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FUEL EFFECTS ON EMISSIONS FROM NON-ROAD ENGINES

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INTRODUCTION

The emission regulations for non-road engines are less stringent than for on-road applications. In addition, it is allowed to use heating type fuel oils in diesel equipment in some countries. The quality requirements for heating oils are much less stringent than for automotive diesel fuels. Within the European Union, some countries will allow the use of heating oil containing 2000 mg/kg sulphur in non-road machinery until the year 2008, whereas the sulphur content of automotive fuels will be limited to a maximum of 50 mg/kg sulphur in 2005.

In Finland, for example, non-road mobile machinery consume some 30 % of the amount of middle distillates used for engine applications. The specific emissions of mobile non-road machinery are higher than those of on-road engines. Thus the relative share of emissions from non-road mobile machines is even higher than their share of energy use. This ratio is growing, as the on-road vehicles are cleaning up faster than the non-road engines.

The operation of non-road mobile machinery often includes very variable duty cycles, including extended periods of low-load operation or even idling. To avoid excessive smoke formation, the fuel used should have good ignition properties (high cetane number). Some machines are used indoors, e.g. forklifts in warehouses, terminal tractors pulling containers out of ships and mining equipment in mines. For these machines it would be very important, also from an occupational safety point of view, to have fuels with high quality, i.e. low sulphur, low aromatics and high cetane.

The engines used in hand-held equipment like chain saws and trimmers and also in equipment like lawn movers are quite simple, and therefore the specific emissions are extremely high compared for example with modern catalyst equipped gasoline cars. The emissions from small gasoline engines can be reduced by improving fuel quality and also by applying simple exhaust aftertreatment systems. People using these engines are normally subjected to the exhaust fumes. Therefore there is also in this case a clear concern for occupational safety.

The main objective of this project was to produce a document on the effects of fuel quality and exhaust gas aftertreatment on emissions from non-road machinery, both diesel and gasoline powered engines. On the international level, new emission regulations and fuel specifications for non-road machinery are under discussion. It is in the interest of the international community to stimulate a positive development in the reduction of emissions also from non-road machinery.

METHODS AND RESULTS

The measurements were done with small gasoline engines and with diesel engines designed for non-road machinery. Engines were tested with different fuels and with and without catalyst. The main fuel variables were sulphur and aromatics contents. With the diesel engines, also one fuel containing two different amounts of bio component (RME) was evaluated. The project was divided into two parts: emissions from small gasoline engines and emissions from diesel engines.

The measured small engines were a 2-stroke chainsaw engine, and a 4-stroke OHV engine, which could be used in different applications. Measurements were done with three different fuels, with and without catalyst. Also a comparison between biodegradable vs. conventional lubrication oil was done with the 2-stroke engine. In addition to the regulated emissions the particle number size distribution was measured using the ELPI instrument. The particle mass samples were analysed for PAH and Ames.

In the second part two different diesel engines were tested with five different fuels. Two of the fuels were biodiesel blends. The engines were chosen to represent old and new engine technology. The old engine (MY 1985) was produced before EU emission regulations were in place, and the new engine fulfilled the current EU Stage 2 emission limits. The following special measurements were done: particle number size distribution with the ELPI instrument, filter smoke number (FSN), PAH and Ames analyses. With the new engine comparison with and without oxidation catalyst was done using two fuels.

Tests were carried out at VTT's and MTT's (Agrifood Research Finland, Agricultural Engineering Research) facilities. Engines were run on test benches according to ISO8178 standard. With each engine/fuel/catalyst combination the test cycle was measured three times to ensure the reliability of the measurements.

Following fuels were used in small gasoline engine measurements:

- EUG2000, gasoline fulfilling the EU year 2000 specifications
- SEG, special alkylate gasoline for small engines, commercially available
- SEGO, special alkylate gasoline for small engines with oxygenate

Fuel quality and catalyst had a clear effect on the NO_x and particle mass emission levels with the chainsaw engine. The lowest particle mass emissions were achieved with SEGO fuel with catalyst (Figure 1). The EUG2000 fuel gave the highest particle mass emissions. This was quite expected due to high sulphur content of EUG2000 fuel. On HC and CO –emission levels the effect of fuel and catalyst was relatively low.

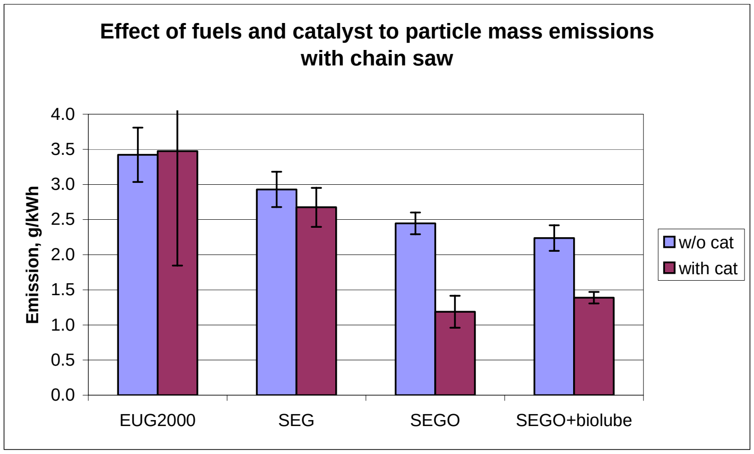

Figure 1. Particle mass emissions with different fuels with and without catalyst.

With the four-stroke engine fuel had a clear effect on all emission levels. Figure 2 presents the effect on HC emissions. The lowest HC emission levels were obtained with SEGO. The difference between EUG2000 and SEGO without catalyst was 25 %. The catalyst turned out to be quite effective on the 4-stroke engine and the conversion ratio of the catalyst varied from 75 % to 85 % depending on the fuel.

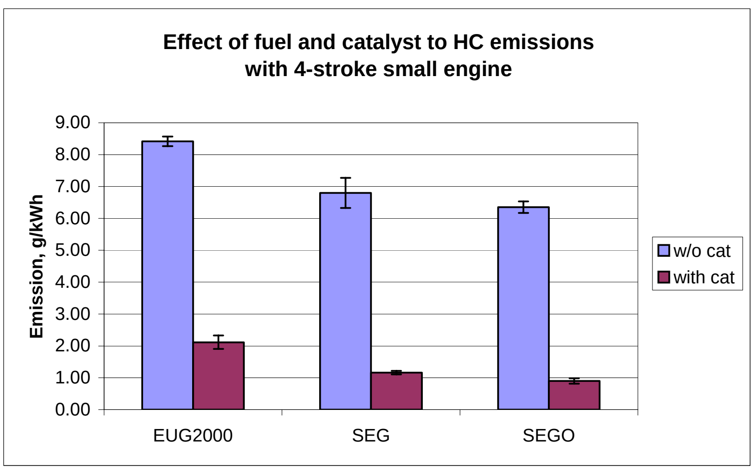

Figure 2. HC emissions from the four-stroke engine.

Following fuels were used in diesel engine measurements

- LFO, light fuel oil, S ≅ 2000 mg/kg
- EUD2000, automotive diesel fulfilling the EU year 2000 specifications, S < 350 mg/kg
- EUD2005, reformulated high quality automotive diesel, S < 50 mg/kg
- BIO5, mixture of EUD2005 and RME, RME ratio 5 vol-%
- BIO30, mixture of EUD2005 and RME, RME ratio 30 vol-%

With diesel engines the fuel effects on emissions were very similar with both engines. With the low sulphur fuels the particle mass emissions were significantly lower than with high sulphur fuels. The highest reductions on particle mass emissions were some 30 to 40 %. Also the NO_x emission levels were lower with good quality fuels. Figure 3 presents an emission level comparison between “old” and “new” engine.

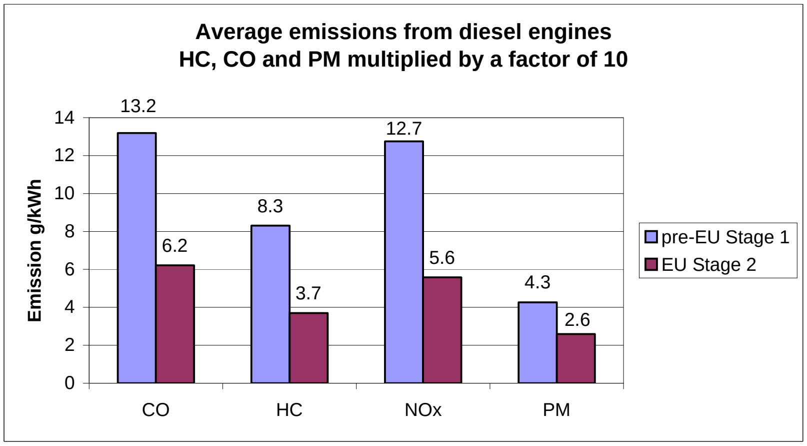

Figure 3. Average emissions from diesel engines HC, CO and PM multiplied by a factor of 10.

PAH and Ames analysis with gasoline and diesel engines gave evidence that reduced aromatics content of the fuel lowers the toxicity and mutagenicity of exhaust particles. In the best cases a very significant reductions were achieved in toxicity and mutagenicity of particles. The correlation between the PAH content and mutagenicity of particles was quite clear.

CONCLUSIONS

This project has shown that fuel quality (e.g. low sulphur, low aromatics) makes a difference to the exhaust gas emissions from non-road engines. The results obtained with gasoline and diesel engines are encouraging. With small gasoline engines the fuel quality generally lowered all exhaust emission, although the reduction of gaseous emissions in some cases was relatively low. With the four-stroke gasoline engine the reductions in all emissions were obvious. The diesel engine results show that it is possible to achieve significant reductions in particle emissions by using a fuel with good quality. The use of catalyst turned out to be an efficient way to reduce emissions from these engines. The only exception was the two-stroke engine with catalyst. The results obtained with this combination were not as good as expected.

The design of small gasoline engines is very simple and that’s why the specific emissions are high. The means for reducing exhaust emission by improving engine technology are limited, because this type of engines needs to be low-priced, reliable and light weighted. This study indicates that one easy way to reduce emissions is to use a fuel with good quality. When combining a good quality fuel and a catalyst, the outcome is generally the best.

Today’s non-road diesel engines require certain functional fuel properties, such as high cetane number, a good fuel lubricity etc. The legislation in many countries allows the use of low quality fuels in non-road machinery. This study has proven that it would be beneficial also from an environmental point of view to use fuels with good quality (meaning low sulphur, low aromatics etc.). One would suppose that also the engine manufacturers would benefit if better fuel qualities were to be used in non-road machinery. This would, for example, give more opportunities to get the engine’s NO_x emissions lower without aftertreatment systems.

People are exposed to the exhaust fumes especially from handheld machinery. Noticing this, the health effects of exhaust gases should be as low as possible. This study points out the positive effect of low sulphur and low aromatics content of the fuel on the health effects of particles.