**Fuel Flexibility**

**O. Bernstrauch, P. Kutne**

Comments from the PB meeting

O. Bernstrauch:

* Modify the title to *Fuel Spectrum*
* Modify second sub-title to *Natural gas/biomass derived syngas mixtures*
* Modify third sub-title and add *coke*
* Modify fourth sub-title to *LNG/CNG*

G. Terzer:

* The challenge is not the GT, it is maintaining the condition of the fuel.
* Shale gas, LPG are not R&D but existing applications of micro gas turbines. They should therefore either not appear in the Recommendation Report, or mention the scope of R&D trends for larger engines.

P. Jansohn:

* Certain topics need to be dropped to focus on the most relevant ones
* Add a *Non-carbon fuels (e.g. NH3)* sub-title
* Add a *Special fuels, including fuel pre-treatment (e.g. sour gas)* sub-title. And mention the existence of prototypes.

The need for gas turbines to be operated safely, with high efficiency and low emissions, using a variety of gaseous & liquid fuels still remains to be an important issue for current and future gas turbine models.

Besides a wide variety of natural gas qualities, including gas compositions with high content (> 1%vol.) of higher hydrocarbons (so-called C2+, like ethane C2H6, propane (C3H8) and butane (C4H10)) or with high content (> 10%vol.) of inert species (N2, CO2), which cover a wide range of Wobbe Index values (35 - 55 MJ/Nm3), additional fuel gas mixtures (syngas - CO/H2, hydrogen - H2) and diluents (CO2, H2O) come into the scene as new gas turbine based processes and new fuel resources (biogas, shale gas, LNG) are being proposed for power generation and industrial applications. Additionally, liquid fuels remain to be of interest for mobile applications (aero engines, marine engines), oil & gas industries, island/off-grid operation and as back-up fuels. Meanwhile, their spectrum is increased by biomass derived liquid products (FAME, DME, pyrolysis oil, etc.).

The issue of wide fuel spectrum capability of gas turbines is strongly coupled with operational flexibility topics such as flame stability and emissions, and can be exacerbated if fuel switch-over procedures are to be considered.

Typically achieving ultra-high efficiency requires very narrow fuel specifications, whereas with widely variable fuels, one needs to accept somewhat lower performance and possibly a redesign of key components in order to arrive at a fuel-flexible gas turbine set-up.

Specific issues, which need to be addressed in this respect, are:

## Natural gas/H2 mixtures

With large capacities of wind & solar PV installed, storage of intermittently produced surplus electricity has become an important challenge. Storage via H2 production from water electrolysis is one option being considered. As storage of pure H2 in large quantities is difficult and expensive, its injection into the natural gas grid is considered to be an attractive option. This would require consumers connected to the grid (like gas turbine power plants) to cope with a variable H2 content in natural gas (may be up to 20%vol.). Issues to be addressed are safe combustion performance (flame stability, flashback, combustor cooling, thermoacoustics) and NOx emission behaviour.

**Natural gas/syngas mixtures**

Biomass derived syngas (CO/H2 mixtures from biomass/ wood gasification) is considered CO2-neutral and thus has to play a role in future power generation scenarios. Co-firing of such syngas in large gas fired combined cycle plants offers high electricity conversion efficiency. With co-firing shares of up to 20% (by energy), the combustion performance is being influenced. Issues to be addressed are safe combustion performance (flame stability, flashback, combustor cooling, thermoacoustics), emission behaviour (NOx, CO) and material degradation due to fuel contaminants (particulates, corrosive species like sulphur, chlorine, sodium).

**H2-rich fuel gases (e.g. syngas)**

High hydrogen concentration (> 50%vol.) in fuel gas mixtures requires significant changes to the fuel-air mixing/burner/combustor design of gas turbine combustion systems. Beyond the findings of the EU funded project “H2-IGCC” it is still important to find solutions and demonstrate the applicability (at full scale/full pressure) of potential low emission, reliable (safe ignition, stable flames) combustion technologies. Issues to be addressed are safe combustion performance (flame stability, flashback, combustor cooling, thermoacoustics) and NOx emission behaviour for process conditions relevant to gas turbines integrated with pre-combustion carbon capture schemes and/or solid fuel gasification (coal, biomass, process residues).

**LNG/LPG**

LNG (liquefied natural gas) and LPG (liquefied petroleum gas) have very peculiar composition when they are re-gasified and used as fuel gases for gas turbine operation. LNG consists of (mainly) CH4 and thus reduces any impacts due to inert species (N2, CO2), but the low levels of higher hydrocarbons (e.g. C2H6/ C2H4) can cause operability issues due to the reduced reactivity of the fuel. LPG consists of propane (C3H8) and butane (C4H10) in various ratios and exhibits strongly different physical and chemical properties (i.e. combustion characteristics). Flame stability, flame speed and ignition delay times can be sufficiently different, such that a re-design of key combustor components could be required. Re-gasified LPG may be an attractive alternative to liquid fuels in locations where a natural gas supply is not available.

**Shale gas**

Shale gas (so called unconventional natural gas) can show an even wider variation in composition than (conventional) natural gas qualities and expands the range towards even lower Wobbe Index values (below 35 MJ/Nm3) due to higher content of inert species (N2, CO2) which can also vary temporarily depending on the exploration conditions.

**Biomass (derived) liquid fuels**

Liquid products generated from syngas of biomass gasification systems (FAME, DME) or directly formed in pyrolysis processes of various types of biomass (i.e. pyrolysis oils of different origin) pose a significant challenge to the operation of gas turbine systems. Not only physical properties (viscosity, lubricity) bear certain difficulties, but also chemical properties (S/N/Cl content; acidity/corrosivity; combustion chemistry/ flame speed) vary significantly and are not yet fully characterized (operational limits such as lean blow out and flashback; NOx/CO/SOx emissions).

