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PNEUMATIC MEASURING OF THE BIOMASS CONSUMPTION FOR TLUD GENERATOR

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***Abstract:** Efficient management of energy production from biomass with thermal generators and generators TLUD requires continuous measurements of biomass consumption correlated with input parameters which is air flow for gasification. As an alternative to electronic measuring systems, which in the exploitation conditions for gasogen are more expensive than the usual ones, it is analyzed the use of pneumatic force sensors at which the measured pressure is not sensitive to temperature variations. Measurement of biomass is performed online with a pneumatic force transducer working under sampled measurements. Measurement structure presented has very low energy consumption, specific to the technical systems with energy independence and low cost automation. The measurement system is connected to PLC for automatic driving of thermal system. Adjusting performances of the thermal generator operating mode and energy consumption for force transducer were determined by simulation experiments conducted with a simulation model and a numerical simulation program, developed in the simulation environment MEDSIMFP10. Simulation experiments confirmed low pneumatic energy consumption and a better measurement accuracy.*

***Keywords**: pneumatic transducer, power, biomass, TLUD, energy consumption, low cost*

1. Introduction

The production of energy from biomass is an ecological and economical method which is in competition with other sources: solar thermal and photovoltaic, wind energy, hydro or geothermal. The main advantage of biomass is that it can be produced energy with it when, where and in the necessary amounts.

At present, in parallel with up-draft and down-draft gasification systems, are developed systems based on the TLUD process that is easy to use and stable in operation; the system has the advantage of being cheap and recently revealed that produces an unconverted carbon quota called biochar, which if is introduced in soil represents a great soil amendment and contributes to the increase of land fertility and through carbon sequestration in soil relatively large periods of time contributes directly to the reduction of the CO_2 in the atmosphere. A TLUD thermal generator consists of a generator with TLUD process of micro-gasification of biomass which produces fuel gas which is combusted in a burner directly coupled to the generator. [2,8,9]. The automatic management of thermal power generation process requires the measurement of biomass C_{bm} consumption ($kg._{bm}/s$) and air flow D_{ag} for gasification ($kg._{aer}/s$). TLUD thermal modules require very little electricity to operate, maximum 0.3% of rated thermal power, TLUD being the thermal energy source suitable for installations with energy independence used in agriculture and isolated areas. [1,3,7,8]

This paper presents and analyzes the operation and performances of a measurement scheme online for the weight of a TLUD generator that uses a pneumatic force transducer working under sampled mode. The solution presented is characterized by very low energy consumption, low price and a measurement error ≤ 2%. The measurement system is connected to the PLC dedicated to automatic management of thermal system.

2. Thermal generator with TLUD gasogen

An ecological and economical alternative for biomass gasification is the process of micro-gasification TLUD (Top-Lit Up-Draft), designed by Thomas Reed in 1985. In this TLUD process biomass layer is fixed in the reactor and the oxidation and pyrolysis front continuously descends consuming biomass, features that ensure safe operation and controllers. Operation is in batches with acceptable variation thermal load from 50 to 100%. In Figure 1 is a functional schematic diagram for a thermal module TLUD and in Figure 2 a thermal module GAZMER FORTE-30. [8]

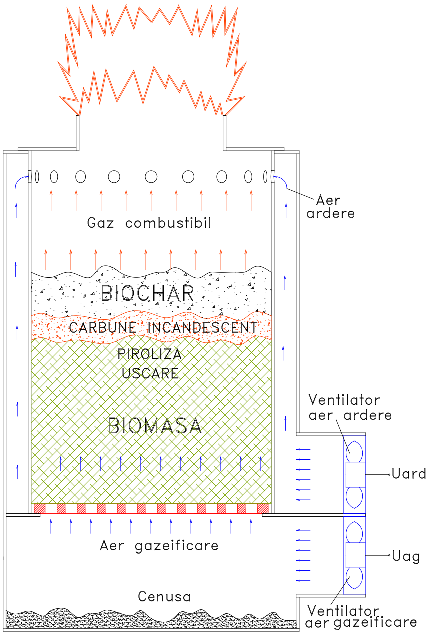

Fig. 1 Schematic functional of a thermal module TLUD

Fig. 2 Thermal module TLUD by 30 kW

G_{MGB} weight thermal module is the weight of the generator and burner G_G and the weight of the biomass and biochar G_{bm} from reactor:

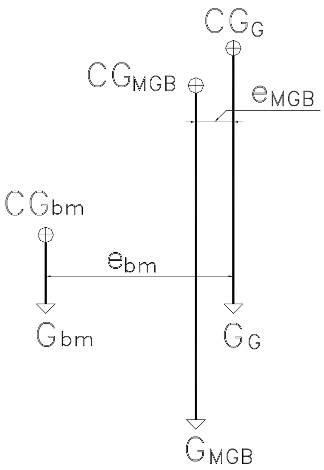

Fig. 3 Diagram of positions for centers of gravity

$$G_{MGB} = G_G + G_{bm} = g \cdot (M_G + M_{bm}) \qquad (1)$$

CG_G center of gravity is fixed as position but the center of gravity CG_{bm} volume of biomass is offset horizontally by ± e_{bm} (figure 3); therefore the center of gravity position CG_{MGB} thermal module is between CG_G and CG_{bm} shifted horizontally by ± e_{MGB} (m). It follows that there is an eccentricity between CG_G and horizontal positions CG_{bm}. Calibration of the weighing system is done with G_G value which is known. When biomass is loaded, thermal module center of gravity moves in CG_{MGB} which is offset from the CG_G with e_{MGB} that will have a value of:

$$e_{MGB} = e_{bm} \frac{G_{bm}}{G_G + G_{bm}} \qquad (2)$$

value decreases during operation due to. This biomass consumption and weight reduction G_{bm} function will affect measurement accuracy.

3. Pneumatic force transducer

Applying the concepts of minimizing energy consumption, energy independence and low cost automation system, there was designed an unconventional pneumatic transducer which don't need a special source of compressed air, consumption being extremely low, which simplifies construction, so the cost of the transducer and total energy consumption is very low. [4,5,6].

It has been chosen pneumatic version because the pressure signal, that is proportional to the measured weight, is not influenced by the environment temperature, measurement accuracy being high. The main element of transducer is the pneumatic load cell that converts the measured force F_{mas} in a pressure p_{mas} that is proportional to the force.

In figure 4 is presented the functional diagram of the pneumatic load cell designed for drying processes that can be used at processes at which variation of the measured force is produced slowly and in a single direction. $F_{mas}(t)$ measured force is applied to the head of a rod 4 fixed to the rigid center 3 of a goffered flexible membrane 2 with effective diameter D_{ef} and constant effective surface S_{ef}, mounted in the body 1. On the rod 4 is fixed a nozzle 5, with diameter d_d, which rests on a ball 6, with diameter d_b, closing the air access from measurement chamber to the outside through holes in the membrane, rigid center and rod. The measuring chamber can be connected in parallel with a pneumatic capacity V_{ad}. The supply of pneumatic circuit is made by a pneumatic variable resistance RP and a distributor DP type 2/2. The pressure source should have $p_{al} \geq 1.5\ p_{mas\ max}$. The measured pressure p_{mas} (t) is applied to a converter p/U, which has at the output a voltage $Y_F \in [1,3]$ Vcc.

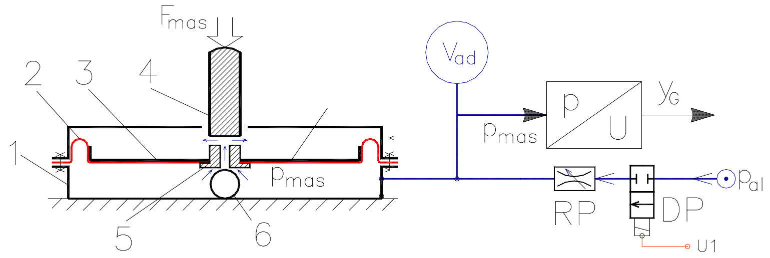

Fig. 4 Functional diagram of the pneumatic force transducer

To measure a force with a variation in a single direction, specific for the gasification processes in the fixed layer of biomass, when the weight of the gasogen decreases continuously, is necessary a single compressed air supply after operation reactor charging with batch biomass. During thermal energy generation F_{mas} decreases continuously, p_{mas} decreases continuously and amount of excess air is discharged outside through the space between the nozzle and the ball to keep the balance of power. This measurement method uses a very small amount of compressed air, therefore very little pneumatic energy. Pneumatic output signal p_{mas} from measuring chamber is converted into electric unified signal with a converter p/U. [5,6].

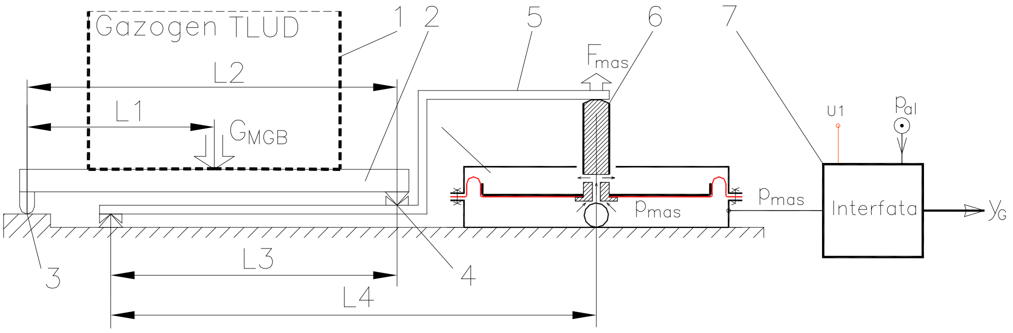

Fig. 5. Functional diagram for a gasogen weighting system

4. Measurement algorithm

For reducing pneumatic and electric energy consumption was designed a management algorithm for transducer operation in regime sampled with a period $T_{es} \in (10...20)$ s only at the start of the gasification process, about 3 -10 min, after that the pneumatic sensor doesn't be need to supplied with compressed air. Reading the transducer output voltage y_G is realized in PLC with a frequency ≥ 10 Hz.

For measurement of biomass consumption, the gasogen 1 is positioned on a support 2 which is leaned on two ball bearings 3 and on another support 4 type knife-wedge, on the lever of weighing 5 which has one end resting on base and the other end resting on the pneumatic force transducer 6 which is connected to the interface block 7 through which the compressed air supply to pressure p_{al} and measuring signal exits Y_G. Vertical center of gravity CG_{MGB} is at the distance L1 from supports 3. The distance between 3 and 4 supports is L2. The measured force F_{mas} applied to the transducer has the value:

$$F_{mas} = (G_G + G_{bm}) \cdot \frac{L_3 \cdot L_1}{L_4 \cdot L_2} = (M_G + M_{bm}) \cdot K_F = F_{masG} + F_{masbn} \tag{3}$$

where: M_G and M_{bm} – weight of gasogen and biomass (kg);

K_F - transfer factor of the weighing machine (s/m^2);

F_{masG} – the component due to gasogen (N);

F_{masbm} – the component due to biomass (N);

Biomass consumption dM_{bm} / dt (kg/s) in the variant of sampled reading with Δt will be:

$$\frac{\Delta M_{bm}}{\Delta t} = \frac{1}{K_F} \cdot \frac{\Delta F_{mas}}{\Delta t} \tag{4}$$

Electrical output interface has the value y_G (V):

$$y_G = F_{mas} \cdot K_{TR} \tag{5}$$

Where: K_{TR} is transfer factor of force transducer (V/N).

The measured biomass consumption $C_{bm\ mass}$ (kg/s) is calculated using:

$$C_{bmmas} = \frac{\Delta M_{bm}}{\Delta t} = \frac{1}{K_F \cdot K_{TR}} \cdot \frac{\Delta y_G}{\Delta t} \tag{6}$$

At calibration:

$$\text{when: } G_{bm} = 0 \text{ results } L_1 = L_{1ini} = \text{const.} \tag{7}$$

Because there is an eccentricity ± e_{MBG} between CG_G and horizontal positions CG_{MGB}, in this case transfer factor K_{Fbm} for biomass will have a value of:

$$K_{Fbm} = (L_{1ini} \pm e_{MGB}) \cdot \frac{L_3}{L_4 \cdot L_2} = (1 \pm \varepsilon_{MGB}) \cdot \frac{L_{1ini} \cdot L_3}{L_4 \cdot L_2} = K_F \cdot (1 \pm \varepsilon_{MGB}) \tag{8}$$

where ε_{MGB} is the relative eccentricity:

$$\varepsilon_{MGB} = \frac{e_{MGB}}{L_{1ini}} = \frac{e_{bm}}{L_{1ini}} \frac{G_{bm}}{G_G + G_{bm}} \tag{9}$$

Considering that $e_{bm}/L_{1ini} \le 0.1$ and $G_{BM} \le 0.25\ G_G$ it results:

$$\varepsilon_{MGB} \le 0.1 \cdot \frac{0.25 G_G}{G_G + 0.25 G_{bm}} = 0{,}02 = 2\% \tag{10}$$

Measured biomass consumption $C_{bm\ mas}$ is:

$$C_{bmmas} = \frac{\Delta M_{bmmas}}{\Delta t} = \frac{1}{K_{Fbm} \cdot K_{TR}} \cdot \frac{\Delta y_G}{\Delta t} = \frac{1}{(1 \pm \varepsilon_{MGB})} \frac{1}{K_F \cdot K_{TR}} \cdot \frac{\Delta y_G}{\Delta t} = \frac{1}{(1 \pm \varepsilon_{MGB})} C_{bm} \qquad (11)$$

It follows that the actual consumption of biomass C_{bm} is:

$$C_{bm} = C_{bmmas} \cdot (1 \pm \varepsilon_{MGB}) \qquad (12)$$

Considering that at the start of the gasification process, the maximum value for $\varepsilon_{MGB} \le 0.02$, or 2%, and decreases continuously at the end of the process, it can be accepted that it is possible to use efficiently for calculating primary energy consumption and optimal management of thermal generator. An important index in generator TLUD is the ratio of air flow D_{ag} and mass flow of gasified biomass C_{bm}; this report is noted with A/F and has an average value of 1.5. A/F will be estimated in the field (1.428; 1.579) as acceptable because the stoichiometric air flow that is specific real gasified biomass varies in the exploitation by ± 10%, much more than the measurement error of biomass consumption. To validate the proposed solution was made a simulation program for thermal generator GAZMER FORTE - 30 with weight M_G = 85 kg and a maximum load of pellets M_{bm0} = 40 kg. It used a pneumatic force transducer with nominal size measurement F_{masn} = 50 N and K_{TR} = 0.06 (V/N). That mechanical balance factor transfer value must K_F> 24.50 and was chosen constructive K_F = 25.00. To ensure the best possible measurement accuracy has been chosen a pneumatic capacity V_{ad} = 500 cm^3, leading to mitigate errors due to imperfections valve-ball settlement.

5. The results of simulated experiments

From the simulation it results that the maximum acceleration lifting the nozzle is only 97.5 mm/s^2 and maximum lift h_{max} = 0.272 mm. It appears that the movement period of the nozzle is up to 4 s, and then measuring chamber pressure remains constant and proportional to the force measured $F_{mas}(t)$. The relocation of nozzle on the ball is made dampered at a zero speed virtually, which doesn't produce shocks in operation and deformation in the contact area nozzle-ball, ensuring high durability for the transducer. Distributor DP is open only 2 s and it is consumed in the startup sequence measuring only 2.257 Ncm^3 air.

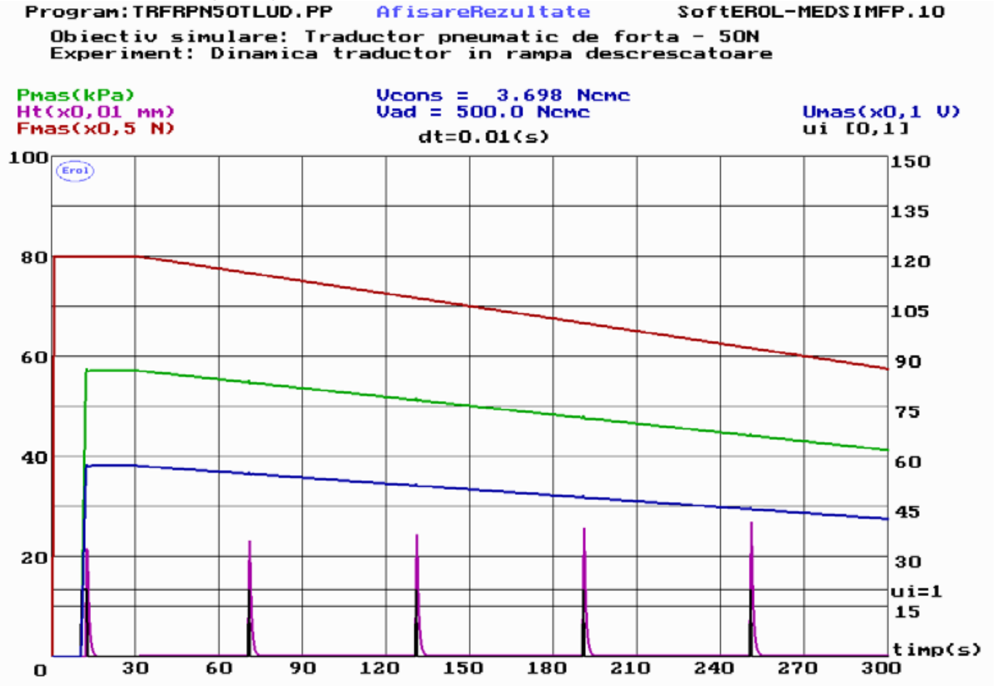

Fig. 7 Experiment measuring the consumption of biomass $dM_{bm}(t)/dt <0$

In Figure 6 is presented a simulated experiment when the weight of biomass decreases continuously and slowly.

Assuming that between two commands for opening distributor DP, pressure can greatly decrease due to leaks and wear, air consumption per hour would be up to 135.42 Ncm^3/h, which is a very small volume. For example, in continuous operation for 24 hours would consume 3.25 Ndm^3 air, which would require a tank by 2 dm^3 which is loaded once a day at 3 bar.

6. Conclusions

It was designed a measuring biomass consumption device for gasogen TLUD in which has been used a pneumatic force transducer designed especially for processes with slow variation measured force, something typical for biomass consumption in TLUD.

To simplify and cheapen constructive solution it was used a single force transducer; the software calibration makes all calibration operations on each recharge of batches of biomass, which provides a maximum error of 2%.

It results from simulation experiments that a transducer with full scale 50 N can operate continuously 24 hours supplied from a 2 liter reservoir loaded to 3 bar once a day.

The measurement system presented operates with very low pneumatic energy consumption, is simple, cheap, durable, and lightweight gauge.

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