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ANALYSIS OF THE FUNCTIONAL SOLUTION OF THE GAZOGEN TLUD

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Abstract: *The paper presents a modern way of preparing and using the vegetal biomass for the ecological production of the cheap thermal energy required in the heating installations, technology specific to the rural economy based on agricultural activities. The goal of the project is to develop a prototype of a generating system based on the TLUD principle, consisting of the gas generator, the burner, the heat exchanger and the electronic drive and control system, intended for the heating of greenhouses, which operates with raw materials from secondary agricultural production, incorporating the latest innovative technical solutions and being clearly superior in performance, features and design compared to products of the same category on the market.*

Keywords*: Gas generator, TLUD, vegetal biomass, biochar*

1. Introduction

Romania has a great potential for renewable energy, especially hydro, wind and biomass. Biomass will play an important role in the National Renewable Energy Action Plan, which should be developed within the framework of the Renewable Energy Directive. The Ministry of Economy, Commerce and Business Environment takes the initiative to develop this action plan.
The Biomass Master Plan focuses on delivering sustainable energy, in which biomass plays an important role. Under the Biomass Master Plan we have identified the important role that biomass can play in our fuel mix. We have also identified the most important stakeholders from government and industry and have defined their role in biomass development as the most important renewable energy source in Romania. Together we can meet the EU's renewable energy obligations in 2020.
Romania has the opportunity to take an important step towards the efficient use of biomass at national level. This will contribute to the achievement of the guidelines set out in the new Directive 2009/28 / EC on the use of energy from renewable sources. It will also allow for the reduction of CO2 emissions in Romania, increase the efficiency of different industries and create new national and international market opportunities for private companies. The Ministry of Economy, Commerce and Business Environment (MECMA) in Romania is responsible for implementing renewable energy and bioenergy policies. The Ministry requested assistance from the Netherlands to implement the "Biomass Master Plan for Romania".
The available statistical data for 2006-2008 on biomass consumption indicate an average final consumption of approx. 140 PJ / year, divided by 121 PJ (2890 thousand tep / year) consumed in traditional rural heating (with about 18% yield) and 19 PJ (455 thousand tep / year) industry and the tertiary sector. Locals using local biomass will remain an important consumer but their contribution will decrease over time as the efficiency of new rural heating systems will increase. If the government will support the purchase of efficient biomass-based residential water heaters and promote the use of efficient residential heating units, the local biomass contribution will drop further.
Table 1 illustrates how modernization of existing rural heating systems leads, for upgraded systems, to the reduction of final gross biomass use.

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Table 1: Possible evolution of biomass use from 140PJ (3350 mii tep/an) in present, at 112 PJ (2675 mii tep/an) in year 2020

Evolution beetwen 20110-2020		**Comments**
Replacement of traditional wood and waste stoves with new biomass-based district heating systems	Approx.20% din sobe	It leads to a decrease in consumption of approx.18 Pj
Replacement of traditional stoves with efficient biomass residential boilers *	Approx.8% din sobe	It leads to a decrease in consumption of approx. 7 PJ
Consumption of biomass for heating in stoves		**approx.86 PJ/an**
Biomass consumption for efficient residential boilers, which replace 8% stoves		**approx. 4PJ/an**
Consumption of biomass for new centralized heating systems, which replace 20% stove		**approx. 6 PJ/an**
Modernizarea unor boilere industriale existente	Cresterea mrdir a eficientei boilerelor cu aprox.15%	Conduce la scaderea consumului cu aprox.3 PJ
Consumul de biomasa in boilere industriale existente si modernizate		**aprox.16 PJ/an**
		TOTAL 112 PJ/an

* Directive SRE, Article 13.6 requires Member States to promote high efficiency boilers for residential heating

2. Analysis of the current state of the TLUD process

In order to cover the demand for heat, the use of residual or other biomass biomass from which thermal energy is obtained through a gasification process resulting in a hot combustible gas which is burned in a burner specific to this type of combustible gas is analyzed.
Large-scale pelletization and briquetting of woody biomass is currently being practiced. For pellet production, energy is consumed which represents an average of 8-10% of the calorific value of the biomass and emits in the atmosphere the amount of CO_2 resulting from the production of the electrical energy consumed and the production of the production equipment. At the same time, pelletizing involves expensive, energy-intensive machines that make the price vary between 120-180 EURO / t depending on the biomass used, the drying needs, the biomass transport distance from the place of harvest to the biomass its processing
As a more environmentally friendly version, the TLUD (Top-Lit UpDraft) process proposes the use of local biomass gasification, minced at 10-50 mm and naturally or ventilated at 10 to 20% humidity. Energy consumption in this variant is less than 3% of the calorific energy used in the biomass and much less CO_2 is emitted into the atmosphere. The cost per usable energy unit falls below 40% of the average pellet size.

The hot air generator system proposed in the project consists of:

1. way of supplying biofuels,
2. gasification mode,
3. burning mode,
4. Heat exchanger,
5. Electronic mode of monitoring and control process
6. tubing
7. Exhaust basket

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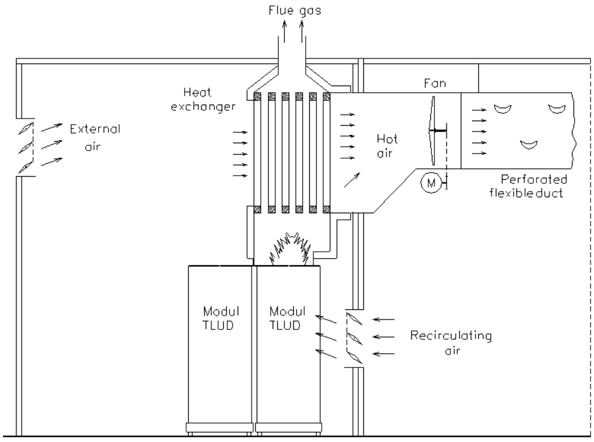

Fig. 1. The principle of the hot air generator with TLUD type biogas (Top-Lit UpDraft)

3. The up-draft procedure

This is the simplest type of fixed bed gasifier. Biomass is fed from the top of the gasifier, and it slowly moves down as its conversion and ash removing take place. The insertion of the gasification agent (the air) is done through the bottom of the gasifier beneath a bar grill, or with a rotary grill, version which has the advantage of adjusting the evacuated ash flow rate, so the possibility to adjust also the speed at which the biomass moves down inside the gasifier. The gases produced pass through the gasifier from the bottom upwards, crossing through the layer of biomass, and they leave the gasifier in the top, sideways, at a level slightly lower than the one at which biomass is fed. In this way, biomass and gas flow is countercurrent, and the sequence of the reaction zones is as shown in Figure 2 (a) [1].

The most important advantage is simplicity, and also intense burning of charcoal and internal heat transfer from gas to biomass, which causes the gas temperature at the outlet to be relatively low and to achieve high efficiency of gasification. In this way, even a gas with a high moisture content (>50 %) could be used [2].

The most important disadvantage is the tar content in the gas, as well as the presence of moisture and pyrolysis gases, because they no longer cross the oxidation zone and are no longer burned, no longer cross the reduction zone and are no longer cracked. This is a minor drawback if we consider direct combustion of gas in regular furnaces. But if it is intended to use the gas for engines, then it is a must to clean the dust and tar off from the gas, otherwise they can cause serious problems.

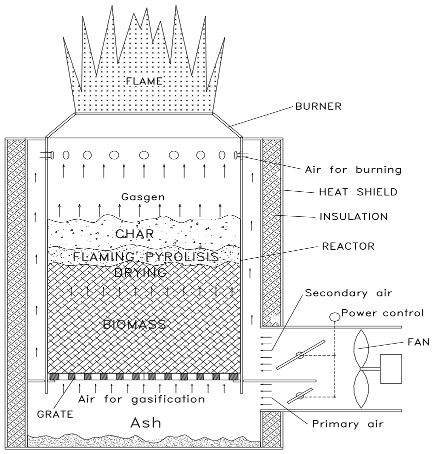

Fig. 2. Schema simplificata a arzatorului cu gazogen

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4. Experimental Modeling and Testing

The paper presents a modern way of preparing and using the vegetal biomass for the ecological production of the cheap thermal energy required in the heating installations, technology specific to the rural economy based on agricultural activities.

In a research project, an experimental model (Figure 5) has been used; it is based on this procedure, which was tested in the laboratories of the Hydraulics and Pneumatics Research Institute (IHP) in Bucharest and CALORIS Group S.A. Thermal energy can be obtained by micro-gasification using the TLUD (Top-Lit UpDraft) process of vegetal biomass, which is characterized by high conversion efficiencies and very low CO and MP 2.5 pollutant emissions. Applying the TLUD process it is possible to efficiently gasify biomass with relatively large variations of the chemical composition, humidity (under 20% water) and granulation properties (1-5 cm), aspect which provides a wide base of usable plant biomass sources [6].

The long-term acceptability of gasification technology and the CHAB concept as well as its introduction on the market depend on the technical, economic and environmental performance of gasification and biofuel plants, efficiency and safety of power plants that is using the gas fuel produced [7].

In order to achieve these goals, the system must have high operational safety and be reliable, environmentally friendly, economically viable and be exploited by a user with a minimum of professional training, trained carefully through a monitored schooling system.

It is in the user and manufacturer's interest that the hot air generator is properly tested so as to achieve the desired performance. Therefore, a methodology has been developed for testing the hot air generator with the TLUD energy module, measuring quantities and necessary equipment, as well as calculation algorithms for the primary processing of experimental data.

Testing is carried out in four test steps:

1. Initial running test **(IRT)**
2. Start test **(ST)**
3. Load operational test **(LOT)**
4. The biochar discharge and off test **(BOT)**

The tests will be carried out in strict surveillance with the labor protection rules specific to hot combustion gases.

Following the mathematical modeling of the equipment, the project has been modified, resulting in the experimental model shown in Figure 3.

Fig. 3. Experimental model of a TLUD gasifier

The micro-gasification process is supplied with air from a variable speed ventilator. Biomass is introduced into the reactor and is based on a grid through which, from bottom to top, passes the air for gasification. Initialization process is done from the free upper layer biomass.
Thermal energy is obtained by burning hot gas generated, resulted during pyrolysis, it is mixed with preheated combustion air introduced into the combustion zone through holes located at the top of the reactor. Mixture with high turbulence burns with flame at the upper mouth of the generator with high temperature 900-1000°C. To adjust the heating power necessary it is varied the air flow for gasification and the air flow for combustion through two flaps, coupled mechanically, or by varying ventilator speed. The TLUD process, at an optimal excess of air for gasification of 25...30% does not consume entirely the carbon in biomass; at the end of the batch gasification process there remains ash and about 15% unconverted charcoal, also called biochar. To obtain a complete reduction of carbon in biomass, resulting in the end in only about 3% biochar, the heat loss through the reactor wall must be reduced to keep in the pyrolysis wall temperatures over 900°C.
The biochair can be gasified or burned to produce heat, or it can be used as a valuable agricultural amendment, procedure that helps seizure in the soil around 25% of the carbon from the gasified biomass, thus resulting in a negative balance of CO_2 [6, 8]. The TLUD process is with fixed bed of biomass and therefore the generator operates in batch mode to recharging.
In order to put into operation, the experimental model of the TLUD hot air generator, the reactor was filled with 15 kg of pellets (conifer, density ≤1.12 kg/dm^3, thermal efficiency 5KWh/kg) and the ignition with 4 pieces of fireplaces igniters was used. The draft fan and the hot air fan were started. After a start-up period, the gasification process stabilized and a stable, slightly turbulent flame of orange color was obtained.
There was observed a high increase in air temperature at the outlet of the heat exchanger. After about 1 hour and 30 minutes, a total blue flame appeared at the burner, indicating the occurrence of gasification of the biochar. At that moment the blower stopped, the gasification and combustion air were closed. At the complete extinction of the blue flame, the reactor was extracted from the generator and the biochar was discharged.
As a result of measurements made with a thermal camera, one can see the heating of the boiler on the entire surface of the boiler (Figure 4).
To achieve thermal performance and functional requirements imposed by current industrial consumers of thermal energy, TLUD heat generator can be equipped with an automatic driving device oriented PLC, as one can see in Figure 5.

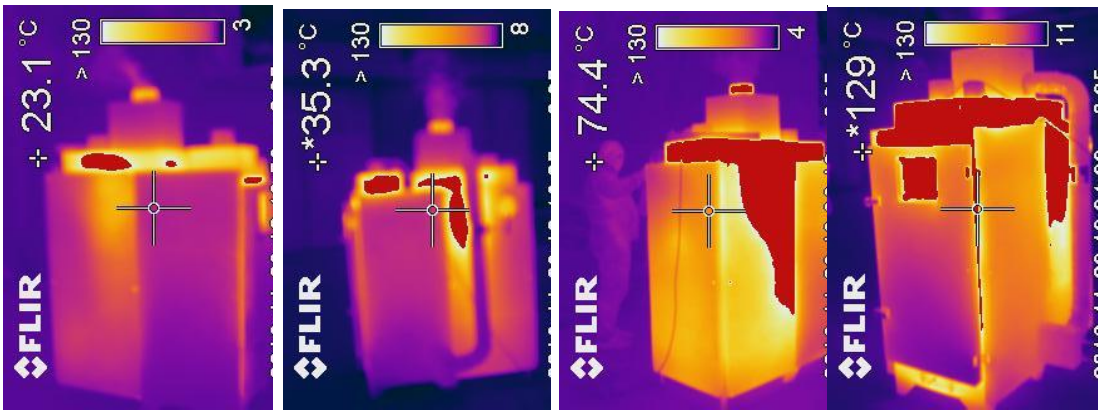

Fig. 4. Thermal camera records showing heating of the boiler

Fig. 5. PLC device equipping the TLUD heat generator

The boiler was equipped with temperature sensors PT1000 type on the hot air outlets, smoke exit, on the energy recovery zone and the gasification air, all connected via 4-20 mA amplifiers to the data acquisition board. Specialized software has been developed for this application, by using LabVIEW; this is shown in Figure 6.

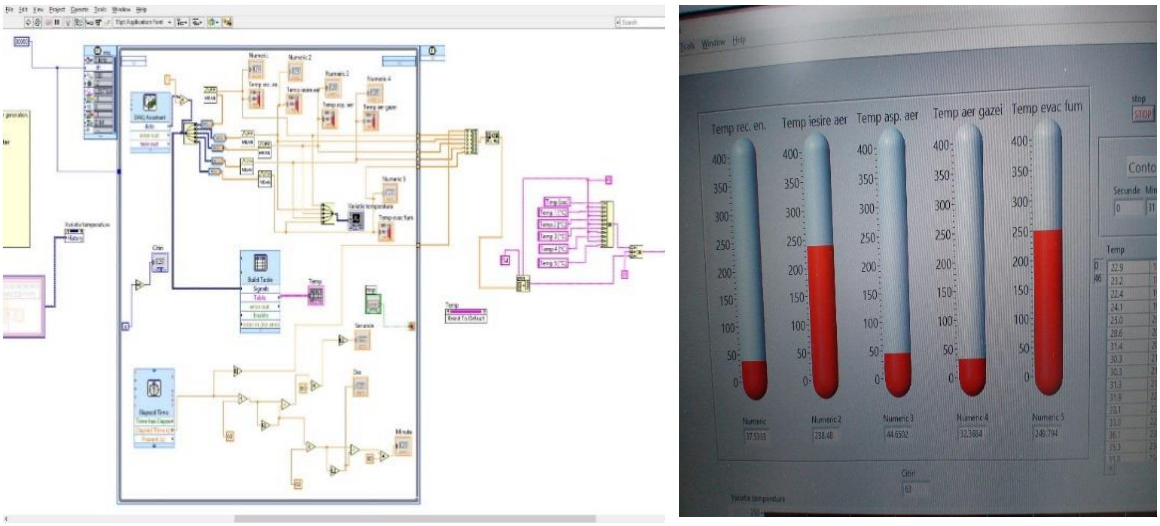

Fig. 6. Screen captures of the specialized software developed

The temperature is taken over at an interval of 30s over the entire duration of the cycle (about 2 h) on the above-mentioned ports, also noticing in the Figure 7 what the temperatures that we recorded were.

The graph below shows the temperature evolution at the end of the service cycle.

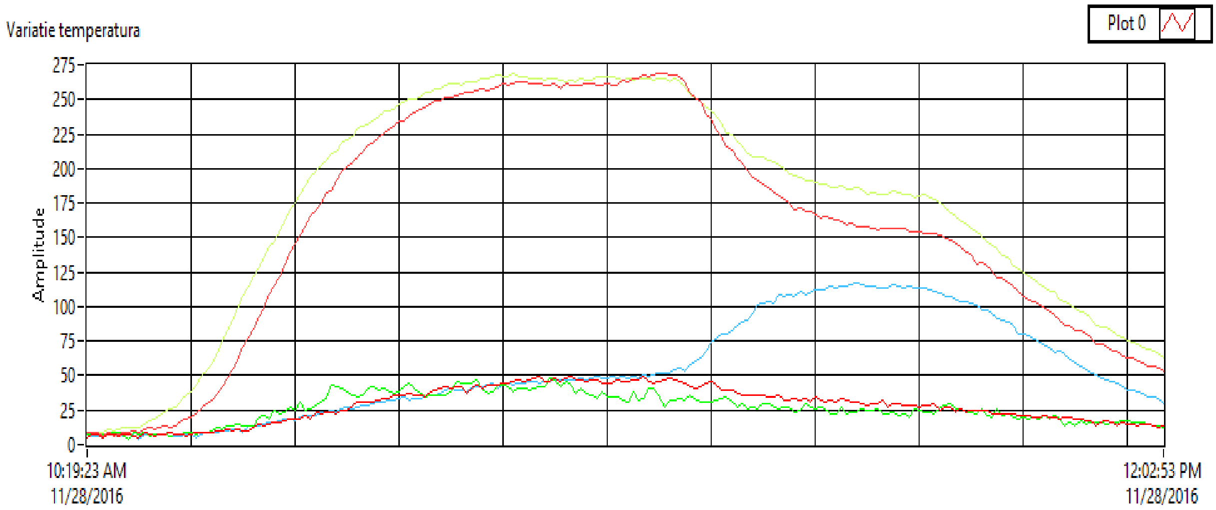

Fig. 7. Recorded temperature points and temperature evolution

5. Conclusions

Designing and testing a completely new prototype of hot air generator system based on the TLUD principle, used to control the heating of greenhouses and solariums, is a daring project. Real time control of exhaust gas temperature, recovering energy from the smoke flue and re-introducing it into the combustion and gasification circuit by using a fully automated system could lead to the development of a hot air generating system comparable in performance with a classic thermal plant but at an affordable price and with lower operating costs. At the same time, the implementation of the project and subsequent marketing would result into promotion of clean energy technologies, environmental protection measures and the reduction of greenhouse gas emissions, as well as an important saving of wood, thus observing the principles of sustainable development.

The ultimate goal of the project is to develop a prototype of a generating system based on the TLUD principle, consisting of the gas generator, the burner, the heat exchanger and the electronic drive and control system, intended for the heating of greenhouses, which operates with raw materials from secondary agricultural production, incorporating the latest innovative technical solutions and being clearly superior in performance, features and design compared to products of the same category on the market.

Results of research on combustion systems with gasification of wood fuels of TLUD type can also be used in other applications, *e.g.*: gas generators, biogas-based green energy cogeneration systems, or other applications detected during the dissemination activities.

It is possible to reduce the emissions of biomass-based plants by the following measures:

- By controlling the temperature in the gasification process, the occurrence of nitrogen oxides is greatly reduced resulting in a reduction of up to 20 times that of conventional combustion;
- By gasification the problems caused by the deposition of molten ash on the heat exchange surfaces, which causes the boilers to clog, are overcome;
- Adjustable thermal power of generator TLUD in the range 35-95% is made through ventilators speed variation; the generator is very easy to control from the level of the operator to the automatic drive controller to a PLC;
- Two types of biomass have been burned: wood pellets and wood chips;
- The amount of biochar was variable depending on the time and level of combustion and air supply.

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