H_2-IGCC Project Update

Second Reporting Period
November 2010 – October 2011

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.

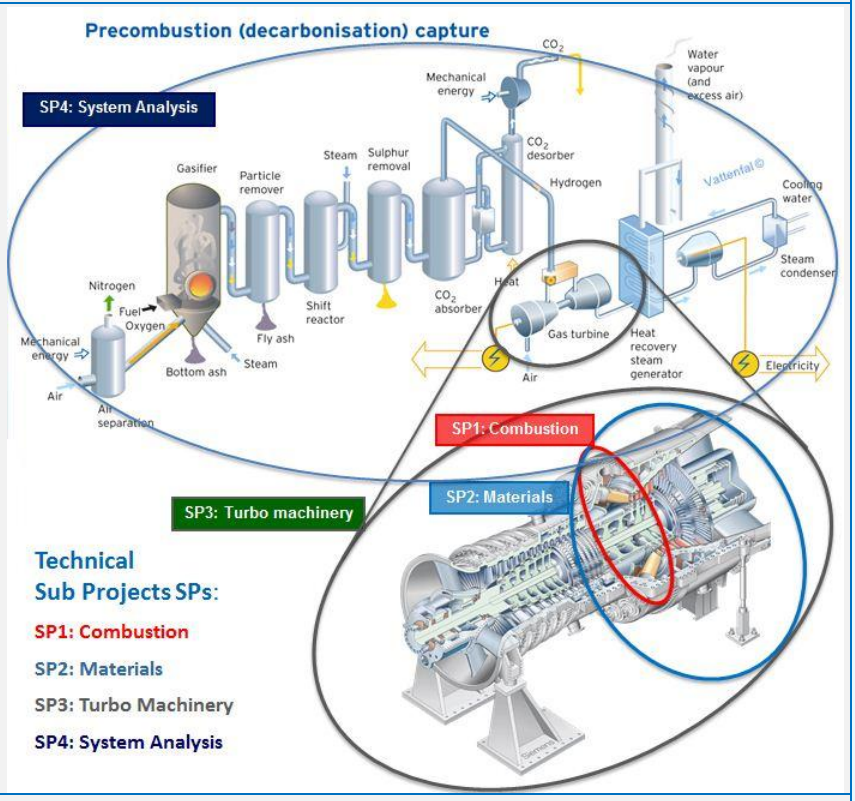
The H_2-IGCC project aims to tackle this challenge as well as fuel flexibility, by enabling the burning of back-up fuels, such as natural gas, without adversely affecting the reliability and availability. The project will be successful when it results in the identification and development of gas turbine 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) will start in early 2012. In the second year the SPs have carried out the following activities and produced preliminary results:

- Manufactured and installed prototype scaled burner on test rig site.
- Developed numerical combustion models and explored alternative models (flameless and wet combustion).
- Started material testing under different conditions, in order to define overall component life prediction.
- Used generic compressor, cooling system and turbine geometries as a reference for thermodynamic analysis.
- Defined the reference plant, investigated options for stable operation under changing fuel compositions and for best cycle performance.

Subproject Updates

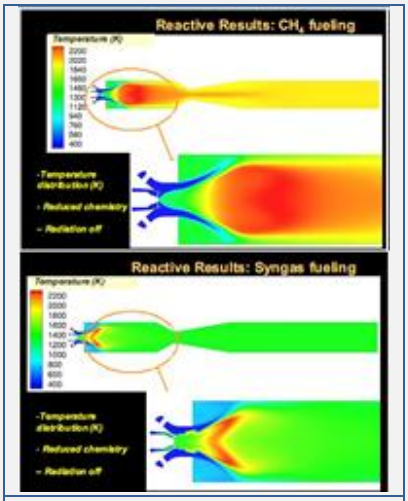
November 2010 – October 2011

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.

Second Year results:

- ✓ Manufactured and installed scaled burner prototypes on test rig sites, where first tests were performed, including isothermal flow field measurements and mixing studies using LIF. The test rig was modified to allow combustion testing at elevated pressure.
- ✓ Updated chemical kinetic mechanisms for H_2/syngas, in order to select universal best-to-use reaction mechanism.
- ✓ Completed the ignition delay time work with respect to H_2/CO mixtures in shock tube and RCM test rigs; additional experiments have been performed in a channel flow reactor in an attempt to expand the range of operating conditions to lower initial mixture temperatures.
- ✓ Developed numerical combustion models and tested against reference cases, including heat loss and preferential diffusion effects of H_2.
- ✓ Explored alternative combustion concepts (flameless combustion, wet combustion) in first preliminary lab scale combustion tests.



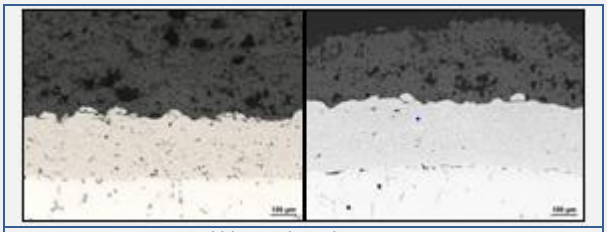
Flame Shape/Combustion Process
for CH_4 and Syngas

SP2 – MATERIALS

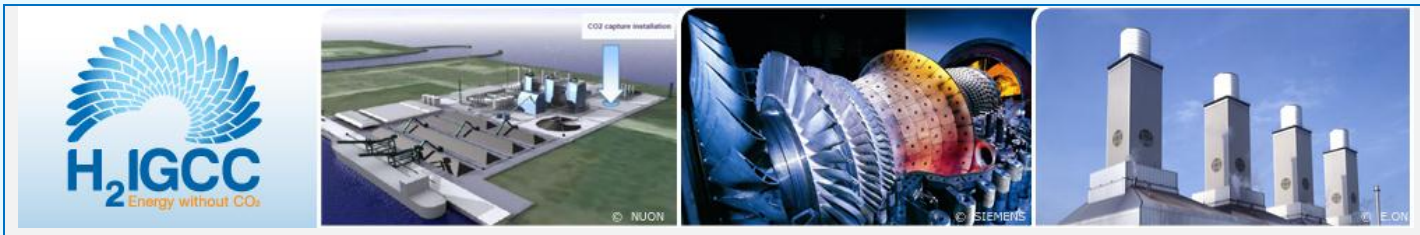
Subproject Objective: demonstrate cost-effective materials and coatings technologies to overcome the component life-limiting problems of overheating and of hot corrosion resulting from the higher temperatures and from residual contaminants in the syngas respectively; validate materials performance data,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

Second Year Results:

- ✓ GT materials supplied (alloys and coatings), test samples were coated, and materials test work started.
- ✓ Further proceeding and evaluation of non-destructive examination (NDE) by performing further NDE trials on combustors and blades, as well as investigation of F-SECT and Raman techniques.
- ✓ Initial investigations took place into concepts for novel multi-layered TBC systems and potential new bond coating compositions.
- ✓ Started to develop models for the specific degradation mechanisms, to form the overall component life prediction activity. Initial activities are focusing on solid particle erosion, hot corrosion and TBC lifing.
- ✓ Developed new test program for the demonstration of new materials and coatings in the novel IGCC operation environment.



Multi-layered coating system
With | Without defects



Subproject Updates

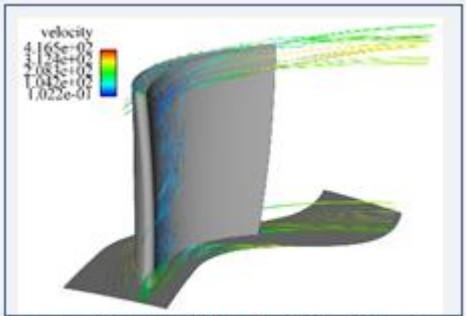
November 2010 – October 2011

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.

Second Year Results:

- ✓ Performed a literature survey to compose a list with gas turbines in the 250-300 MW class currently on the market, to serve as a basis to select a reference machine.
- ✓ Designed the baseline geometry of the compressor.
- ✓ Completed the generic geometry for the turbine and the cooling passages of the turbines.
- ✓ Guidelines were established for the modification required to alter the compressor and expander to match syngas operation while maintaining fuel flexibility. Also, significant efficiency improvements have been made to the compressor and the design of the cooling systems for the expander has commenced.



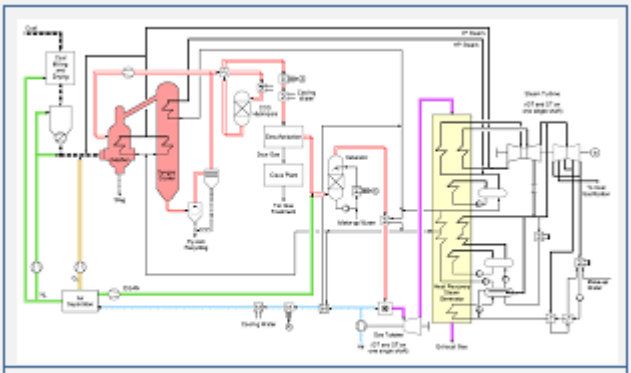
Turbine First Stage Rotor Flow Before Redesign

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.

Second Year Results:

- ✓ Defined the reference plant based on the characteristics received from partners, with the base case being defined as operating with H_2-rich syngas.
- ✓ Replaced theoretical best case efficiencies by realistic state of the art values to generate a realistic base case.
- ✓ Described the models used to simulate the various components in detail.
- ✓ Defined and investigated options for best cycle performance.
- ✓ Continuously updated the characteristics of the GT.
- ✓ Investigated options for stable operation under changing fuel compositions (i.e. with or without CO_2 capture).


IGCC plant schematic layout

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)

Project website: www.h2-igcc.eu

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