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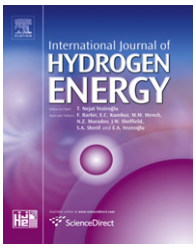

The Sotacarbo coal gasification experimental plant for a CO_2-free hydrogen production

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ABSTRACT

Being hydrogen the most promising energy carrier for distributed power generation and being the coal-to-hydrogen technologies far from their large-scale application, mainly due to their high costs, Sotacarbo has recently built up a pilot platform for the combined production of hydrogen and electrical energy from coal. The platform includes two different units: a 5 MW_{th} demonstrative plant and a 200 kW_{th} pilot plant (feed with a maximum of 35 kg/h of coal).

This paper, together with a detailed description of the pilot plant (which includes a fixed-bed up-draft gasifier and the whole syngas treatment line for power generation and hydrogen production), reports a critical analysis of the main results obtained in the first experimental campaigns, carried out by using a low sulphur South African coal and a high sulphur Sardinian coal (for both kinds of coal, a hot gas desulphurization system allows to reduce at about 10 ppm the H_2S concentration in the clean syngas).

In particular, a hydrogen production of about 1.4–1.6 kg/h (depending on the primary fuel composition and the operating conditions) has been obtained from a portion of syngas corresponding to the gasification of 7 kg/h of coal.

1. Introduction

Otherwise oil and natural gas, which main fields are confined in a relatively small area, coal is widely available in the world and distributed more uniformly than other fossil fuels. This allows a great price stability and represents a secure source from a strategic point of view [1]. Moreover, the advanced in development of clean coal technologies, allows an environmental-friendly use of coal, in particular for power generation.

Among clean coal technologies, gasification is particularly interesting since it allows both power generation (mainly by using integrated gasification combined cycles power plants, IGCC) and clean fuels production, with a particular reference to hydrogen, which promises to be the most important energy carrier [2,3]. The current worldwide hydrogen production is greater than one billion of cubic meters per day, and 18% is produced from coal [4,5].

All over the world, gasification processes, due to the low flexibility of synthesis gas (syngas) production, are, so far, mainly used in large-scale IGCC power plants in order to supply base energy load. But in a short-term future, the possibility to use syngas to co-produce hydrogen and electrical energy [6–10] could make gasification technologies very interesting for medium and small-scale industrial applications.

In this context, Sotacarbo, through different research projects regarding hydrogen production for distributed power generation, is developing an integrated gasification and syngas treatment process for combined production of hydrogen and

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Fig. 1 – The Sotacarbo pilot platform.

electrical energy, to be used, in particular, in medium and small-scale commercial plants. To this goal, a flexible and fully equipped pilot platform has been recently built up at the Sotacarbo Research Centre in Carbonia, in South-West Sardinia (Italy). The platform includes a demonstrative (700 kg/h) and a pilot (35 kg/h) coal gasifiers; in particular, the latter is equipped with a syngas treatment process for hydrogen and electrical energy production.

This paper reports the main results of the first experimental campaigns in the pilot plant, with particular reference to hydrogen production.

2. Experimental plant configuration

In order to test different plant solutions and different operating conditions, a very flexible and simple layout for the experimental equipments has been considered.

The current layout of the Sotacarbo pilot platform (Fig. 1) includes two fixed-bed up-draft Wellman-Galusha gasifiers: a 700 kg/h (corresponding to about 5 MW_{th}) demonstrative gasifier and a 35 kg/h (200 kW_{th}) pilot gasifier. The choice of this kind of gasification process is a consequence of the particular commercial interest in the field of medium and small-scale industrial applications.

Whereas the main goal of the experimental tests on the demonstrative plant is the optimization of the gasification process and the definition of start-up and shut-down procedures, pilot plant is used to develop the syngas treatment process for hydrogen production. Therefore, whereas demonstrative plant is only equipped with a wet scrubber (for syngas cooling and tar and dust removal) and the cold syngas are directly sent to a flare, pilot plant is equipped with a complete and flexible syngas treatment process for hydrogen production (schematically represented in Fig. 2) [11].

In the Sotacarbo pilot plant, raw syngas from the gasification process is sent to a skid which includes a wet scrubber (in order to reduce syngas temperature from about 300 to 50 °C and to operate a primary dust and tar separation), a first cold gas desulphurization stage (which currently uses a soda-based solvent) and an electrostatic precipitator (ESP), which allows to achieve a fine particulate and tar removal.

According to the design conditions, downstream the ESP, syngas is split in two streams: the main stream, about 80% of the produced syngas, is sent to the power generation line, whereas the secondary stream, that is the remaining 20%, is sent to the hydrogen production line.

In particular, power generation line is constituted by the second cold gas desulphurization stage, based on a hydrogen sulphide (H_2S) absorption process (which uses a mixture of soda and sodium hypochlorite, diluted in water, as solvent), directly followed by a syngas-feed internal combustion engine.

On the other hand, hydrogen production line includes a compressor, which increases the pressure to about 0.14 MPa (in order to win the pressure drops of the treatment line), followed by an electric heater, a two-stages dry hot gas desulphurization process (which employs metal oxide-based sorbents), an integrated CO-shift and CO_2 absorption system and a hydrogen purification system, based on the PSA (pressure swing adsorption) technology, which is widely common in the industrial applications due to its low costs [12,13]. The

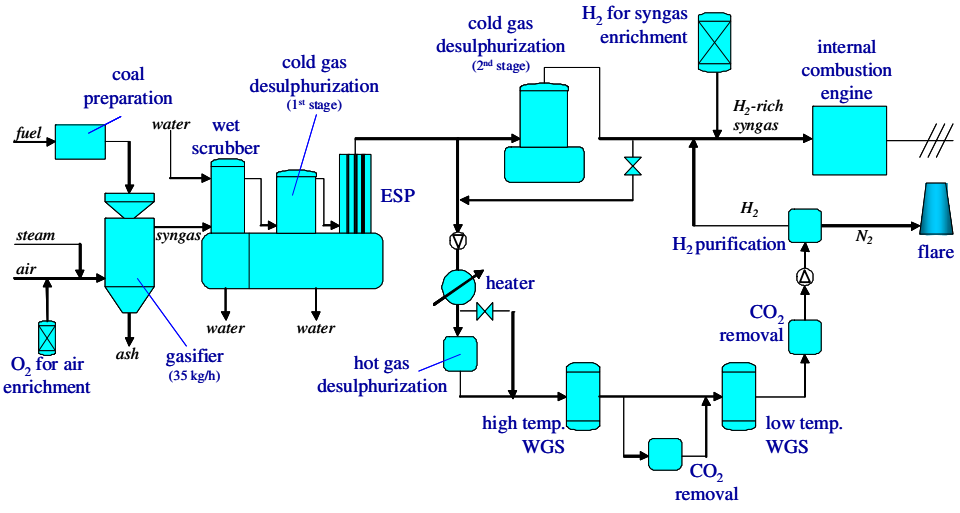

Fig. 2 – Pilot plant simplified scheme.