Gasification of Miscanthus X Giganteus in catalytic conditions Production of syngas, preliminary results

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The continuous increase in CO_2 content in the atmosphere, mainly due to the combustion of fossil fuels, is predicted to lead to the global warming. Biomass is considered as a promising renewable energy source. The conventional method for the production of synthesis gas from biomass is gasification. The gasification of biomass provides the most attractive solution for the introduction of biomass in decentralised power production.
Conversion of biomass to synthesis gas becomes more and more important in terms of renewable energy sources. Moreover, in the different processes of gasification, the main problems remain the total removal of tars and light hydrocarbons like methane formed during the thermal treatment.

In fact, it is necessary to obtain a very pure and stoichiometric mixture of CO and H_2 that can be used for the preparation of hydrocarbons via the Fischer-Tropsch synthesis. To solve this problem, beside temperature reaction process, it is also necessary to select an appropriate and efficient catalyst. Among the factors affecting the activity of the tar decomposition reactions, the positive catalytic role of iron has been demonstrated[1,2]. This good catalytic behaviour is exhibited by olivine, an iron-containing mineral, in a systematic study of bed inventories for the biomass gasification process. As reported extensively in the literature, biomass steam gasification (performed in main cases in fluidised bed reactors) results in the conversion of carbonaceous materials to permanent gases (H_2, CO, CO_2, CH_4, and light hydrocarbons), chars and tars[1]. The addition of steam water as gasifying agent and catalyst in gasification process makes it possible to obtain high-grade product[3].

This study concerns the first results obtained in Miscanthus X Giganteus (MxG) gasification. Since about ten years, several works are devoted to the valorisation of MxG as culture, materials, combustion or pyrolysis.

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Table 1: Composition of Miscanthus X Giganteus

Composition % of dry matter			
Cellulose	Hemicellulose	Lignin	Ash
43	27	24	<4

Ultimate Analysis (%)		Composition of ash (%)			
C	48,67	CO_3^-	4,53	CaO	4,57
H	5,45	SO_3^-	3,42	MgO	3,25
O	42,50	Cl^-	3,39	Na_2O	0,21
S	0,04	P_2O_6	3,00	K_2O	23,74
N	0,45	SiO_2	49,17	Others	4,32
Cl	0,23	Fe_2O_3	0,20		
Ash	2,76	Al_2O_3	0,20		

Miscanthus X Giganteus (MxG) is one of the most promising biomass crops for energy utilization. It's a renewable resource with almost net CO_2 emission since carbon is completely fixed during the growth especially for C4 plants like MxG. Moreover, MxG present some advantages which are favourable for its valorisation in different ways (combustion, pyrolysis, gasification) in order to produce bio-oils, bio-fuels or hydrogen:

- MxG is a hardy perennial grass producing very high yields of bamboo like cane up to 4m tall. The yields found in the literature ranged from 15 to 40t/ha.
- Starting from the same rhizome, MxG can be harvested all the year during twenty years and content less than 15% moisture if the harvesting is done in march. MxG is an environmentally friendly crop which requires little or no pesticide or fertiliser.
- MxG can be cultivated in all type of ground (pH between 5 and 7.5 for example).
- MxG contains an average of 2% of mineral part, and not more than 0.2 % of elemental sulphur (Table 1).
- In term of vegetable structure, MxG is well organized and contains 43% of cellulose. The calorific power of MxG is the half of the petroleum one (1TEP ≈ 2t MxG) and calorific value of 16400 kj/kg.

The aim of this work is to obtain synthesis gas from biomass gasification among five ways (Fig.1.). Hot gas conditioning is achieved by passing the raw gasifier product gas over a solid catalyst in a fluidised-bed (or a fixed-bed) under temperature and pressure conditions that essentially match those of the gasifier. Air gasification reported higher efficiency being achieved by lower oxygen consumption, better heat recovery and higher carbon conversion compared to a process based on non-catalytic techniques. The thermal cracking of the hydrocarbons is also possible; however, this method is not considered a feasible option as it requires high temperatures (>1100 °C) to achieve high cleaning efficiency and it also produces soot[4].

Fig.1. Gasification process

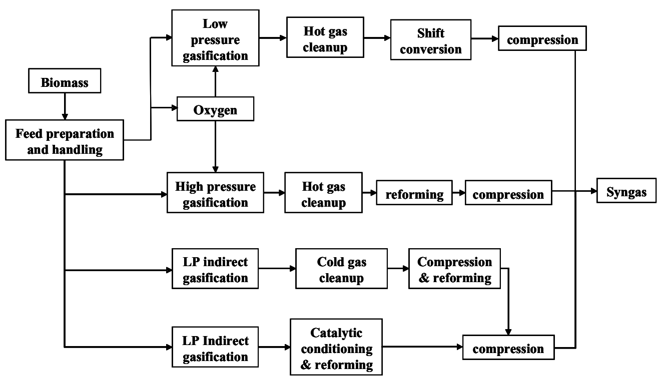

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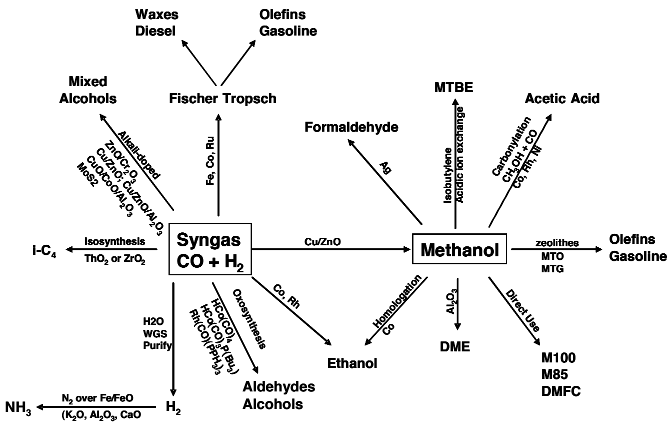
Fig.2. Syngas conversion processes

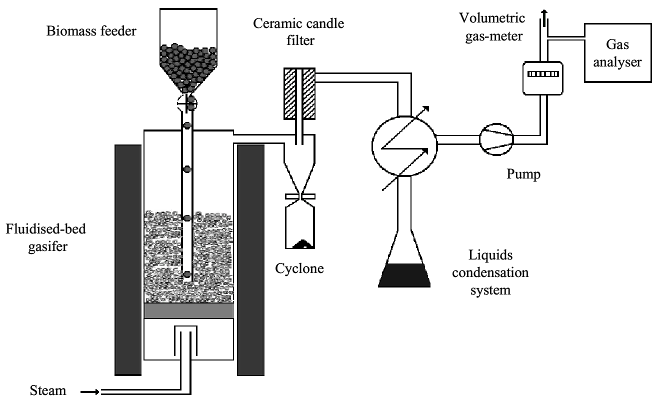


As the raw gas passes over the catalyst, the hydrocarbons may be reformed on a catalyst surface with either steam or carbon dioxide or both to produce additional carbon monoxide and hydrogen[4].

From syngas, we can produce different compounds (Fig.2.). Either increase the yield of H_2 using water gas shift reaction, then production of ammonia or methanol synthesis or production of bio-hydrocarbon by Fischer Tropsch synthesis.

The experiments were carried out in a fluidised-bed gasifer in catalytic conditions with water steam flow[5,6]. The biomass is continuously fed inside the system (Fig.3.) and gases are cleaning by cyclone with ceramic candle filter. Water and organic vapours (tars) are condensed by a cooling system. The fluidising medium is steam, the flow rate is controlled by a water dosing pump positioned upstream the steam generator.

Fig.3. Experimental system



The olivine affects the activity of the tars decomposition reactions, avoid carbon deposition on the surface by his positive catalytic role of iron and keep good mechanical intensity after calcination and high temperature reactions[1,5,6]. Thats why the fluidized bed consisted of 3 kg of 0.48 mm olivine particles of 2500 kg.m^{-3} density.

MxG was provided in form of pellets (diameter: 8 mm). The pellets were too large to obtain a constant flow; therefore they were crushed in order to obtain a mixture of powder and crushed pellets. Then, the biomass is feed continuously inside the fluidised bed. For each gasification run, the biomass feed rate was fixed between 7 and 8 g.min^{-1}.

The amount of the condensed organic material with water is determined by weighting. The quantity of dry gas produced is measured by a volumetric gas-meter. The concentrations of the dry gas are continuously monitored: CO, CO_2 and CH_4 with an infrared analyser and H_2 with a thermal conductivity detector. The quantity of char is obtained by determination of CO and CO_2 after burning air with the whole carbonaceous residue trapped inside the reactor at the end of each gasification run.

The experimental runs with olivine were performed at three different temperatures (815°C, 860°C and 880°C). The time of each runs is 60 minutes.

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The evolution of gas amounts (Fig.4.) (calculated considering the carrier gas i.e. N_2) is carry out during the run at 880°C. The gasification occurs before 60 minutes and after the combustion takes place to determine the char content by measure of CO_2 and CO. The flow of gases is irregular because the flow of MxG is not constant and involves variation of pressure in reactor. This point will be improved in the future by optimising the MxG particle size.

The distribution of gases (Fig.5.) shows different yield of gases. The percentages are calculated without N_2. The amount of H_2 is higher than 40% and increases with temperature while CH_4, CO_2 and CO contents decrease. CO amount is about 25%. We have good H_2/CO ratio for methanol synthesis.

Fig.4. Evolution of gases

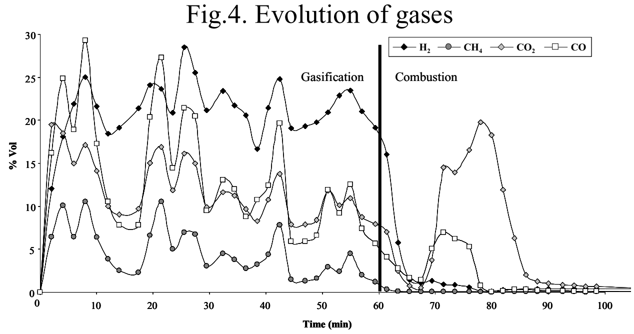
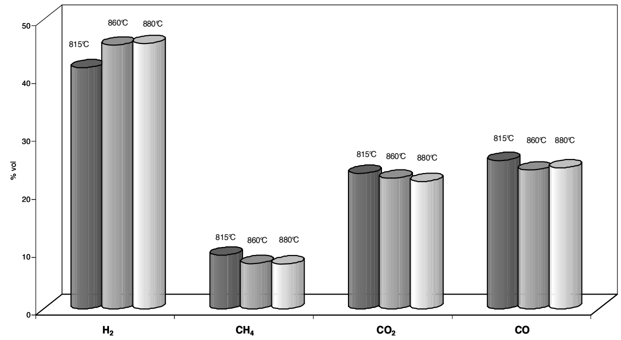


Fig.5. Distribution of gases



The experimental results show that Miscanthus X Giganteus is suitable for gasification. About $1.1 N.m^3.kg^{-1}_{(biomass)}$ of gases are obtained, with H_2 content higher than 40% and about 25% of CO by volume. This cleaning gas with this specification is suitable for industrial applications, both for highly efficient electricity production and as a feedstock for chemical synthesis like methanol synthesis. However, problems of particle size of MxG are unfavourable for the flow steadiness. These experiments are preliminary for MxG. Modifications can be made to increase the production of H_2 by the addition of a nickel based catalyst[4], because interesting results have been obtained with Ni/olivine in the gasification of wood ships[7].

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