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Issues of various alternative fuels for internal combustion engines

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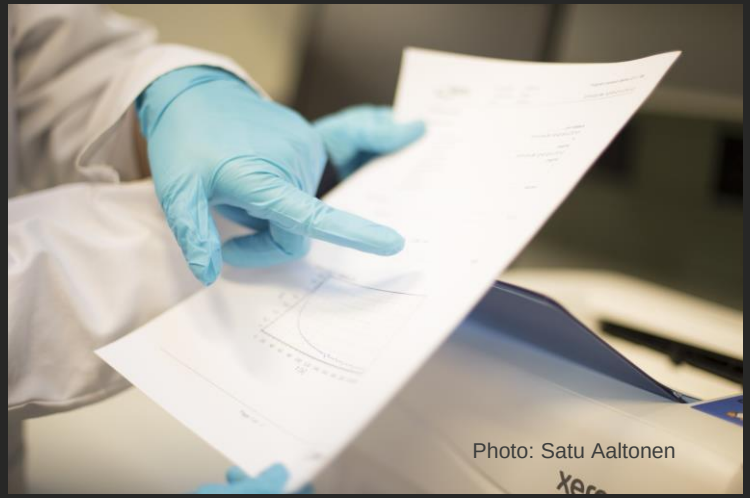
Content of the presentation



What are alternative fuels and why they need to be studied?

Issues that need to be taken into account regarding alternative fuels

Research results of alternative fuels

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What are alternative fuels?

- In this presentation liquid fuels that are not traditional fossil diesel fuels
- Can be used as power source for IC-engines (off-road, marine, power plant applications)
- Biodiesels and their blends with fossil diesel
- Other blend options

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Why alternative fuels?

Photo: Satu Aaltonen

- Fossil oil major transportation fuel still for 50 years
- Liquid fuels will be utilized in power production for at least an equivalent time frame

- Existing prime mover technology
- The energy density of liquid fuels

- Heavy-duty transportation and marine prime movers, grid balancing power plants
- Emissions legislation!

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Fuel standardization

- The quality of fuels is ensured to protect the customer
- A correlation between the fuel and the operability and reliability of the power generation application
- All commercial fuels are standardized
- The quality parameters for new fuels?
  - Detailed study of the new fuel properties is needed

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Important fuel properties

- Cetane number
- Oxidation stability (OSI)
- Acid number
- Na, K, Mg, Ca, P (bio-oils and biodiesels)
- Density
- Distillation curve
- Cold properties
- Lubricity
- Flash point
- Kinematic viscosity

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Fuel blending

- Various blends of renewable and fossil liquid fuels
  - Availability of renewable fuels
- Facilitates the technical transitional period
- Renewable fuels, fuels from circular economy, conventional fuels
  - The blends with biodiesel (already standardized)
  - HVO and other high qualified alternative fuels, are also blended with fossil fuels
  - In this study, recycled MGO
- The diversity constitutes a complication


Photo: Satu Aaltonen

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Fuel blending, FAMEs

- A long-run analysis is needed for the assessment of engine lifetime
- Operating complications
  - The fuel blend needs to be stable and compatible with engine, lubricant and other fuels
- Carbon deposition, lubricating oil dilution, piston ring sticking, and injector nozzle choking[1]
- Accelerated ageing of exhaust after-treatment (alkaline metals!)
- B20 blend not recommended for state-of-the-art heavy-duty engines unless the limit values of biodiesel standard (EN14214) for alkali and earth alkaline metals are revised[2]

[1]Patel et al., 2016, [2]Aakko-Saksa et al., 2014

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Fuel blending- results

- Several fuel blends for medium-speed engines were studied
- Renewable naphtha and RME: is the blend suitable for medium-speed engine applications?
  - RME had a positive effect on the viscosity of naphtha
  - RME also raised the lubricity to an acceptable level
- Circular economy product MGO and RME: is this suitable for medium-speed engine applications?
  - A low-sulphur marine fuel apart from arctic areas. In arctic regions, the limited cold properties may restrict the usability of the blend
- In terms of the measured properties, both blends can be used as alternative fuels

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Effect of fuel blend on lubricating oil

- Lubricating oil serves several functions in an engine
  - Protect the engine and extend engine lifetime
  - Improve fuel economy and assist in sustaining a low level of emissions
  - Engine lifetime may be shortened by alternative fuels or fuel blends (especially FAME)
- B20 fuels effects on the quality of lubricating oil in long-term engine operation were studied
  - A high-technology engine will safely tolerate B20 fuels in terms of lubricant quality
  - Still: B20 is not recommended
  - The most of the catalyzing after treatment systems does not fully work together with B20 fuels[3,4,5]

[3]Coda Zabetta, et al. 2006; [4]He, 2016; [5]Schobing et al, 2018

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Storage stability, unsaturation level and antioxidants

- Storage stability is one of the main quality parameters related to FAMEs
- Unsaturated fatty acids are the most reactive compounds in biodiesels[6,7]
- Antioxidants inhibit the autoxidation process, used as additives to extend the storage time of biofuels[8]
- The antioxidant has to be selected according to the feedstock used
- Rather high unsaturation level and the inefficient antioxidant led to a high required concentration of antioxidant (2000 ppm)

[6]Yaakob et al. 2014, [7]Shahabuddin et al. 2012, [8]Knothe, 2007

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Storage stability

- How long Soy bean methyl ester can be stored in clean laboratory conditions?
  - Four different conditions: the vessel material (steel or high-density plastic) or the temperature (4 or 20° C) varied
- The fuels maintained their quality during the 12 months of storage
- The storage temperature and storage vessel material: no effect on the fuel quality
- The biodiesels were not particularly reactive
  - Some oxidation reactions occurred
  - The effect of the reversible transesterification reaction was not significant

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Effects of sulphur content

- Sulphur compounds harmful both environmentally and for people. The amount of sulphur should be decreased in all kinds of fuels
- Increases particulate matter and soot emissions and causes corrosion and has a deleterious effect on advanced catalytic systems[9,10]
- Some studies indicate that higher sulphur contents may benefit the oxidation stability of fuel blends[11] or neat fossil diesel[12]
- Biochemistry: Organic sulphuric compounds, such as glutathione protect cells from free radicals and reactive oxygen compounds
  - Interesting similarity!

[9]Kalghatgi, 2014, [10]Zhao et al., 2016, [11]McCormick & Westbrook, 2007, [12]Kalitchin et al., 1992

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Effects of sulphur content-results

- The effect of sulphur on the storage stability of the fuel blends was studied
- An increasing concentration of sulphur enhances the oxidation stability of fuel blends
- Composition and oxidation stability of the fossil component plays a greater role in the stability of the blend than the biocomponent?
- More research work and detailed analyses of the chemical structure of these fuels required

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Conclusions

- The diversity of alternative fuels complicates engine development and the compatibility of the new fuels should be studied
- Blending new fuels with conventional ones facilitates the technical transitional period
- There are several options for different fuel blending components
  - Also FAMEs but the problems (storage stability, catalyst poisons) should be taken into account!
  - Sulphur improves the storage stability
- The fuel blending and decisions on which fuels should be used are case-specific
  - Application where the fuel is used, fuel blendability, effects of fuel on the blend, and fuel availability
- Additional results should be obtained concerning the combustion behaviour of all kinds of blends (especially low viscosity fuels)

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Thank you!

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