H_2-IGCC Project Update

Third Reporting Period
November 2011 – October 2012

The overall objective of the H_2-IGCC project is to provide and demonstrate technical solutions which will allow the use of state-of-the-art highly efficient reliable gas turbines (GT) in the next generation of Integrated Gasification Combined Cycle (IGCC) plants. The goal is to enable combustion of undiluted hydrogen-rich syngas with low NO_X emissions and also allowing for high fuel flexibility. The challenge is to operate a stable and controllable gas turbine on hydrogen-rich syngas with emissions and processes similar to current state-of-the-art natural gas turbine engines.

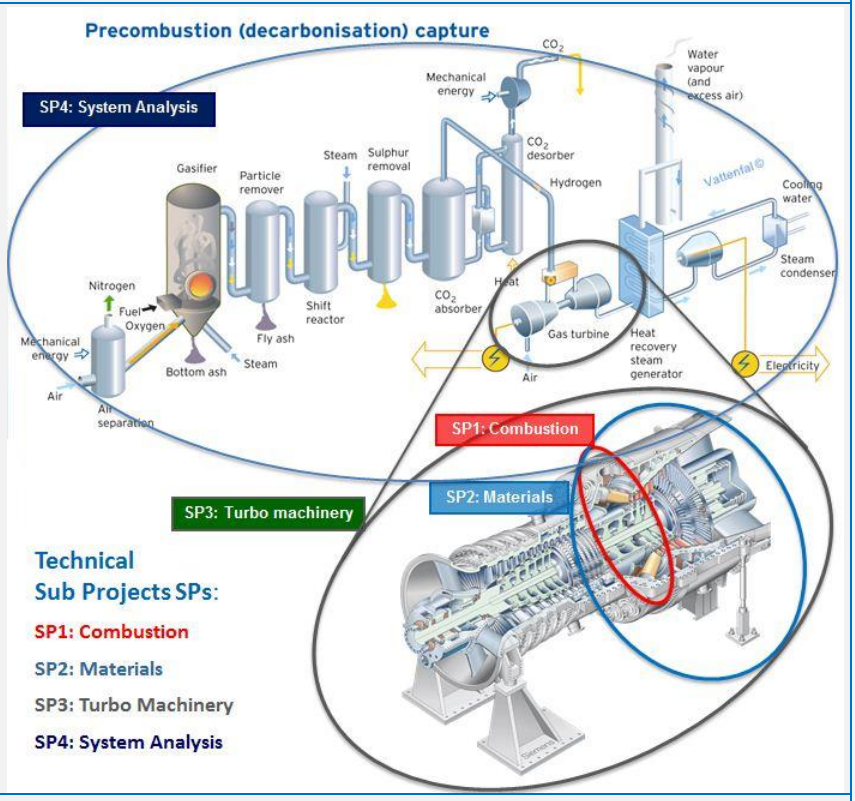
The H_2-IGCC project aims to tackle this challenge as well as fuel flexibility, by enabling the burning of back-up fuels, such as natural gas, without adversely affecting the reliability and availability. The project will be successful when it results in the identification and development of gas turbine technology able to operate on undiluted H_2-rich fuel gas (approx. 80 Vol. % of hydrogen) from a CO_2 capture process in an IGCC plant configuration which offers less than 5% efficiency penalty (compared to a non-CCS scheme).

Over the past decade, a number of initiatives on clean coal technology and IGCC have started around the world. Successful mitigation of climate change requires global efforts. Therefore, international knowledge sharing is essential to significantly reduce the time and the cost of bringing CCS to the market.

A successful outcome of this project will be an important step towards opening up the market for a commercial implementation of IGCC-CCS technology.

The H_2-IGCC project brings together 24 partners from industry and academia with the common goal to increase gas turbine efficiency and fuel flexibility without affecting the reliability and availability in a pre-combustion IGCC-CCS plant configuration.

The technical challenges addressed by the H_2-IGCC project are divided into 4 Subprojects (SP).



The H_2-IGCC project has completed its 1st phase of research and development, and its 2nd phase of proof of principle (lab-scale) has also produced significant results. The 3rd phase of proof of concept (pilot) started in early 2012. In the third year the SPs have carried out the following activities and produced preliminary results:

- Tested various burner hardware configurations at ambient and medium pressure levels
- Performed test and evaluated alternative combustion technologies (flameless and wet combustion).
- Continued the material testing and evaluation activities with the investigation of high temperature oxidation and thermal cycling, hot corrosion, CMAS/F corrosion, high temperature erosion, mechanical properties and thermal conductivity of thermal barrier coatings.
- Several different options for the modification of the GT have been identified, researched and discussed and the best option selected for detailed design
- The techno-economic modelling and systems optimization activities have been initiated.

More information on the project and the public deliverables can be found on the H_2-IGCC website.

Subproject Updates

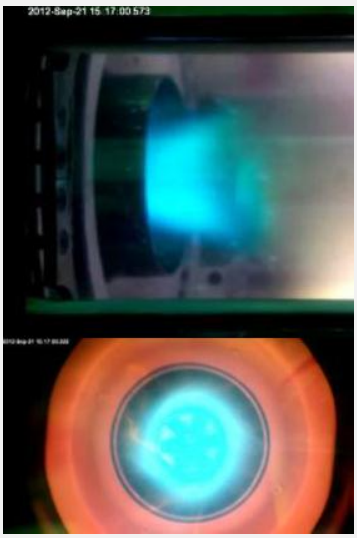
November 2011 – October 2012

SP1 – COMBUSTION

Subproject Objective: demonstrate the use of (undiluted) high hydrogen syngas in typical natural gas combustion systems with minimal modifications in order to conserve the ability to burn a variety of fuels; demonstrate the safe use of (undiluted) high hydrogen syngas in lean premixed combustion mode at competitive low emission levels.

Third Year results:

- ✓ Various burner hardware configurations at ambient and medium pressure levels. As expected, the tests with H_2-rich fuel gas showed a limited operational range due to flashback events and increased NOx emission likely due to imperfect fuel/air mixing.
- ✓ The evaluation of the ignition delay time data was finalised and a reaction mechanism best suited for modelling of syngas/H_2-rich fuel gas combustion was selected.
- ✓ Simulation runs were performed using code based on a fast transient Navier-Stokes solver with Very-Large Eddy Simulation capabilities for methane and methane/syngas mixture. These modeling efforts revealed the specific challenges which come about the operation of a variety of fuels with the same burner geometry and support corresponding experimental combustion activities.
- ✓ Advanced knowledge on the performance of alternative combustion concepts (flameless combustion, wet combustion) in lab scale combustion tests, with respect to lean blowout, flashback and emissions for Natural Gas (NG), hydrogen and NG/hydrogen blends.



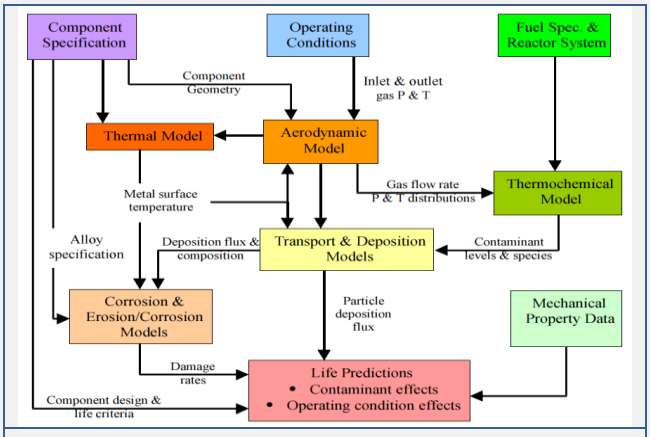
Flashback during Syngas operation

SP2 – MATERIALS

Subproject Objective: demonstrate cost-effective materials and coatings technologies to overcome the component life-limiting problems of overheating and of hot corrosion resulting from the higher temperatures and from residual contaminants in the syngas respectively; validate materials performance data, life prediction and monitoring methods applicable to the industrial implementation in advanced IGCC plants.

Third Year Results:

- ✓ Continued the material testing and evaluation activities with the investigation of high temperature oxidation and thermal cycling, hot corrosion, CMAS/F corrosion, high temperature erosion, mechanical properties and thermal conductivity of thermal barrier coatings.
- ✓ The development of novel multi-layered thermal barrier coating systems is continuing and a potential new bond coating composition has been identified. For both types of novel coatings, the focus has moved from manufacturing of the coating systems using industrial processes to more detailed test work.
- ✓ Developed and initiated the program for the demonstration of new materials and coating in the novel IGCC operation environment.



Schematic of component lifetime prediction model

Subproject Updates

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SP 3 – TURBOMACHINERY

Subproject Objective: deliver a compressor design with a stability margin enabling the switch between fuels without compromising its efficiency; deliver a turbine design and cooling system capable of coping with the resulting heat transfer environment dominated by water vapour; verify designs using large scale virtual testing environment to meet industrial standards.

Third Year results:

- ✓ Three different options for the modification of the GT have been identified, researched and discussed and the best option selected for detailed design:
  1. Re-staggering the first four stator vanes to reduce the compressor mass flow and meet the full load syngas operation. Results have shown good component behaviour at nominal operating point and safe operations up to 70% VIGV opening.
  2. Introduction of VSV's for the first three stages to better adapt the machine behaviour at part load conditions. According to investigation on the 3.5 stages axial compressor, higher efficiency and better stability could be achieved at part load conditions with respect to a certain VIGV configuration.
  3. Addition of a 16th rear stage to allow for higher pressure ratio, maintaining the compressor inlet volumetric flow. This option moves the nominal point away from the anti-surge line and makes the compressor more flexible in the off-design conditions. However, a decrease in the compressor efficiency has been highlighted and some modifications to the expander and cooling system are needed due to the higher expander blade temperatures.

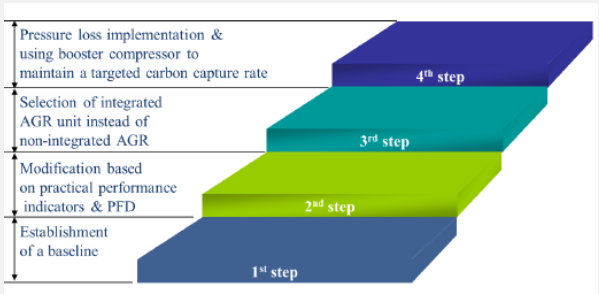
  The opening of the first NGV of the expander was thought to be the most promising solution as it showed to have the best GT overall efficiency, power increase and no changes in the shaft and casing arrangements would be necessary.

SP 4 – SYSTEM ANALYSIS

Subproject Objective: provide a detailed system solution/system analysis that generates realistic techno-economical results for future gas turbine based IGCC plants.

Third Year Results:

- ✓ Selection and optimisation of the final IGCC process for operation with H_2-rich syngas as fuel. Special focus was put on realistic (current stage of technology) conditions and characteristics of components and sub systems.
- ✓ Refinement of the modelling of plant components used in the simulation
- ✓ Refinement of the overall plant process, introducing realistic, state-of-the-art pressure losses of the various components
- ✓ Creation of a techno-economic model to investigate the different scenarios addressed in the H_2-IGCC project which allows for comparison with other public models



Iteration Level of the final IGCC process simulation

The H_2-IGCC project is financed under the European Union's 7th Framework Programme - FP7-ENERGY-2008-TREN-1ENERGY 6.1.4:
Advanced Gas Turbines for Solid Fuel Gasification Processes
Low Emission Gas Turbine Technology for Hydrogen-Rich Syngas

*Acronym: **H_2-IGCC***
*Collaborative Project: **FP7-239349***
Duration: 4 years (2009-2013)
Budget: 17.8 M Euro (11.3 M Euro EU funding)

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