC	CO	NOx	PM
Measured (diesel)	0,006	0,55	4,8	0,07
Measured (PPO)	0,027	0,45	6,3	0,09
Euro III norm	0,66	2,1	5,0	0,1

The measurements follow the usual European ESC 13-mode test, of which a schematic representation is given below [5].

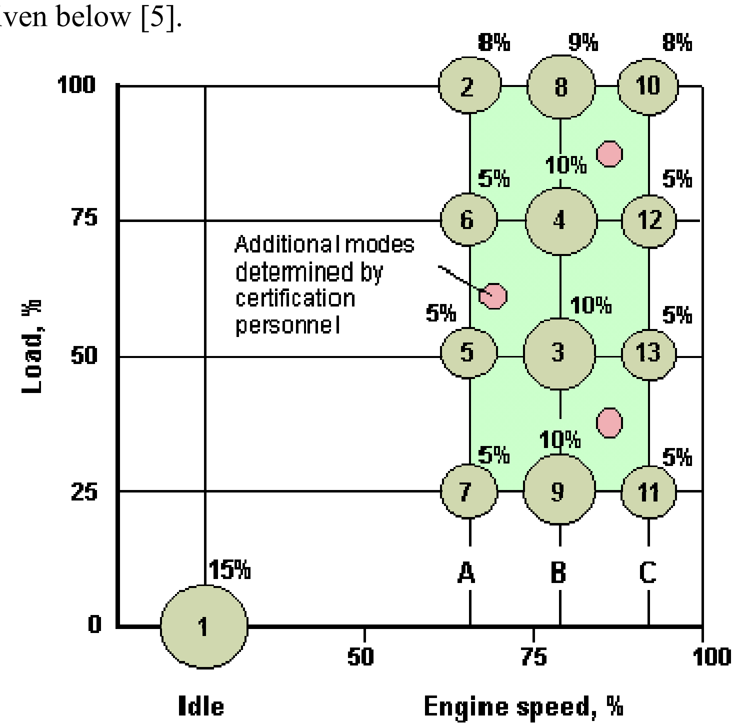

Figure 1 – the ESC 13-mode test [5]

It can be seen that the engine runs idle (i.e. no load) for 15% of the time and it runs at only 25% load for 20% of the time. In the meantime it is common knowledge that operation of unconverted DI diesel engines with PPO at low loads is undesired because of incomplete combustion of the fuel. The effect hereof is twofold [6]. First the engine is contaminated with particulate matter and greasy half burnt reaction products, leading to increased soot emission and the risk of engine damage, e.g. as a result of lubrication oil dilution. Second the incomplete reaction products of PPO combustion are noticeable as undesired emissions, partly exceeding the criteria stated in emission norms. Products from incomplete combustion include CO (carbon monoxide), PM (particulate matter, soot) and HC (hydrocarbons). The last category contains for example aldehydes, ketones and aromates. Many of these substances have a strong smell and may be mutagenic. The research showed a larger mutagenicity for PPO emissions than for diesel emissions. It can be doubted whether a properly converted engine would have emitted so much mutagens running on PPO [6].
As far as the soot is concerned, it would be interesting to investigate the adverse health effects of PM from PPO combustion compared to the PM from diesel combustion. The particle size in PPO soot is notably larger, which leads to the suspicion that it's less invasive to the human body and hence less dangerous [6]. Furthermore, the absence of ring structured components in vegetable fuels might also decrease the potential carcinogenity.
As the German researchers themselves already state in a comment to the Panorama TV documentary, far more research is needed to conclude anything at all about the carcinogenity of PPO engine emissions [2].

German research on test bed engine emissions with biodiesel

In 2003 the same German researchers from FAL did tail pipe emission measurements on a Mercedes-Benz OM 904 LA engine with biodiesel (rapeseed methyl ester, RME) as a fuel, compared to various kinds of diesel fuel. This engine is comparable to the one described above and Euro II compatible. The ECE R-49 test cycle that was followed, is depicted schematically in the figure below [5].

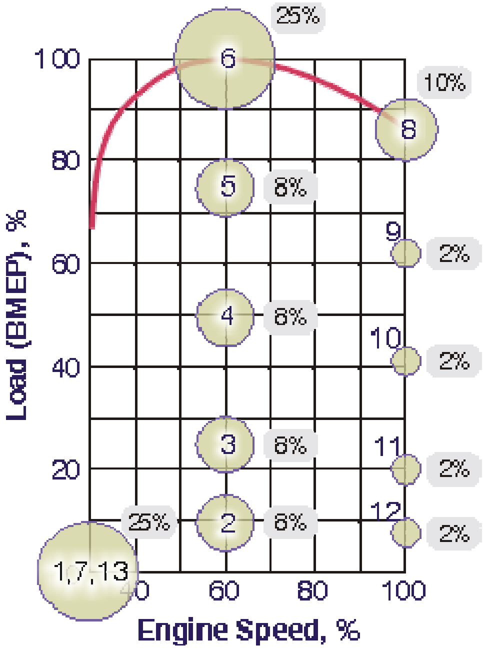

Figure 2 – the ECE R-49 emission test cycle [5]

The conclusions were that [8]:

- Fuel quality has a considerable effect on the emissions and the mutagenic power of these emissions;
- The use of RME led to a slight increase in the emission of NOx and an increase in the emission of ultra fine particles. More research is needed on this point;
- The use of RME led to a considerable decrease in the emission of alkenes, aldehydes and benzene, compared to the use of Swedish (MK1) fossil diesel;
- The mutagenity of RME exhaust gases is lower than that of fossil diesel.

In a further investigation the researchers tried the effect of mixing biodiesel and diesel in various concentrations. Their measurements showed that the emissions of NOx, CO, PM and HC follow a linear tendency with the concentration of biodiesel in the mixture. Hence it can be concluded that an extrapolation of results for pure biodiesel and for pure diesel to mixtures is allowed [7].

Conclusion

Fuelling a stock DI diesel engine with PPO leads to an increase in the shaft power and specific fuel consumption, to an increase in the emission of HC, NOx and particulate matter, and to a decrease in the emission of CO. Far more research is needed to conclude anything at all about the carcinogenity of PPO engine emissions. In first researches the mutagenity of biodiesel emissions is lower than that of diesel emissions.

One thing that can be concluded is that it is necessary to apply a proper conversion to the engine before fuelling it with PPO instead of diesel. Sophisticated conversions like offered by Elsbett and others contain measures to prevent incomplete combustion as far as possible, thereby both reducing the risk of severe engine damage and the environmental burden of our increasing mobility.

Suggestions for further research

On behalf of our partners in developing countries, FACT would welcome more research on the emissions from the use of biofuels and mixtures in other types of engines, like small stationary power generators. In this respect we welcome the recent, very complete study by Wörgetter et al. [9]. This work might well be extended to engines with indirect injection, like the Lister type, and to other fuels and mixtures. Suggestions for fuels are jatropha curcas oil, palm oil, soy oil and sunflower oil, their methyl esters and their mixtures with diesel.

Literature used

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