UDK 662.69

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Biomass Processing Research in Enea CR Trisaia (Italy) and in the Gas Institute of NAS of Ukraine

The main results of R&D activities on biofuel research area of Biomass laboratory at ENEA CR Trisaia and Combustion Processes Department of the Gas Institute of NAS of Ukraine such as synthesis gas, ethanol and produced gas production for natural gas substitution in industrial steam boilers are presented.

Ключевые слова: biomass, synthesis gas, ethanol, generator, produced gas, biogas, steam boiler.

Представлено основні результати технологічних досліджень з біопаливної тематики лабораторії біомаси дослідного центру ENEA CR Trisaia (Италия) та відділу процесів горіння Інституту газу НАН України, а саме з виробництва синтез-газу, етанолу та генераторного газу як замінювача природного газу у промислових парових котлах.

Ключові слова: біомаса, синтез-газ, етанол, генератор, генераторний газ, біогаз, паровий котел.

Enea Research Centre Trisaia (Italy)

Amongst different renewable energy, biomass represents a very interesting though difficult to utilise, energy source, in Italy [1]. The difficulties of varied nature and of significant importance, concern mainly the management of raw material, final uses, technologies, social/economic impact, articulation of the systems, normative, etc. This, in fact, explain why in spite of so big potential of biomass (not inferior than 21–23 Mtep) even as on today, around 2,5 % of the National energy demand (well under the European average) is met using this source.

The principal sectors of biomass uses are, the domestic heating, production of process heat, production of electric energy in centralised plants using agro-industrial residues, solid urban wastes, biogas from sewage sludge and, finally, the liquid bio fuels (biodiesel, bioethanol and sun-diesel) in for gradual replacement of the traditional fossil fuels as expected by the European Commission.

Because of the high potential awarded to this energy source, ENEA efforts are mainly focussed to sharply increase the utilisation of biomass in Italy. To this purpose, about 20 permanent researchers/technicians (located in Trisaia Research Centre) are engaged on experimental activities, which cover many specific items, starting from the availability of biomass, through the biofuel and hydrogen production, to the energy production plants [2–4].

The biomass gasification has been selected by ENEA as a high priority technology. Consequent to such choice, several projects (thermo-chemical conversion process of biomass via gasification) in co-operation with both national and international institutions have either already been completed or are in progress.

A number of experimental plants based upon different technologies (fixed bed, BFB, FICFB gasifiers) and of different sizes (10 kW, 100 kW, 500 kW, 1 MW), are available at Trisaia (Fig.1, Table 1).

The plants have been investigated experimentally to test the most promising field of application (production of fuel gas for power generation) following different possible ways such as via internal combustion engine, gas turbines and high temperature fuel cell (MCFC). The use of biomass gasification for syngas production to biofuels conversion has also been considered. More recent activities are aimed at the development of gasifiers dedicated to the production of syngas (to be used in an internal combustion engine), synthetic biofuels (sun-diesel, methanol) as well as hydrogen.

As on today, development of a 1,3 MW reactor for the production of a fuel gas to be fed to a

gas turbine, is under investigation. The product gas will be produced by oxygen/steam gasification of biomass by means of a bubbling fluidized bed. The associated plant is under construction. The 1MWth reactor will be the starting point of the prototype reactor that will be developed and tested throughout the Unique project.

More recent activities are aimed at the development of gasifiers dedicated to the production of syngas (to be used in an internal combustion engine), synthetic bio fuels (sundiesel, methanol) as well as hydrogen. Lastly, fixed bed gasifier plants have been developed, most appropriate for their use, especially, in the developing countries as well as for their wide spread diffusion at the national level.

The design of the reactor and the use of steam as gasification agent gives this process a nearly nitrogen free product gas with a high calorific value of around 12 MJ/Nmi dry gas. By using a natural catalyst as bed material and gasification temperature above 800 °C, the tar content was reduced below 5 g/Nmi. However an adequate purification of the product gas is obtained thanks to the inclusion of a high temperature ceramic filter in the cleaning section. By adding in the reactor a specific catalysts, the hydrogen content in the product gas can go over 50 % and its quality can be further improved.

Table 1. Development of processes for synthetic gas production

Syngas composition, % (vol.)	Process technology			
	Fluidised bed Enriched Air/Steam, 1 MW	Circulating fluidized bed Air/Steam, 500 kW	Updraft fixed bed Air/steam, 150 kW	Downdraft bed Air/steam, 150–450 kW
H_2	23	34,1	20	15
CO	17	25,1	21	22
CH_4	6,2	10,4	4	3
N_2	0,9	9,6	40	40
CO_2	20,9	20,8	6	20
H_2O	32	–	9	–

Production of bio ethanol from lignin-cellulose material

The technology for bio ethanol production from sugar and starch crops (sugar cane, sugar beet, maize, etc.) is mature enough to permit to achieve liquid fuel competitive, both for price and performances, to gasoline and diesel. With perspective of its diffusion on large scale use, not to penalise the alimentation product market, it will be necessary to find alternative raw materials. It is in this context that ENEA has focussed its research on the use of lignocellulosic biomass that could be specifically cultivated or easily recovered from agricultural, forests or agro-industrial wastes.

These materials, in contrast to the sugar syrups obtainable from reed or beet, must be attached with acids or enzymes to achieve simple sugar to start fermentation. It is because of this reason that the production of ethanol from lignocellulosic biomass, time being, is bit costly when compared with sugar and starch.

In spite of quality and availability of the raw material, it is necessary to improve the technologies for pre-treatment, enzymatic hydrolysis and separation of alcohol from the broth, apart from the valorisation of the current processes that of lignin and hemicellulose.

In view of international fervent activities and increasing economic affair, ENEA has chosen to focus its attention predominantly on pre/treatment stages of biomass and developing technical-scientific collaborations with leading European institutions in the sector. Steam explosion with low environmental impact and producing highly biodegradable substrate, has been selected as the appropriate technology for the biomass pre-treatment.

The process is based upon on the natural ability of the water vapour at high temperature and pressure to penetrate and breaking of chemical bonding of the polymeric, cellulose, hemicellulose and lignin, in the vegetal materials. The final result is to make available the sugars contained in the feed material that otherwise could not be metabolised easily by the micro-organisms used in the successive stages of bio-conversion.

Fig.1. 500 KW_{th} FICFB gasifier at Trisaia.

Two pilot plants have been realised in Trisaia, to study experimentally, Steam Explosion, both in batch and continuous version. The plant operating in continuous mode, called STELE, is capable to treat nearly 300 Kg/h of biomass. It is equipped with a system for the treatment of the stream of product exposed. Extraction with water, caustic solutions and filters are made on semi-industrial scale to separate cellulose and hemicellulose, and lignin. The optimised exploration processes, together with energetic applications, certainly reduces the cost of bio fuel production.

Some of the R&D activities have been recently undertaken, both on thermo-chemical and biotechnological processes for hydrogen production, due to the well known strategic role of this gas as an energy vector, and on products non-energetic, as a follow-up of experience gained on biomass.

Concerning hydrogen production, a few processes are under investigation, namely, reforming of pyrolytic bi-oil obtained from «fast pyrolysis», to be used in carbonate fuel cell, reforming of bio ethanol and photosynthesis micro-organisms and, finally, technologies of separation applied on product gas from biomass gasification plants.

The Gas Institute of National Academy of Sciences of Ukraine

Along with traditional for the Gas Institute R&D activities in the area of effective natural gas use in industry and municipal sector (effective and ecologically acceptable technologies and equipment) last two decades Institute actively joined to the biofuel research area. The main directions of this activities are the next:

— biogas utilization — landfill gas separation and utilization for power production, aeration stations and alcohol plants biogas use as fuel in industrial boilers;

— producer gas production and use as fuel in industrial boilers;

— biomass application in industry as natural gas substitute in industrial furnaces.

Last two directions are in progress in our Institute Department of Combustion Processes. In it R&D activities in Department are combined basis and applied researches that are finally directed for developing proper technologies and equipment for farther implementation at industrial enterprises.

Before to select process of produced gas production for biomass processing relative to direct biomass combustion have been estimated preferences and limitations of mentioned above processes. Gasification process has such preferences as smaller cost of transition at biomass use — not necessity for boiler substitution (need only for burners substitution), after re-equipment exploitation as at biomass as well as at natural gas (in failure of raw material supply) or at the it mixtures is possible, fuel with 40 % humidity is possible for use, biomass of different fractional composition and biomass mixtures are possible for use, less harmful influence on environment, produced gas can be used as fuel and for electricity production. To the limitations of biomass gasification are related necessity of qualitative produced gas cleaning from resin and cooling, necessity of generator location out from the boiler house, relative more complicated automation system.

From the other side biomass combustion also has some preferences such as relative equipment simplicity and comparatively more high efficiency of primary energy use. To the limitations of combustion process are typical fuel fractional composition and kind limitations, requirements to the fuel quality, necessity of preliminary fuel drying, necessity of fuel reserves accumulation for it regular feeding.

Summarizing the gasification process preferences and limitations we came to the conclusion that gasification process is more universal and represents proper interests for commercial structures relative to combustion process.

Experimental research works have been undertaken at the pilot complex 300 kW capacity at different raw materials, such as wood chips, sunflower husk and pit (Fig.2). Combustion of received generator gas showed rather low level of contaminant concentration in the products of produced gas combustion. So, carbon dioxide concentration was zero for wood chips and peat and 13 ppm for sunflower husks, NO_x concentration was accordingly 93, 31 and 29 ppm, SO concentration — 35, 1 and zero.

Considerable research work has been undertaken also to design and develop different kind of burner devices. All burner devices passed proper test and certification. Department together with some Ukrainian private companies develops generators with thermal capacity ranging from 0,3 to 3 MW_{th}. Such generators constructed at the different Ukrainian enterprises and now are working in testing regime.

At the Paper factory (city of Malin) is constructed generator 3 MW capacity (apparently is most powerful in Europe) that are operated at the wood chips. Produced gas is directed to the steam boiler 25 t/hour capacity (Fig.3). Average monthly produced gas generation in recalculation on the natural gas consists 50 thousands nm^3.

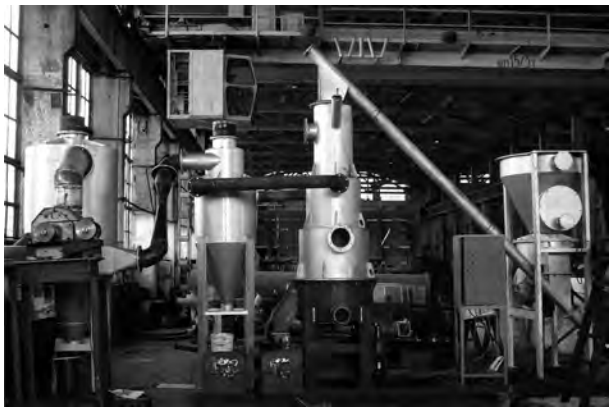

Fig.2.Gas-producing complex for biomass processing 300 kW.

Fig.3. 3 MW generator at Malin paper factory.

Below at the Table 1 represented producer gas composition and at the Table 2 produced gas characteristics.

In the Table 3 are represented characteristics of manufactured produced gas received on the basis of thermodynamic calculations.

As follows from the table data the growing of generator capacity leads to the calorific values lowering as a consequence of combustion theoretical temperature decrease.

Opportunties for collaboration based on mutual concern

At present, companies and R&D institutions of several countries, are conducting significant pre-industrial R&D on of 2nd generation biofuels. It is possible that similar research activities are carried out by different organizations around the world at the same time and without any kind of coordination. One of the reasons for this lack of international coordination is the willingness to achieve a technological edge over prospective competitors by

Table 2. Producer gas composition (reverse process, wood chips, 30 % humidity

Numbers	Components	Generator capacity, %		
		30	70	100
1	H_2	8,71	9,99	7,04
2	O_2	3,24	2,05	1,63
3	N_2	49,9	54,48	57,38
4	CH_4	3,46	3,22	1,84
5	CO	16,45	10,86	18,78
6	CO_2	14,07	15,08	10,09
7	C_2H_4	1,23	1,25	0,55
8	C_2H_6	0,33	0,39	0,15
9	C_2H_2	0,13	0,19	0,08
10	C_3H_6	0,25	0,26	0,12
11	C_3H_8	0,03	0,04	0,0
12	iC_4H_{10}	0,11	0,08	0,05
13	nC_4H_{10}	0,04	0,09	0,04
14	H_2O	2,05	2,02	2,25
	Σ	100	100	100

the many players engaged in this sector, which are often investing significant resources in R&D and therefore have a strong interest in protecting IPRs. However, this lack of coordinated international R&D efforts will result in turn in a slower pace of industrialization of such technologies, whereas if international cooperation is boosted, 2nd generation biofuels could reach a widespread industrial deployment sooner than most analysts expect.

In the above context, it is worth to note that so far generation of biofuel using different kind of biomass resources such as sugar cane bagasse, straw, wood and agricultural residues, are concerned, it is important that efforts be made to explore prospects and potential of production of «second-generation» bioethanol, in Ukraine, with possible collaboration at the international level.

The feasibility study based on scientific collaboration between Ukraine and Italy will identify the areas where a joint Ukraine-Italian R&D effort could have the highest potential of creating synergies for industrial cooperation. A review on the activities carried out and the expertise available in Ukraine and Italian Research Centres,

Table 3. Produced Gas Characteristics

Parameter	Generator capacity, %		
	30	70	100
Gross calorific value, MG/nm³	6,07	5,55	4,70
Lower calorific value, MG/nm³	5,62	5,09	4,43
Stoichiometric coefficient ratio	1,12	1,08	0,875
Combustion theoretical temperature, K	1933,0	1830,6	1809,6

universities and companies, will be conducted in order to identify such areas of synergy.

Possibile research and development activities

1. High-Efficiency Energy (Non-Food) Crops And Waste – Derived Biomass; 2. Pre-Treatment Process; 3. Enzymatic Hydrolysis; 4. Fermentation; 5. Process Plant Analysis; 6. Techno-economic assessment.

Expected results

It is expected that the results obtained from the proposed feasibility study will be useful in terms of creating the conditions for conducting joint ukraine-italian pilot projects or even industrial activities aimed at accelerating the deployment of second-generation bioethanol technologies.

Conclusion

Use of biofuels in transport are important for reducing emission of green house gases (GHG) and the EU duly recognising the roles biofuels have to play support the need for increasing the share of biofuels in the transport sector, especially in road transport that generates nearly 85 % of the transport sector's emission.

To build trust, good interface with all stakeholders including the vehicle manufacturers and oil companies, is a must. Given the present state of market progress and a strong political support, ENEA focused its R&D activities on biomass for the distributed electricity production and biofuels in the framework of European project.

In view of significant gains on energy and environmental benefit it is very important to have a close collaboration with countries having ever increasing demand for energy for sustainable development, in the near future.

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Received February 9, 2011

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Исследования процессов переработки биомассы в ENEA CR Trisaia (Италия) и в Институте газа НАН Украины

Представлены основные результаты технологических исследований по биотопливной тематике лаборатории биомассы исследовательского центра ENEA CR Trisaia (Италия) и отдела процессов горения Института газа НАН Украины в области производства синтез-газа, этанола и генераторного газа как заменителя природного газа в промышленных паровых котлах.

Ключевые слова: биомасса, синтез-газ, этанол, генератор, генераторный газ, биогаз, паровой котел.

Поступила в редакцию 09.02.11