HEATING GREENHOUSES WITH TLUD BIOMASS ENERGY MODULES

Erol Murad, Edmond Maican, Ştefan Sorin Biriş, Valentin Vlăduț

***Abstract**: For greenhouses with relatively small area: 100 .. 300 m^2 was examined the operation of a hot air heating system equipped with energy modules type TLUD where biomass, as pellets or finely minced, is first gasified and gasgen is propely burned. Gasification process TLUD is characterized by very low concentrations of CO and particulate matter, under EU rules imposed. The process of heating a greenhouse supplied from the TLUD modules with automatic control of operation was simulated, for a very cold winter day. Simulated experiments have shown that it is possible to use technical and functional TLUD modules for greater energy independence of the greenhouses.*

***Key words**: geenhouse, heating, biomass, gasification.*

INTRODUCTION

In order to reduce greenhouse heating costs and CO_2 emissions the renewable energies, especially the biomass are more and more used, as they can ensure thermal energy with diminished costs and zero CO_2 emissions. Agro-residue is one of the important biomass resources in Romania and its efficient utilization is crucial for providing bio-energy, releasing risk of environmental pollution, and enhancing rural incomes. [1,4,6,7]

The paper researches the heating of a vegetable greenhouse with hot air supplied through a flexible tube endowed with slots for air jets..We have renounced at hot water heating both for reducing the initial investment and raising the control degree of greenhouse microclimate through the controlled ventilation. [6]

In order to produce electric power the paper's authors propose to use energetic modules TLUD (Top-Lit-Up-Draft) comprising an inverted down-draft gasifier (IDD) and a burner. They have a simple structure, are cheap and can gasify a great biomass diversity, which increases the level of energetic independence and heating costs. The modules are build-up and controlled by a programme developed rezident in PLC series. [3,4,6]

We have chosen a freezing winter day, in Ilfov district, in order to verify the functionality of the system to be analyzed, as well as the heating costs estimation. The simulated experiments were performed with CLIMSERE programme which simulates the greenhouse microclimate, software developped in Free Pascal at the Chair of Biotechnical Systems. [6]

MATERIAL AND METHODS

The tunnel-type greenhouse, which is to be studied is of 6m·25m·2.7m, having a frame made of galvanized sheet, covered with double polyethylene foil (figure 1 and 2).

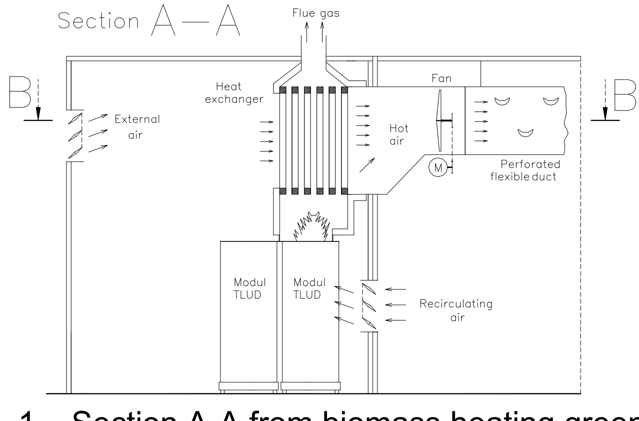

Fig. 1 – Section A-A from biomass heating greenhouse

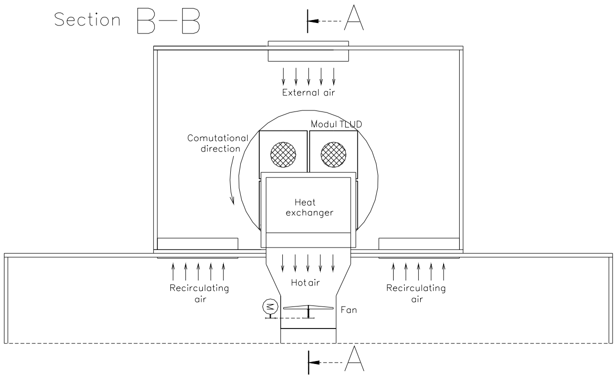

Fig. 2 - Section B-B from biomass heating greenhouse

The greenhouse has a soil surface S_{sol}=150 m^2 and a volume of V_{ser}=271 m^3. It is heated by the hot air distributed through a flexible polyethylene pipe with jet slots. The air is heated by a heat exchanger (SC) burnt gases - fireproof tubes air, with cross currents and an exchanging surface of 3.6 m^2. The air entering the greenhouse is obtained by mixing a flow rate of recirculating air D_{arec}, with an outdoor air flow rate D_{av}, adjusted to ensure the appropriate concentration of O_2, CO_2 , as well as the internal humidity. The greenhouse humidity is maintained due to air flow rate evacuated $D_{aev}=D_{av.}$ In order to obtain a constant distribution of hot air, it was adopted the variant of steady air flow rate D_{ah}=ct. for heating, which ensures also a rather constant output of SC. [2,6,9]

For producing thermal energy from biomass it is used the thermo-chemical biomass gazeification. The biomass is calcined into a reactor with 20...30% out of the air needed to stoichiometric burning It results a gas, named gas generator, which has a typical composition: CO – 20% , H_2 – 18%, CO_2 – 10%, CH_4 – 4% and N_2 – difference. The thermal energy conversion output varies along with the gazeification procedure, the characteristics of biomass used and the insulation level, within the range of 75..85%. The calorific inferior power of gas produced is $PCI_{gas} \in (4.5...5.5)$ MJ/Nm^3; depending on the biomass chemical composition and humidity. TLUD procedure has been adopted, being efficient for small power applications, less exigent to biomass quality, and simply and efficently built. [3,4,5]

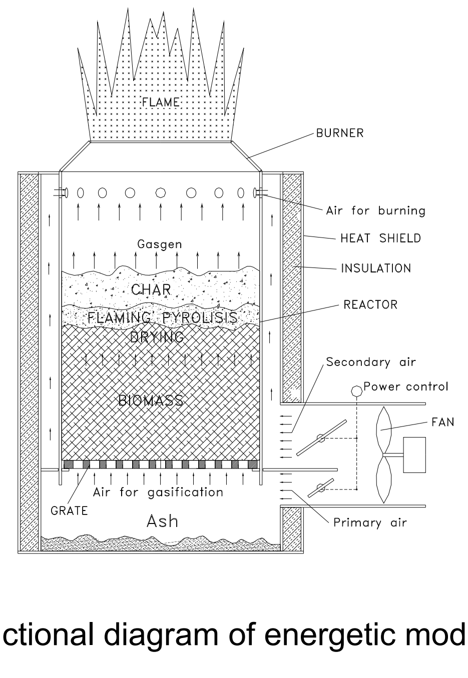

Fig.3 Functional diagram of energetic module TLUD

TLUD energetic module , shown in figure 3, is made of an inverted down-draft gasifier connected to a burner. The biomass is introduced into the reactor and is supported on a grate through which the primary air designed to gazeification passes up and down. Fast pyrolisis runs in a flaming pyrolisis environment and keeps going down through the reactor biomass layer. From fast pyrolisis result gas, tar and char. Tar passes through the burning coal layer, then is cracked and totally reduced by the heat radiated from the pyrolysis and the upper flame. The gas resulted is mixed with the secondary burning air, pre-heated by the reactor wall, introduced within the burning area through the slots situated at the reactor upper part. The mixture endowed with high vorticity burns with flame at approx.900ºC temperatures.

The thermal power adjusting is achieved by varying the primary and secondary flow rates. [3,4,5].

A burner comprising four energetic modules TLUD with nominal power of P_{arzn}=25 kW (figures 1 and 2) is used for heating the greenhouse. The thermal power produced can be regulated within the load range $S_m \in (0.5;1.0)$ out of the nominal power through the variation of ventilator rotative speed. The modules are fired by a thermo-chemical device electrically initiated from PLC. When a biomass charge is finally gasified (bulking agent), the thermal power suddenly decreases. In this situation the respective module, through the switching command is taken out from the burning chamber and another module, which is re-supplied is introduced, receiving the resetting command. When two empty reactor modules are at the burning chamber outer part, they are manually or semi-automatically refilled and the initialization device is placed. The energetic modules can operate with pellets or chips. In table 1 are shown the main data regarding the energetic module type TLUDMER BGM-33/100.

Table1 Charateristics of energetic module TLUD

Parameter	***U.M.***	***Value***	
Reactor Diameter	cm	33	
Reactor Height	cm	100	
Biomass fuel	-	Pellets	Chips
Weight of Fuel per Load	Kg	45	20
Fuel Consumption Rate	Kg/h	8.2	9.5
Specific Gasification Rate	Kg/m^2h	110	95
Power Output	kW	12..25	12..25
Energetic Efficency	%	75..85	75..85
CO concentration (in flue gas)	g/kg	0.35	0.42
NOx concentration	%	0.01	0.012
PM concentration	mg/kg	0.6	0.8

The effective output of heating exchanger is of at least 85% and following NTU [2] type analysis it has been found that this output is steady within the whole utilization range, since D_{ah}=cnt. [2]

For environmental control has ben used a numeric-PID regulator for indoor temperature and humidity, and a switching program for the modules in the burner chamber. As control variables are mentioned the load coeficients which have to be set, noted as S_{m1} and S_{m2}. Another parameter is represented by fuel mass in the reactor noted with M_{bm}. [8,9,10]

The operating conditions imposed are:

$$S_{m1}, S_{m2} \in [0,5 ; 1,0] \quad (1)$$

$$S_{arz} \in [0,5 ; 2,0] \quad (2)$$

$$S_{arz} = S_{m1} + S_{m2} \quad (3)$$

$$S_{arz} = U_{PID} *(2/10) \quad (4)$$

$$\text{if } S_{arz} > 1,5 \text{ then } S_{m1}=1 \text{ AND } S_{m2} > 0.5 \quad (5)$$

$$\text{if } S_{arz} < 1 \text{ then } S_{m1}=0 \text{ AND } S_{m2} > 0.5 \quad (6)$$

$$\text{if } M_{b1} = 0 \text{ then } S_{m1}= 0 \text{ AND Comutare=1} \quad (7)$$

$$\text{if switching=1 then } S_{m1}=S_{m2} \text{ AND } S_{m2}=1 \quad (8)$$

$$P_{arz} = S_{arz} * P_{arzn} \quad (9)$$

In order to determine the values characterizing the microclimate and power consumption, simulated experiments were performed with simulating programme CLIMSERE developed in FreePascal v.2.1.2 at the Chair of Biotecnical Systems. It has been aimed the make varying the following parameters:indoor temperature, inner relative humidity, solar radiation P_{srad} (W/m^2), water evaporation into the soil and on plants (kg./s.m^2). [6]

RESULTS AND DISCUSSION

In figure 4 is shown the evolution of a greenhouse microclimate, when a larger power heating stock exists. There has been found that for Ilfov county, in a freezing day with -5...-25 ºC temperature, at a reference of 15 ºC indoor temperature, the heating power varies within the range of 10 ..40 kW. [ ]

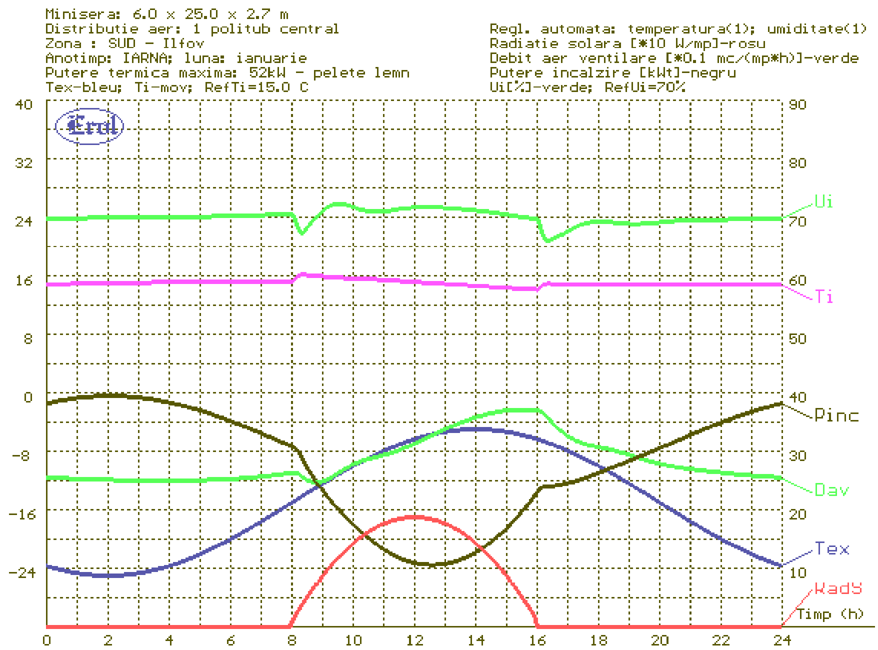

Fig. 4 Microclimate parameters and heating

requirements

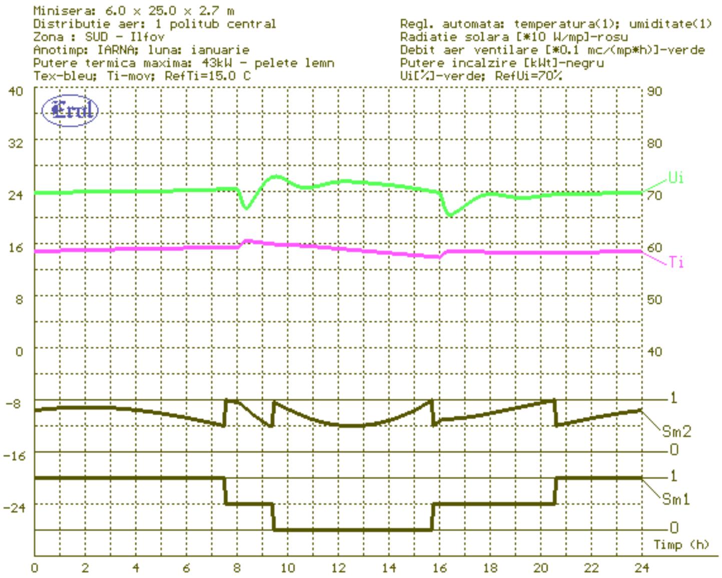

Fig. 5 Microclimate parameters when heating with TLUD modules

In figure 5 is shown the evolution of greenhose microclimate, when TLUD energetic modules are used. The load coefficient variations S_{m1} and S_{m2} of modules in burning chamber are shown. During dark periods, between 6pm. – 8am., four supplying charges are enough and any operator is not necessary. The variation of indoor temperature and humidity is similar to that from previuos case, which fully proves that the solution analyzed is technically, functionally and economically viable.

Table 2 Environmental control performances

Parameter	UM	Biomass	
		Pellet	**Chips**
IndoorTemperature min/max	°C	13.9/16.4	14.3/15.9
Indoor humidity min/max	%	66/73	66/72
Hot air jet temperature min/max	°C	16.9/38.2	19.7/38.3
Heating power min/max	kW	10.6/39.5	10.6/39.5
Burner average load	%	66	66

In table 2 are shown the control performances of microclimate in case of using energetic modules TLUD. In table 3 are shown the results of experiments related to the biomass consumption and heating costs. There has been found that local biomass utilization as chips is more economical and ensures an increment of labour occupational degree.

Table 3 Biomass consumption and heating costs

Parameter	UM	Biomass	
		Pellet	**Chips**
Low Heating Value	MJ/kg	17	15
Fuel price	€/t	160	100
Daily energy for heating	kWh/day	672	672

Daily fuel consumption	kg/day	186	213
Daily fuel cost	€/day	29.8	21.3
Specifc fuel cost	€/m^{2}day	0.2	0,142
Relative costs	%	100	71
CO_2 emission	kg/day	0	0

CONCLUSIONS AND FUTURE WORK

1. It has been studied the heating of a vegetable greenhouse with biomass gasified in energetic modulesTLUD for determining both the adjustment quality of microclimate parameters and the economic and ecological aspects. The greenhouse of 150 m^2 surface is heated with warm air and during a very cold day the maximum heating power required is of 40 kW, namely, about 0.27 kW/m^2.
2. The thermal power producing system out of biomass is of an original design, comprising four energetic modulesTLUD of 25 kW controlled by a PLC which ensure the enerrgy supply necessary for greenhouse heating. Any type of biomass can be used as pellets or chips from local agro-residues.
3. It has been conceived an algorhitm of controlling the burner comprising four energetic modules TLUD with which high microclimate parameter regulation is obtained.
4. Utilization of biomass reduces heating costs, ensures a significant increment of energetic independence with economic and ecological effects. For 190 day –period with an average temperature of 2.3°C the specific cost is 16.02 €/m^2 for pellets and 11.42 €/m^2 for chips. The amount of CO_2 emission in the atmosphere is zero.
5. A simulating programme of greenhouses heated by biomass hot air generators has been achieved, as a software product able to be used and improved for studying and designing heating systems.

REFERENCES

[1]. Adams S., Meyer G., Fitzgerald J., 2008. *Biomass Heating in the Commercial Greenhouse*. University of Nebraska, Biological Sciences Engineering, 2008
[2]. Badea A., ş.a., 2003 - *Echipamente şi instalații termice,* Editura Tehnică, Bucureşti, 2003
[3]. Mukunda H. s., ş.a, 20*10. Gasifier stoves – science, technology and field outreach,* CURRENT SCIENCE, vol. 98, no. 5, 10 march 2010
[4]. Murad E., 2002. *Producing energy by gasifying the agricultural biomass renewable resources.*INMATEH- 2002, Romania, Bucharest, May 2002
[5]. Murad Erol, 2005. *Optimisation of biomass gasification load regime*, International Conferece ENERGIE - MEDIU CIEM 2005, UPB, Bucharest Oct. 2005
[6]. Murad E., Maican E., Haraga G., Biriş Ş.S.,2011. Greenhouse heating with biomass,
[7]. Popovska-Vasilevska Sanja, 2007. *Researches on energetic efficency and availability of greenhose heating systems.* Ph.D. Thesis. University Oradea 2007
[8]. Ramírez-Arias A., Rodríguez F., Guzmán J.L., Arahal M.R., Berenguel M., López J.C., 2005. *Improving efficiency of greenhouse heating systems using model predictive control*. *Copyright © 2005 IFAC*
[9]. Yildiz Ilhami, 1993. *Simulation of greenhouse microclimates and environmental control strategies using a Rankine cycle heat pump,* Dissertation, School of The Ohio State University

[10]. Yildiz I., Stombaugh D.P., 2006. *Dynamic Modeling of Microclimate and Environmental Control Strategies in a Greenhouse Coupled with a Heat Pump System***.** Proc. IIIrd IS on HORTIMODEL 2006 Eds. L.F.M. Marcelis et al., Acta Hort. 718, ISHS 2006

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