Modeling Of The Combustion Of Municipal Solid Waste

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Abstract

For almost three hundred years, from the Industrial Revolution until now, the human kind has ignored the environment. Fortunately the things are about to change, the environmental protection being one of the top issues of our times. The recent progress made in technology, biology or chemistry is helping us to achieve this goal.

In these last years, the major concern of people and especially of the big companies was to keep the Earth clean. The first step in this process is using the energy resources in the most efficient way, followed by the decrease of the annual production of wastes.

Keywords: waste, municipal waste, combustion, refusal derived fuels

The model for the combustion process deals with the municipal solid waste combustion process. The purpose of this model is to obtain the energy necessary for the combustion of the municipal solid waste from Bucharest when the equilibrium state is zero. This implies that the residence time is long enough to allow the chemical reactions to reach an equilibrium state.

When it is taken into account a combustion process of a combustible composed of carbon hydrogen and oxygen, the final products are CO_2, H_2O, SO_2 and O_2 and N_2 when it is used air such as fuel. For the combustion process in the model it is used grate cooled air and grate cooled water with different value for temperatures of combustion and for excess air. When the combustion process takes place with oxygen or an inadequate quantity of air or at a lower temperature the products of reactions are: CO_2, H_2O, CO, H_2 and unburned carbon particles.

The used fuel can be air or industrial oxygen, with a purity degree of 95%. When the combustion process taken place with air (excess air in especially) is important to take also into account the nitrogen and the oxygen presence among the products of reactions.

The energy resulting from the combustion process depends first on the composition of the waste and the ratio of the waste, then on the ratio of air and on the temperatures for which it is taken into account the thermodynamic equilibrium of the reaction products.

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To create a numerical modeling for such a process I is necessary to be done some simplifying assumptions and to take into account only the most representative equilibrium reaction for the process. The inaccuracies of this simplification are any way negligible. It can be doe the assumption that the thermodynamic equilibrium between the products is realized in gas phase.

Therefore we can consider a thermodynamic combustion process with stationary flow and constant pressure.

If we neglect the NO_2 and SO_2 (because we neglect the percentage of nitrogen and sulfur) and consider only dissociation of water molecules and carbon anhydride, the combustion reaction, assumes:

$$xC + yH + zO + jO_2 + j\frac{79}{21}N_2 \rightarrow aCO_2 + bH_2O + CO_2 + j\frac{79}{21}N_2 \quad (1)$$

In this equation we can see the difference between the atomic oxygen provided by the waste (with the molar fraction equal to z) and the molecular oxygen provided as fuel (with the molar fraction equal to j).

If we know the elementary composition of waste we can find the quantity of the products of reactions, too. The municipal solid waste from Bucharest are formatted by cellulose material, plastic materials, glass and inert materials, organic materials, textiles, metals, mixed materials and other (this is the merceological composition). The chemical composition is:

Table 1

The merceological composition of the waste

Components	***kg cl.j/kg MSW***
Carbon (C)	0.189
Hydrogen (H)	0.023
Oxygen (O)	0.143
Nitrogen (N)	0.030
Volatile solids (SV)	0.385
Non – volatile solids (SNV)	0.158
Humidity (H_2O)	0.457

When the municipal solid waste is burned, the carbon, oxygen and nitrogen are oxidized.

The elementary compositions of the municipal solid waste from Bucharest (MSW), biodrying waste (biodried) and for refuse derived fuel (RDF) are:

Table 2

Elementary compositions of the MSW

Components	***MSW (kg/kg MSW)***	***Biodried (kg/kg bdd)***	***RDF (kg/kg RDF)***
Carbon (C)	0.189	0.227	0.290
Hydrogen (H)	0.023	0.028	0.035
Oxygen (O)	0.143	0.158	0.202
Nitrogen (N)	0.030	0.030	0.040
Volatile solids (SV)	0.385	0.443	0.567
Non – volatile solids (SNV)	0.158	0.263	0.064
Humidity (H_2O)	0.457	0.294	0.369

The initial waste that is used for the combustion process is liable to different process and is drying, then are separately the components like glass, metals, inert materials, poliaccopiati and another material which can't burned. Then all this waste is processed and is obtained the refuse derived fuel (RDF).

For this model we decide to use the equation (2), which needs the elementary composition of the waste, air, ash and products of reaction, the temperatures before and after combustion process (the temperature of the air, of the products and of the ash) and the high heating value.

$$\dot{m}_w \cdot h_w(T_a) + \dot{m} \cdot h_a(T_a) \rightarrow \dot{m}_p \cdot h_p(T_p) + \dot{m}_{ash} \cdot h_{pash}(T_{ash}) + \sum Q \quad (2)$$

$$\sum Q = Q_{lost} + Q_{used} \quad (3)$$

Where:

$\dot{m}_w$ = flow capacity of waste (kg/s);

$\dot{m}_a$ = flow capacity of air (kg/s);

$\dot{m}_p$ = flow capacity of products (kg/s);

$\dot{m}_{ash}$ = flow capacity of ash (kg/s);

h_w = enthalpy of waste (kJ/kmol);

h_a = enthalpy of air (kJ/kmol);

h_p = enthalpy of products (kJ/kmol);

h_{ash} = enthalpy of ash (kJ/kmol);

T_a = temperature of air (K);

T_p = temperature of products (K);

T_{ash} = temperature of ash (K);

Q_{lost} = the energy lost through combustion chamber (kW);

Q_{used} = the energy necessary for combustion process (kW).

For a perfect combustion with excess air is a necessary by 1 part fuel /waste, 1 part carbon and 4 parts hydrogen and 1 parts air. After we burned all this obtained 1 part carbon dioxide, 2 parts water vapor and 8 parts nitrogen. Therefore, the elementary composition of the waste is written in the next table.

Table 3

The elementary composition of the waste

Chemical elements	***Weight fraction (kg/kg MSW)***	***Weight fraction (kg/kg bdd)***	***Weight fraction (kg/kg RDF)***
Carbon (C)	0.189	0.163	0.161
Hydrogen (H)	0.023	0.020	0.019
Oxygen (O)	0.143	0.113	0.112
Sulfur (S)	0.030	0.021	0.022
Ash	0.158	0.469	0.479
Humidity (H_2O)	0.457	0.211	0.205

Each elements of this wastes, for combustion, have need by a quantity of oxygen which can be determined with a theoretically formula. The value what are determined in this way are presented in *Table 4:*

Table 4

The oxygen quantity used in the combustion

Components	***Oxygen for MSW***	***Oxygen for bdd***	***Oxygen for RDF***

Components	*Oxygen for MSW*	*Oxygen for bdd*	*Oxygen for RDF*
Carbon (C)	0.504	0.436	0.430
Hydrogen (H)	0.368	0.323	0.312
Oxygen (O)	0.030	0.022	0.022
Oxygen by waste	-0.143	-0.143	-0.112
Total	0.760	0.667	0.652

The quantity of the products of reaction are presented in the next table:

Table 5

The quantity of the products of reaction

Product of reaction	*MSW (kg/kg MSW)*	*Biodried (kg/kg bdd)*	*RDF (kg/kg RDF)*
Carbon dioxide (CO_2)	0.693	0.599	0.591
Water of reaction $(H_2O)_r$	0.103	0.090	0.088
Water of waste $(H_2O)_w$	0.457	0.211	0.205
Sulfur dioxide (SO_2)	0.060	.043	0.044
Nitrogen (N_2)	2.726	2.393	2.339
Oxygen (O_2)	0.068	0.060	0.059

After the combustion process we obtain the products of reaction and the ash. The quantity of ash that is obtain for municipal solid waste, biodried and refuse derived fuel is written in the next table and depends only by the ratio of waste that is introduced in the combustion chamber. The ash that is form during the combustion process contain in specially the carbon unburned and sulfur.

Table 6

The ratio of ash for each type of waste

Type of waste	***Ratio of waste (kg/s)***	***Ratio of ash (kg/s)***	***Ratio of waste (kg/s)***	***Ratio of ash (kg/s)***
MSW	17.403	2.750	1	0.158
Bdd	14.408	3.789	1	0.263
RDF	12.740	0.815	1	0.064

During the combustion process, each components that are part of the process (products of reaction, ash) produces a quantity of energy. Making a energy balance, we can see that a part of this heat lost through chamber walls (3%) and another part is lost with the ash (approximately 1%). In the next tables are written all the quantities of heat what are produced in the combustion process.

- Municipal solid waste

Table 7

The heat quantity for MSW

Type of heat	***Ratio of waste (kg/s)***	***Quantity of heat (kW)***	***Ratio of waste (kg/s)***	***Quantity of heat (kW)***
Heat of product	17.403	-131,487.92	1	-7,555.57
Heat of ash	17.403	1,409.78	1	81.008
Heat lost	17.403	3,801.65	1	218.45

- Biodried waste

Table 8

The heat quantity for biodried

Type of heat	*Ratio of waste (kg/s)*	*Quantity of heat (kW)*	*Ratio of waste (kg/s)*	*Quantity of heat (kW)*
Heat of product	14.408	-54,888.52	1	-3,806.03
Heat of ash	14.408	1,942.87	1	134.84
Heat lost	14.408	2,800.87	1	194.40

- Refuse derived fuel

Table 9

The heat quantity for RDF

Type of heat	*Ratio of waste (kg/s)*	*Quantity of heat (kW)*	*Ratio of waste (kg/s)*	*Quantity of heat (kW)*
Heat of product	12.74	-47,087.74	1	-3,395.77
Heat of ash	12.74	418.08	1	32.81
Heat lost	12.74	2,421.92	1	190.09

If we make a analysis for all this values, can see that the quantity of the heat by products is the biggest comparatively with the heat lost through the combustion chamber walls and the heat lost with the ash eliminated after combustion. This is true because the quantity of the products is biggest comparatively with the quantity by ash.

1 Conclusions

In Romania this type of incinerator (grate cooled air and grate cooled water) don't exist. One of this reason is related to the characteristics of MSW: the calorific values is not suitable for a direct combustion because of the high humidity. Using this installation with grate system a part of the energy result from off-gas produced could be used for the own consuming or for central heating. Presently Romania, a part from some pilot experience (hazardous waste that are burned in a special incinerator plant at Fundeni Hospital, Bucharest) all the waste (industrial and residual) are stored in the uncontrolled landfill. The biggest landfill of Romania, at Glina 400,000 m^2 where all waste are stored without any pre-treatment (all the products of bio-chemical reaction are release directly in the air).

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