Hydrogen Co-Firing in Siemens Low NO$_x$ Industrial Gas Turbines

Adj Professor Jenny Larfeldt
Senior Combustor Expert
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Fundamentals on H₂ co-firing 1(2)

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

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

Heavy hydrocarbons

1. 100 % H₂
2. 75/25 H₂/N₂
3. 50/50 H₂/N₂

Standard range NG WI: 42 to 53 MJ/Nm³

0 10 20 30 40 50 60 70 80 90

0 10 20 30 40 50 60 70 80 90

Lower Heating Value [MJ/kg]

Wobbe Index [MJ/Nm³]
Fundamentals on H₂ co-firing 2(2)

H₂ has ten times higher flame speed compared to natural gas.

Co-firing H₂ and CH₄/C₂H₆/C₃H₈
- H₂ < 60 vol-%: slight increase in burning velocity and chemistry hydrocarbon dominated
- 60 < H₂ < 90 vol-% intermediate regime
- H₂ > 90 vol-% dramatic increase in laminar burning velocity and chemistry is hydrogen dominated.
From fundamentals to real engines
SGT-800 / 53MW

- 30 DLE burners of so called 3rd generation in an annular combustor
- Air entering combustor with about 20 bar and 700 K

https://www.youtube.com/watch?v=uY-iQYpO_a8
From fundamentals to real engines
Step 1. Atmospheric combustion rig test
From fundamentals to real engines
Step 2a. Pressurized single burner test 1(2)

Single burner feed in engine

- LNG
- GU1
- GU2
- Buffer
- GU1
- GU2
- Hydrogen
- Other fuels

EBIT
- Experimental burner:
  - Separate fuel feed
  - Extra instrumentation including dynamics measurement

EBIT Boroscope probe

Engine Dynamics probes

Engine stack
- Emissions probe

Engines 16 circumferential T7 probes
- Outer
- Inner

36MW generator

0% H₂
12% H₂
20% H₂
32% H₂
From fundamentals to real engines
Step 2. Pressurized single burner test 2(2)

- Customer had a constant flow of hydrogen corresponding to approximately 0.5 ton/h.
- For a SGT-700 this resulted in hydrogen content in the fuel varying between 50-75 % for loads between 27 and 10 MW.
- A small increase of NO\textsubscript{X} was seen as hydrogen content increases, but the increase is only significant above 45 % hydrogen.
- The 2014 tests confirmed the possibility to run the SGT-700 on high hydrogen fuels with results indicating that 40-50 % H\textsubscript{2} is possible at high loads.
- At 10 MW load, 100 % H\textsubscript{2} was tested and it was fully possible to run, but the hydrogen flow had to be doubled and NO\textsubscript{X} emissions were about 60 % higher than the high load emissions.
Additive manufacturing of SGT-600/700/800 standard burner
Rapid prototyping speeds up development

Traditionally manufactured burner front
- 13 machined parts, joined by 18 welds.
- External pilot gas feed
- Weight: 4.5 kg

SLM adapted burner front
- One single part
- Pilot gas feed integrated in structure
- Lead time reduction of >75%
- Weight: 3.6 kg
From fundamentals to real engine SGT-750
Step 2b. Pressurized single can test

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Conclusions

Next steps:

- SGT-800 string test with 50 vol% H₂ co-firing (Aug 2017)
- Co-firing with 15 vol% H₂ in SGT-800 at Industriepark Höchst, Frankfurt (Dec 2017).
- Burner design for 100% H₂ to be tested at pressure in Siemens combustion test facility in Berlin (ongoing R&D).
- SGT-750 scaled burner tests for NH₃/N₂/H₂ mixtures together with universities.

<table>
<thead>
<tr>
<th>Gas Fuel Constituents</th>
<th>SGT-800</th>
<th>SGT-750</th>
<th>SGT-700</th>
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Thank you for your attention

Ajdunct professor Jenny Larfeldt
Senior Combustor Expert
PG DG GPS CTV
Slottsvagen 3
612 38 Finspång
Phone: +46 122 82 789
Mobile: +46 70 180 14 147
E-mail: jenny.larfeldt@siemens.com

siemens.com
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