INTEGRATED TOOL FOR IGCC POWER PLANTS POWER, EMISSIONS AND COST PREDICTIONS

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Abstract: This work tackles the question of power generation by means of gasification. Growing economies and global warming are important challenges these years: so that cleaner and more efficient power plants designs have to be achieved. In this context, Integrated Gasification Combined Cycle (IGCC) power plants have an important role, due to their more efficient way of producing energy since fossil fuels. Actions are focused on clean power and H_2 from coal, and also in bioproducts. So, one of the future of coal-based power generation strategies should be CO_2 transport and storage in order to obtain a purer hydrogen stream. This work proposes a tool for estimating final plant outputs and economics for different scenarios. The technical performance has been modeled in Aspen Hysys and Aspen Plus, and models have been validated with real power plant data. Comparisons, in terms of power, emissions, efficiencies and costs between sixteen different plant designs are presented: they enhance differences in raw material, purification units layout, and hydrogen obtention.

Keywords: IGCC power plant, conceptual modelling, predictions, Aspen Hysys, different layout, COE

1. MODELLING PERFORMANCE AND PREDICTIONS

In this work, an integrated platform for different scenarios prediction has been done. On the one hand, Aspen Hysys is the software used as a main platform of the conceptual model. On the other hand, Microsoft Excel is the tool used for the economic calculations. The IGCC plant flowsheet can be changed (by the addition or the sustraction of units, or directly by changing the layout of the flowsheet). From the Aspen Hysys model, data such as power, emissions and efficiency can be obtained. From Microsoft Excel calculations it is possible to estimate preliminary costs: direct costs, the total capital requierement, operating costs and the cost of electricity (COE). The two platforms works in an integrated way.

1.1 Conceptual Modelling.

The model is implemented using two main chemical flowsheeting environments: Aspen Hysys and Aspen Plus, which are flexible tools for process simulation by providing thermodynamic models for the estimation of chemical properties and unit operation models for many processes. Aspen Hysys has been chosen as the platform for the overall process simulation because of its capability of accepting custom models as extensions, and it ease of coding. These models could be complex chemical reactions (COS hydrolysis) or partial gasification steps (pyrolysis). It also allows creating new chemical components not included in its database, such as non stoichiometric solids for raw material and char definition. Alternatively, Aspen Plus is used for calculations involving water systems and electrolytes. These ionic models are required to solve phase equilibrium problems for unit operation systems such as venturi scrubbers, SWS or MDEA absorbers. The aforementioned models have been integrated in Aspen Hysys by means of ANN extensions. Data required to train each of the ANN's comes from sensitivity analysis performed within Aspen Plus while the neural network training is carried out using the ANN package provided with Matlab 6.5. Matlab has been also used for gasifier model parameters estimation.

The global flowsheet studied in this work is a typical IGCC layout. It includes a PRENFLO gasifier and a series of purification units, i.e. a ceramic filter, a venturi scrubber, a COS hydrolysis reactor, a sour water stripper, a MDEA absorber and a Claus plant. An ASU is used to obtain oxygen at a purity of 85 wt%. Steam, oxygen and fuel raw materials enter the gasifier and they are converted into syngas, which is cooled down before entering the purification units. Heat is recovered by producing steam in the HRSG, which is used in a vapor turbine. In the venturi scrubber, syngas is put into contact with water that absorbs and removes acid and basic pollutants. Water is treated in the sour water stripper (SWS) and recycled back to the venturi, decreasing water consumption. After a purge from the SWS unit is required, this water is finally treated (this last step is not simulated). Syngas is further purified through the COS hydrolysis reactor. This unit converts COS into H_2S, which is removed in the MDEA absorber. Polluted streams from SWS, COS hydrolysis reactor and MDEA absorber are sent to the Claus plant, where sulfur from H_2S is recovered in liquid form. The obtained clean gas, after the MDEA absorber, is sent to the gas turbine. Heat from exhaust gas after the gas turbine is recovered in the HRSG. This model has been validated with industrial data from ELCOGAS plant in Puertollano (Spain). The ELCOGAS power plant is designed to produce around 335 MW of gross power with relatively low emissions. SO_2 emissions are controlled by removing sulfur species from the syngas before the combustion in the gas turbine cycle, and producing liquid sulphur. NO_x emissions are avoided by using preventive methods such as nitrogen saturation of the gas also before the combustion. It is worthwhile to mention that ashes are highly removed as slag in the gasification reactor due to high pressure and temperature conditions. Nevertheless, remaining particles are extracted from the syngas by means of filters. In relation to CO_2 and CO emissions, they are assumed to be produced in the gas turbine cycle. Other contaminants such as chlorine, mercury and heavy metals are distributed in the streams flowsheet by using experimental correlations, based on data found in the field of AGAPUTE (Advanced GAs Purification TEchnologies for co-gasification of coal, refinery by-products, biomass and waste, targeted to clean power produced from gas ans steam turbine-sets generator and fuel cells, supported by Agapute-RFS-CR-04006, 2005-2008) European project.
The model shows good agreement between simulated results and industrial data for outlet streams of purification gas units: venturi scrubber, sour water stripper, MDEA absorber, and Claus plant, as seen in Fig. 1. The error is a maximum of 25%.

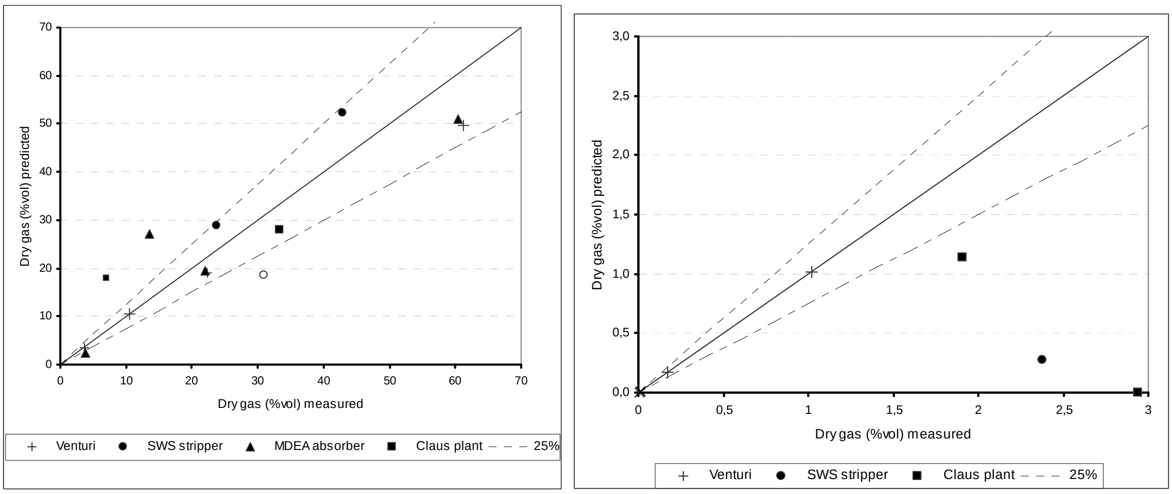

Fig. 1. Purification models validation with real power plant data.

Also, in orther to assure the model confidence, the result of the whole plant has been evaluated by means of the clean gas composition (where again a maximum error of 25% has been observed) and the final net power (with a maximum error of 17%). See Fig. 2. C2 to C6 make reference to Case 2 to Case 6 in different scenarios modelling, which are cases with different raw material compositions: by modifying the composition of coal and coke (which are the main feedstocks for ELCOGAS power plant).

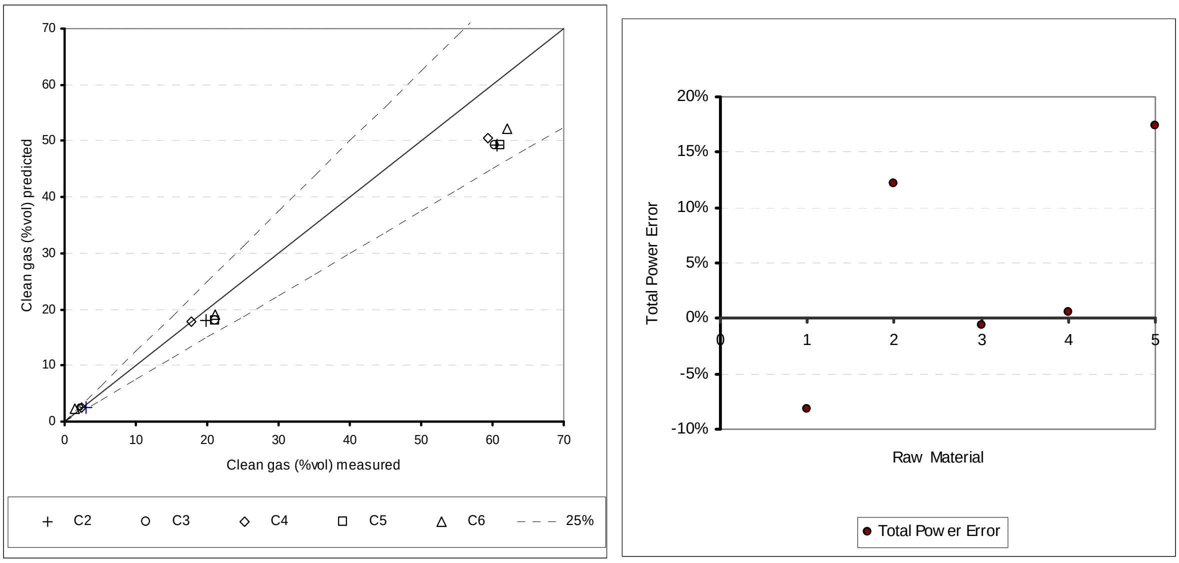

Fig. 2. Clean gas and net power validation.

1.2 Costs Evaluation.

Costs are evaluated by following the methodology of Christopher Frey and Akunuri (2001), which describes specific equations for IGCC power plants, based on empirical correlations. They are divided into equipment cost, total capital requirement, operating cost and COE. As example see Fig. 3 and 4: an example of breakdown of the capital cost distribution, and a COE formation for one of the simulated scenarios.

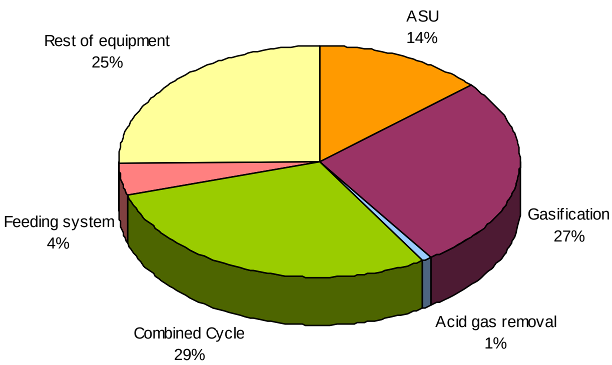

Fig. 3: Breakdown of equipment cost, in €

1.3 Results: Scenarios comparison

The scenarios comparison enhance sixteen different cases:

- Eight with different raw materials (coal , coke, a mistureof them, and a mixture of them plus a waste biomass, orujillo)
- Six more cases with different purification gas units layout: by avoiding some units, and also by adding a Selexol absorber or a Dolomite unit.

- Two more by adding a CO_2 purification train (with water gas shift reactor, MEA absorber and PSA) and considering hydrogen to the market or to power production.

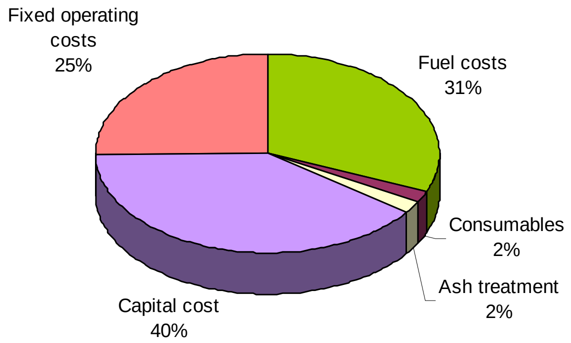

Fig. 4: Breakdown of COE, in cts€/kWh

All the scenarios have been compared by means of an objective function that takes into account emissions, power and COE. It can be said that this tool is completely useful for IGCC power plants prediction and study of investment.

REFERENCES

Christopher Frey H, Akunuri, N. (2001). Probabilistic Modeling and Evaluation of the Performance, Emissions, and Cost of Texaco Gasifier-Based Integrated Gasification Combined Cycle Systems Using ASPEN. Prepared by North Carolina State University for Carnegie Mellon University and U.S. Dept. of Energy, Pittsburgh.