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Modelling of a chemical quasi-equilibrium system of fluidised-bed biomass gasifier multiphase reactor using Aspen Plus

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1. Introduction

Local renewable energy sources can allow greenhouse gas emission and foreign fossil fuels reduction and energy security increase. Within renewable energy, biomass-gasification power plants can convert local low cost solid waste biomass to high grade fuel gas [1]. The process works at high temperature (750-1000 °C) and, by means of oxidising agents, produces a fuel gas, called syngas, mostly rich in H_2, CO, CO_2, CH_4 and steam along with several organic and inorganic contaminants [1]. The investigation of plant behaviour, varying the operative conditions, is needful for design and operation of such complex plant [2]. Thus, system simulation models, that have good description of both chemical and physical phenomena of the multiphase reactors involved and thus assessing the plant behaviour with minimal temporal and costs, are needed [3]. Aspen Plus, a chemical engineering process optimization software, represents one of the best tool to simulate chemical plants [3]. Nevertheless, in literature, there is a lack of flexible and fast, but accurate, model of biomass gasification that are able to give results closer to the real ones taking into account both organic and inorganic contaminants. In order to do that, a model of fluidised-bed biomass gasification is developed using Aspen Plus, including the production of inorganic (hydrogen sulphide, hydrogen chloride, ammonia and alkali) and organic (toluene, benzene and naphthalene) components. The results obtained were compared and validated against experimental data reported in literature.

2. Methods

The developed model is based on the Gibbs free energy minimization applying the restricted quasi-equilibrium approach via Data-Fit from experimental data by means of Aspen Plus software. This approach gives an accurate description of the syngas composition and does not require specific information on the dimensions, capacity and structure of the reactor [4]. By means of the Data-fit, it is possible to utilise the QET (Quasi-Equilibrium Temperature), at which each specific chemical reaction is considered to reach equilibrium, rather than the actual gasification temperature of the gasifier. , simulated as a RGibbs reactor, and the biomass is hazelnut shells, which represent an abundant agricultural sub-product in regions of moderate climate.

3. Results and discussion

In Table 1, the results from the simulative model (a) have been validated against experimental data of Rapagnà and Latif (b) [5], who used a lab-scale fluidised-bed reactor as gasifier, worked at 1 bar and 800 °C with hazelnut shells as biomass feedstock and silica sand as bed-material; pure steam is the oxidising agent (steam to biomass ratio equal to 0.8).

Table 1 Simulative results compared to experimental ones

	H_2 [*,1]	CO [*,1]	CO_2 [*,1]	CH_4 [*,1]	NH_3 [*,1]	H_2S [*,2]	HCl [*,2]	NaOH [*,2]	KOH [*,2]	C_7H_8 [*,3]	C_6H_6 [*,3]	$C_{10}H_8$ [*,3]
a)	44.2	16.7	22.1	5.3	1112.2	1479.1	701.3	87.7	172.6	4.5	10.6	4.5
b)	45.0	26.7	20.0	6.0	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.	n.e.

[*,1] %dry mole fraction, [*,2] ppm, [*,3] g/Nm^3, n.e. abbreviation of "not evaluated"

The comparison shows a very comparable product syngas composition. Tar and inorganic contaminants, not evaluated by Rapagnà and Latif, are compared with other literature data, showing a good reliability of the model [6,7]. The gas yield and the LHV (low heating value) predicted by means of the developed simulation reached the value of 1.3 Nm^3/kg and the 9.3 MJ/kg respectively. The Aspen Plus flow sheet of the developed model is shown in Figure 1.

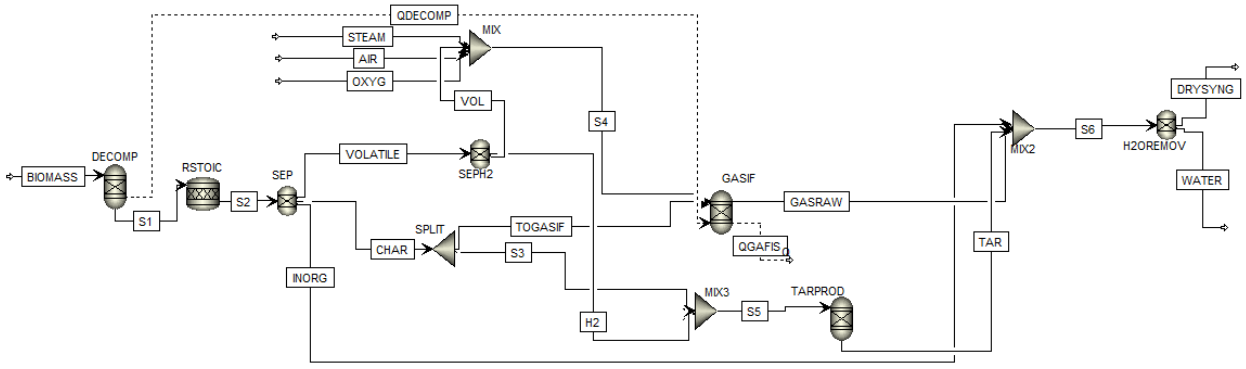

Figure 1 - Flowsheet of the plant evaluated in this study

4. Conclusions

The proposed model gives a syngas composition in good agreement with experimental data. The discrepancy value obtained for hydrogen, respect to experimental data, is only of 1.7%. So, by means of the developed model, it will be possible to predict a trustable syngas composition and contaminants; evaluating, moreover, the effect of several variables including gasification temperature and steam to biomass ratio on the gas composition.

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