Thuwal, 8th of March 2016
Fuel Utilization in Flexible Industrial Gas Turbines
Jenny Larfeldt
Introduction to industrial gas turbines

Stationary gas turbines are continuously flowed through fixed-drive machines with high power densities, meaning that they deliver a large amount of energy in relation to their size and weight. The combustion process takes place at a pressure generated by the compressor and the airflow including the products of combustion (and excess air) is then delivered to the turbine which drives the compressor as well as generating power to the generator or other external equipment depending on application.

![Diagram of a gas turbine system](image)

Combustor
Compressor
Turbine

20 bar
693K

SGT-800 50MWel
Gas Turbine Fuel Flexibility for Environmental Protection and Plant Profitability

Intermittent production of power from growing share of renewables leads to storing demands.

Converting wind power to H₂ (P2G) and potentially back to power or feed H₂ directly in natural gas grid.

Use “waste” gas streams in chemical plants for increased profitability. For instance ethane, propane and hydrogen rich gases.

Improve availability by avoiding complex and expensive fuel treatment equipment.

About 140 billion cubic meters of associated gas are estimated as flared or vented annually. This is equivalent to almost a third of the EU’s gas consumption. Reducing CO₂ emissions from flaring would equal taking 70 million cars off the road.
Industrial gas turbine gaseous fuel map

Wobbe-index = \( \frac{LHV}{\sqrt{\rho_{rel}}} \)

\( (\rho_{rel} = \frac{\rho_{gas}}{\rho_{air}}) \)

Fuel testing NG with:
1. Nitrogen 50 vol%
2. Pentane 23 vol%
3. Ethane 100 vol%
4. Hydrogen 20 - 40 vol%

Standard range NG WI: 42 to 53 MJ/nm³

Heavy hydrocarbons

High N₂, CO₂, CO

High H₂

0 10 20 30 40 50 60 70 80 90
0 10 20 30 40 50 60 70 80 90
The key performance of an industrial gas turbine combustor

- High-combustion efficiency (i.e. the fuel should be completely burned so that all its chemical energy is liberated as heat).
- Low pressure loss.
- An outlet temperature distribution (pattern factor) that is tailored to maximize the lives of the turbine blades and nozzle guide vanes.
- Low emissions of smoke and gaseous pollutant species.
- Freedom from pressure pulsations and other manifestations of combustion-induced instability.
- Wide stability limits (i.e., the flame should stay alight at pressures and air/fuel ratios corresponding to the whole gas turbine operating range).
- Fuel flexibility.
- Design for minimum cost and ease of manufacturing.
- Size and shape compatible with engine envelope.
- Maintainability.
- Durability.
- Reliable and smooth ignition at the ambient conditions of relevance for an industrial gas turbine.

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Combustion in Industrial Gas Turbines 1(3)
SGT-800 30 DLE burners in an annular combustor

- Main gas
- Film air holes
- Partly premixed pilot gas
- Compressor air
- Burner outlet

20 bar
\( \lambda \ 2 \)
693K

SGT-800 50MWel
Combustion in Industrial Gas Turbines 2(3)
Emissions versus load

Below 50% load
Full load

- CO ppmvd@15
- UHC ppmvd@15
- NOx ppmvd@15
- PFR gas incl purge to oil %

Load (MW)

CO UHC ppm at 15%O2

NOx ppm at 15%O2

PFR %
Combustion in Industrial Gas Turbines 3(3)
Emissions versus combustion induced instabilities

Flow and mixture perturbations ↔ Heat release oscillations ↔ Acoustic oscillations

Damping softwall
Industrial gas turbine gaseous fuel map

Fuel testing NG with:
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2. Pentane 23 vol%
3. Ethane 100 vol%
4. Hydrogen 20 - 40 vol%
Challenges with high hydrogen fuels:
- Flashback due to flame speed

Flame position at various hydrogen content in natural gas at atmospheric combustion conditions

Test with single burner feed shows potential up to 40 vol-% H2 in today standard DLE burner.

Siemens released capability for SGT-800 is today 30 vol-% H2.
Challenges with higher hydrocarbons in fuels:
- Flashback due to auto ignition delay time

Ignition delay for straight chained hydrocarbons at 500 °C

Average residence time in burner mixing tube ~3-5 ms

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Challenges with higher hydrocarbons in fuels:
- SGT-700 our fleet leader at PDH plant in China

Power output during 150 days continuous operation

- SGT-700 in mechanical drive
  - >5000 OH since start-up 2014
  - Propane as fuel during plant start-up
  - Waste process gas with variable composition during normal operation
    - Ethane, propane, but also methane, butanes, alkenes, hydrogen, etc
    - NOx emissions below 15 ppm
Challenges with higher hydrocarbons in fuels: - PDH plant in China fuel detail

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<th>Component (mol %)</th>
<th>Hydrogen H2</th>
<th>Nitrogen N2</th>
<th>Methane CH4</th>
<th>Ethane C2H6</th>
<th>Ethylene C2H4</th>
<th>Propane C3H8</th>
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<th>Butanes C4H10</th>
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</table>

* C6+, Dienes, Propyne, Acetylene, etc
Challenges with high inert fuels:
- LBO … and do not forget the auxiliary system!

Fired duty 120 MWth (~50 MWel in SGT-800)
Std NG 2.5 kg/s
Gorzow gas 5.4 kg/s
Future needs and challenges for fuel flexible industrial gas turbines

Extended use of alternative fuels
- Margin to LBO and FB

High availability and reliability
- Flame position and temperature distribution

Reduced emissions
- Fuel and species distribution

Higher efficiency
- Flame stability and flame interactions
From SGT-800 compressor

To SGT-800 turbine

SGT-800 ITM process integration 2(2)
DOE DE-FC26-98FT40343 Turbo machinery
Thank you for your attention

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