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ANTIENTROPIC CONCEPT CHAB

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Abstract: *To reduce the emission of CO2 and the environmental entropy, production of energy should be done with zero or negative carbon balance. The residual agricultural, forest and industry biomass can be converted in TLUD gasifier with the CHAB concept in heat and quality biochar with a negative entropic balance of -15 338 kJ / kWhth. Compared with the direct burning of biomass, which is theoretically a zero entropic balance, introducing biochar in agricultural soil produces negative entropy of -15.3 kJ/kg.bm.K, contributing to increased anti-entropic activity of agricultural soil and improves soil health, which enables plants to sequester carbon into the ground. This is known as the carbon multiplier effect.*

Keywords*: Entropy, biomass, CHAB concept, biochar, TLUD*

1. Introduction

The currently developped concept called CHAB (Combined Heat And Biochar production) consists in concurrently obtainingheat and biochar from biomass. Agricultural biochar amendment is a valuable contribution to agricultural soils, certified to increase their productive capacity. Biochar is produced from pyrolysis of biomass in different conditions with a specified temperature and oxygen supply. [1. 2. 3. 4]
Incorporation of biochar into the agricultural soil produces negative entropy variation of the environment, contributing economically and environmentally to atmospheric carbon sequestration for long periods, resulting in the absolute reduction of CO2 concentration in atmosphere. Biochar contributes directly to increasing soil fertility, which results in an increase in plant mass, which leads to a decrease of environment entropy, by fixing more CO2 through photosynthesis. This is known as carbon multiplier effect. [1.5.6]
It appears that using the concept CHAB has an anti-entropic nature, contributing directly to reducing both the environmental and agricultural soil entropy balance. A Monte Carlo analysisof the entropic balance, called Cross Entropy Method, enables optimization of processes used to obtain energy from renewable sources [7. 8. 9. 10]
Unlike energy production through biomass burning,in which in theory entropy remains constant, using the concept CHAB lowers the atmosphere and soil entropy. CHAB is an anti-entropic process. [9. 10.11]
Onecurrent application of the CHAB concept uses an anoxidic pyrolizor operating at 773 K in which, the exiting pyrolysis gas condensation produces bio-oil and syngas and a high proportion of biochar with VOC (Volatile Organic Componnents). Analysis shows that the system produces negative entropy. It appears that the greatest positive entropy is produced by the condenser unit. If possible the CHAB concept should avoid the condensation step. [12, 13]
This paper analyzes the entropic balance of the gasification process type TLUD (Top-Lit-Up-Draft) with CHAB concept for the production of heat and biochar. The gasifier TLUD can operate at a temperature of the mygratory pyrolysis front (MPF) higher than 973 K. It produces syngas with very little tar and does not have a condensation step,resulting at the output in a larger negative entropy value. [13]

2. TLUD gasifier with CHAB concept

The thermal system with CHAB concept shown in block diagram in figure 1 consists of TLUD gasification reactor, a gas burner and a biochar cooler. The analysis of the system entropy variation considers an isolated thermodynamic system which consists of three open subsystems.

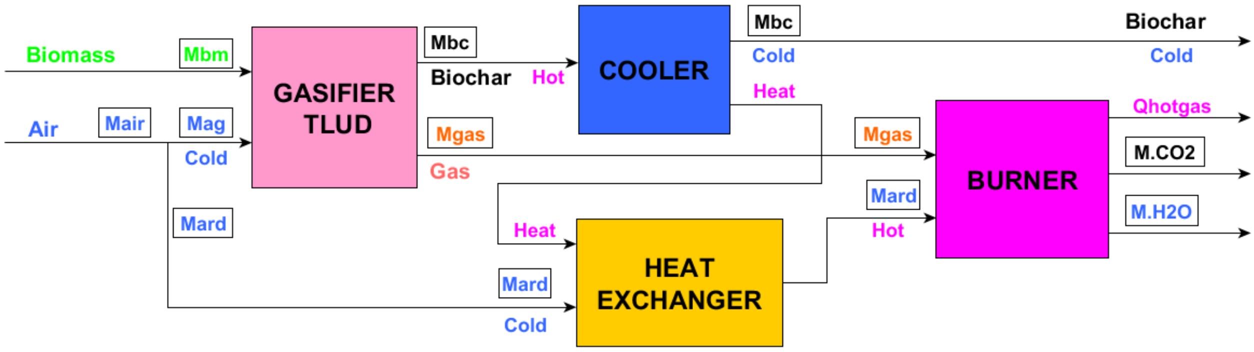

Fig. 1. Block diagram of CHAB concept thermal system

The batch input in the TLUD gasifier reactor is a M_{bm} (kg.bm) biomass at standard temperature 298Kwith known physical, chemical and energy characteristic. Initialize the ignition and gasification process by feeding an air mass input $M_{ag} = k_{ag} \cdot M_{bmg}$ (kg.air) at standard temperature. [3.4.14.15]
In gasification processes, some of biomass M_{bmg} is completely gasified and in reactor remains a warm biochar mass $M_{bc}$of average temperature Tbch.
The output warm biochar mass M_{bc} is:

$$M_{bc} = k_{BC} \cdot M_{bm} \quad (kg.bc)$$

The output mass of fully gasified biomass M_{bmg} is:

$$M_{bmb} = M_{bm} - M_{bc} = M_{bm} - k_{BC} \cdot M_{bm} \quad = (1 - k_{BC}) \cdot M_{bm} \quad (kg.bmg)$$

For further uses biochar is cooled to standard temperature 298K with a special cooler, which heats the air needed for combustion in the burner.
From gasification process result a mass of combustible gases M_{gas} (kg.gas):

$$M_{gas} = M_{bmg} + M_{ag} = (1 + k_{ag}) \cdot M_{bmg} \quad (kg.gas)$$

Produced gases M_{gas} are burned with a special burner with outdoor air intake mass M_{ard}:

$$M_{ard} = k_{ard} \cdot M_{ag} = k_{ard} \cdot k_{ag} \cdot M_{bmg} = k_{ard} \cdot k_{ag} \cdot (1 - k_{BC}) \cdot M_{bm} \quad (kg.air)$$

The combustion air is heated with the exit heat of biochar cooler, which makes the system emitting outdoor only the enthalpy Q_{hotgas} of fully gasified biomass M_{bmg}. [3. 14.15]
Theoretically, the ecological entropic balance burning biomass is null. The fully gasified biomass M_{bmg} releases an amount of water in the surroundings and the CO2 will be fixed by vegetation through photosynthesis, leading to a zero entropy variation. [6. 9]
The system with CHAB concept will return in environment the standard entropy of cold biochar. Depending on usage it can be positive if it is used as fuel for gasification, or negative if inserted into the agricultural soil.
The total entropy balance is:

$$\Delta S_{total} = S_R - S_C + S_{gent} = 0$$

where - S_R entropy generated by the reactor TLUD.
S_C - the entropy generated by the cooler. In this case the $S_C = 0$.
S_{gent} - entropy generated by the system.
With the entropy generated by the cooler being 0, the total entropic balance becomes:

$$\Delta S_{total} = S_R + S_{gent} = 0$$

3. Entropy balance of the TLUD gasifier

In general, in the analysis of entropic balances, absolute entropy, standard entropy and specific entropy are used. The entropy flow measurement is done using units specific to the different processes analyzed. This study uses specific entropy relative to one kilogram of biomass introduced reactor and measured kJ/kg.bm.K. [13. 16]
The entropy change ΔSR in gasifier TLUD, producing fuel gas and biochar (BC), considered as an independent subsystem, is null. The entropic balance is:

$$\Delta S_R = S_{inpr} - S_{outr} + S_{genr} = 0$$

where: S_{inpr}- entropy input in reactor.
S_{outr}- entropy output from reactor.
S_{genr} - entropy produced by the reactor.
In the present paper only the entropy input calculations will be explained.
The entropy input results from summing specific standard entropy S_{bm} of one biomass kilogram with the entropy S_{airg} of the air mass M_{ags} for gasification of a kilogram of biomass.

$$S_{inpr} = S_{bm} + S_{airg}$$

The standard enthalpy of biomass can be calculated with little approximation as the ratio of High Heating Value (HHV) (kJ/kg.bm) to the standard temperature of 298 K (25 C).

$$S_{bm} = \frac{HHV_{bm}\ (kJ / kg_{bm})}{298(K)}$$

The error of this approximation is within 3% for most biomass gasifiers. [12. 16.17.19]

HHV biomass can be determined experimentally with a calorimeter bomb, or if known chemical composition of biomass is known with semi-empirical models. The most used models are: Demirbaş (2000), Chang (2005), Azevedo (2005), Friedl (2005) and all. [17.18.19.20].
For this study, the data from experiments of doctoral thesis developed by S. Varunkumar were used. The chemical composition and Low Heating Value (LHV) for biomass pellets are given. These data are used to estimate the HHV value of biomass as 15.8 MJ/kg.bm. [7.15.17.20.21. 22]
Biochar entropy is calculated similar to that of biomass knowing the HHV value, or its experimentally determined value based on the chemical composition of biochar. In the analyzed experiment the high heating value of biochar HHV_{bc} = 27.8 MJ/kg.bc. [2.4.5. 14.15]
S_{ags} specific air entropy for of a kilogram of biomass gasification is:

$$S_{ags} = S_{airS} \cdot k_{ag} \cdot (1 - k_{BC})$$

where: Sags – standard air entropy. [23]
kag = 1.50.[15]
k_{BC} = 0.164. [15]
The heat losses of the reactor by convection and radiation are taken in consideration for the heated combustion air. The heat loss was determined experimentally to be 3% of the enthalpy of the biomass gasified. [15]

4. Cooler entropy balance

The biochar enters the cooler with a high temperature of 500 C and exits from the system with a low temperature. The heat taken up by cooling of the air is used to heat the combustion air, recovering some of the of the biomass source energy. Thus almost all the energy from gasified biomass Mbmg is found at the exit of the burner in the hot gases enthalpy.

5. Results and discussions

With the above considerations, calculations to determine the final entropy balance, as presented in tables 1 and 2have been performed. It appears that the overall balance of TLUD gasifier operating in CHAB concept with initial hypothesis conditions, is negative at - 3 353 kJ/kg.bm.K. By incorporating biochar in agricultural soil a environment entropy decrease with -15 299 kJ/kg.bm.K results.

Table 1: Gasifier TLUD with CHAB concept

Feature	M.U.	Value	Obs.
HHV pellets (BM)	MJ/kg.bm	**15.8000**	[20]
Standard input temperature	grade K	298.0000	[6]
Biomass input entropy	kJ/kg.bm.K	**53.0201**	
Input air entropy	kJ/kg.air.K	**6.8480**	[6]
A/F range	kg.air/kg.bmg	**1.5000**	[20]
Biochar yield	kg.bc/kg.bm	**0.1640**	[20]
Gasified biomass yield (BMG)	kg.bmg/kg.bm	**0.8360**	
Syngas mass	kg.gas/kg.bm	**2.0900**	
Carbon in biochar	kg.C/kg.bc	0.9100	[20]
Carbon of BM in BMG	kg.C/kg.bm	**0.1492**	[20]
HHV of biochar	MJ/kg.bc	**27.8000**	[20]
HHV of gasified biomass	MJ/kg.bmg	**13.4459**	
Specific heat of biochar	kJ/kg.bc.K	0.9500	[18]
Out reactor temperature	grade K	773.0000	[20]
Standard biochar entropy	kJ/kg.bc.K	**93.2886**	
Output biochar entropy	kJ/kg.bc.K	**36.5783**	
HHV output syngas	MJ/kg.gas	4.6000	[20]
Standard entropy syngas	MJ/kg.gas.K	11.5578	
Syngas specific heat	kJ/kg.gas	1.0000	[20]
Output syngas entropy	kJ/kg.gas.K	5.1025	
Heat loss - 3% of HHV.bm	kJ/kg.bm	474.0000	[20]
Heat loss entropy	kJ/kg.bm.K	1.5906	

(bm – biomass ; bmg – gasified biomass ; bc – biochar)

Table 2: Thermal system entropic balances

Feature	M.U.	Value
Balance reactor inputs		
Biomass mass	kg.bm	1.000
Input biomass entropy	kJ/kg.bm.K	53.0201
Input air entropy	kJ/kg.bm.K	8.5874
Total entropy inputs	kJ/kg.bm K	**61.6075**
Balance reactor outputs		
Output biochar entropy	kJ/kg.bm K	5.9988
Output syngas entropy	kJ/kg.bm K	10.6642
Thermal entropy loss	kJ/kg.bm K	1.5906
Total outputs entropy	kJ/kg.bm K	**18.2536**
Entropy generated in reactor	kJ/kg.bm K	**-43.3539**

Incorporating biochar in soil helps to increase crop production in same environmental conditions, which can decrease the environment entropy by sequestration in agricultural soil of about 0.153 kg.C/kg.bm or a 0.560 kg.CO2/kg.bm. This calculation confirms that the application of the CHAB concept can effectively contribute to decreasing the environment entropy.
Using the CHAB concept to achieve the same heat production, compared to the case of heat produced by directly burning biomass results in an average decrease of entropy by 15.338 kJ/kWhth.

Table 3: Environment entropic balance

Feature	M.U.	Value
Entropy of BC introduced in soil	kJ/kg.bm.K	**-15.299**
Carbon sequestered in biochar	kg.C/kg.bm	0.153
Carbon dioxide sequestered in soil	kg.CO2/kg.bm	**0.560**
Overall TLUD yield	real	0.912
Pellet burner yield	real	0.930
Burner energy with CHAB	MJ/kg.bm	10.143
Pellet burner energy	MJ/kg.bm	14.694
Specific entropy reduction	kJ/kWhth	**-15.338**

6. Conclusions

Using CHAB concept for the production of heat and biochar helps reduce the entropy of the environment so it is anti-entropic action, typical for the vegetation, contributing efficiently and directly to the sustainable development of agriculture and therefore for entire society.
The use of TLUD gasification process operating in CHAB conditions leads to a negative entropic balance of -43.353 kJ/kg.bm.K, a much higher entropy change than any other applications of the CHAB concept.
CHAB concept produces a unit of heat compared with the direct burning of biomass systems reducing the entropy with-15.338 kJ/ kWhth.
Compared with the direct burning of biomass with zero entropy balance, by introducing biochar in agricultural soil, a decrease of soil entropy with -15.3 kJ/kg.bm.K results, helping to increase the anti-entropic activity of agricultural soil.
An effective economic and ecologic optimization of similar thermal systems can be done by applying a Monte Carlo type analysis called the Cross Entropy Method.
This study may by used as a basis for advanced analysis of anti-entropic nature of energy production from biomass with CHAB concept.

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