Technical feasibility analysis of innovative fuels

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Introduction

With the increasing number of alternative fuels used as energy carriers, an overall approach from modeling of combustion process up to utilization on a macro level is necessary. To support this procedure, a series of tools is being developed to research and analyze the suitability of fuels in advanced combustion devices. Starting with fundamental combustion research which is further applied to case-models, prototype development and pilot studies are often necessary to provide realistic data on overall system response or to be used as validation tools for state of the art numerical models. This study is specifically focused on the intermediate level where transferring of virtual findings to real-life energy systems needs to be backed up by experimental data oriented toward interrelated influences of fuel properties and required engine operating characteristics which often limit the design and operation space of internal combustion engines. Attention will be mainly dedicated to turbine engines considering two different innovative/alternative fuels; liquefied wood (LW) and tire pyrolysis oil (TPO) by covering fuel conditioning process, mixture formation and emission response together with durability studies to provide a holistic experimental assessment of advanced combustion system.

Materials and methods

The data will be obtained through analysis of several cross-related influences of fuel and engine components by parametric study in a dedicated micro gas turbine (MGT) system, serving as a test rig for combustion analysis, as an apparatus for performing dedicated experiments for spray visualization and as a test site for hot components and materials. Furthermore, impact of fuels on fuel system components will also be evaluated through laboratory corrosion studies with different fuel subtypes. Applied methods will comprise of:

- Fuel conditioning system; immersion tests of specimens exposed to different fuel temperatures for most commonly used austenitic stainless steels and copper-based alloys. Specimens will be further analyzed by weight-loss method and SEM, coupled to EDX to reveal the surface composition and morphology of corroded materials.
- Fuel injection system; quantification of fuel spray parameters and mixture formation dynamics will be observed with fast spray imaging and concentration and velocity field analysis based on advection-diffusion equation. [3]
- Combustion process; a cause and effect relation in the chain of fuel properties, combustion and emission formation phenomena will be used to provide an insight into crucial parameters for MGT performance and compliancy with emission regulation by studying the effects of primary air temperature (PAT) and turbine inlet temperature (TIT).
- Hot components; the impact of combustion products on hot components will be provided through deposit analyses with SEM and EDX method to provide the data on fouling, abrasion and corrosion processes in the flow of hot combustion gasses.

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Results

The main findings of the study revealed several interrelated influences that need to be taken into account when transferring virtual results from decoupled components on a complex internal combustion system. A short overview of the most important parameters in Table 1 and in the following highlights reveals their cross-relation and impact on required operating parameters.

Table 1: Impact of fuel properties and operating parameters on emissions, durability and technical feasibility (+; beneficial, -; negative, 0; no effect, x; not analyzed)

LW/TPO	CO	NO_x	Corrosion rate	Injection nozzle deposits	Technical difficulty
TIT	+/0	-/-	0/0	-/0	-/-
PAT	+/0	-/-	0/0	-/0	-/-
pH value increase	0/x	-/x	+/x	0/x	+/x
Fuel temperature	+/x	0/x	-/x	-/x	-/x

- Results on the fuel temperature related phenomena indicate that an optimum preheating temperature exists where viscosity is the lowest and fuel injection nozzle is not yet prone to coke formation. In presented experimental setup this temperature is 100°C. [2]
- Regarding thermodynamic parameters, the use of high PAT is beneficial to reduce the CO emissions, however this again influences the NOx emissions by elevating them. [2]
- Similar influence is also observable with TIT. Thus, to obtain low CO emissions, operation at high TIT is necessary, but the maximum achievable TIT would most likely be constrained by NOx emissions and hot components deposits.
- For high viscosity fuels, reduction of CO emissions is also possible through elevation of fuel temperature, although in the case of low pH values this is constrained by corrosion in fuel system, which is offset by neutralization that in turn elevates NOx emission. For a fuel with high viscosity and low pH value, a trade-off between PAT, TIT and pH value of the fuel is necessary to obtain minimum CO and NOx emissions.
- Corrosion in the fuel system during optimization of emissions must be necessarily avoided as it can also influence the quantity and composition of deposits on hot components of the MGT.

References

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