JOURNAL OF ENGINEERING
annals OF
FACULTY OF ENGINEERING HUNEDOARA
Tome V (year 2007), Fascicole 3, (ISSN 1584 – 2673)

MODELING AND INVESTIGATIONS OF BALED CEREALS STRAW COMBUSTION

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Summary
Direct combustion of wheat and other cereals straw is in rural valley areas perspective way of producing energy. For the purpose of setting the right concept for new facilities, beside the information about the static relationships it is necessary to have date on kinetics of development of all present processes (drying, pyrolysis, gasification and oxidation.)
In this paper is presented construction of experimental facility which enables investigation on integral charecteristics of combustion kinetic of baled straw in the regime of >>burning out<<. Applied hanging position of bale enables appropriate accuracy of measurement of mass change during the time. To the reaction exposed is only the bottom side of the compressed straw parallelepiped. Regime parameters are adjusted with variations of temperature and gas composition which flows onto reacting surface.
Basis for the experimental investigation is a semi-phisical one-dimensional model of stationary combustion of baled straw.
Key words: Straw combustion, Modeling

1. INTRODUCTION

Analysis of perspective needs of fuel and energy and possibility of forefeeling its requests, leads to conclusion, that in the conditions of putten deficit of some sort of organic fuels (petroleum and natural gas) results necessarily reorientation energetics to coal and new non traditional sources as a biofuel [(1).]

We do not treat wheat straw (as a kind of the biofuel) as a respectable source of energy but in the agricultural areas with intensive production and developed process industry usage wheat straw and other sorts of cereals straw for energy production has a justifiable foundation.This is especially characteristic for the rural valley areas that in one hand are deficient with energy resources and in the other hand it has considerable potentional for production this raw [(2).]

Constructions for burning agricultural waste are still in the developing phase and today on the world market there are not contented solutions. For the purpose of setting the right concept for new facilities, beside the information about the static relationships it is necessary to have date on kinetics of development of all present processes (drying, pyrolysis, gasification and oxidation).

Purpose of this investigation is to show the experimental construction, which provides investigation on integral charasteristics of combustion kinetic of baled straw, i.e. measuring the velocity of the combustion according to the one-dimensional mathematical model.

2. MATHEMATICAL MODEL OF BURNING

Wheat straw, wheather it is pulverized , in rimfuze or comprimed in bales or brickets, presents in general solid porous material. When that kind of the fuel is exposed to intensive outside fluks source, in the beginning phase ocures the decomposition of surface layer material,which results by releasing gas products (volatils) and by forming solid rest (char) on the fuel surface. Volatils are mixed with the surrounding air and burning on the some certain level above the fuel level, while the pyrolysis zone is moving according to the inside of the solid mass under the char mass according to the progression of term field.

Dominant process which determines the kinetic combustion is pyrolysis, specially in the low temperature phase of the process. Abstraching the concrete contents of all process by mechanism of pyrolysis reactions, kinetic of total reaction is possible to show by Arrhenius
monomoleculus equation of the first order:

$$-\rho \frac{dm}{d\tau} = m\,k\left(T\right)\exp\left\{-\frac{E}{RT}\right\} \tag{1}$$

Suggesed formulation of the low express proportion of negative velocity in changing mass of unburned fuel with mass of remained unburned fuel, as a proportion of this parameter with Arrhenius temperature function.

In this projected experiment it is predicted comparative measurment of mass and temperature in the time period. For those kind of cases it is better to calculate parameters from upper rearanged equation:

$$-\frac{\left(\frac{dm}{d\tau}\right)}{m} = \frac{k}{\rho}\exp\left\{-\frac{E}{RT}\right\} \tag{2}$$

Density ρ relates to the mass of reacted matter in total temperature interval per unit of volume and presents a fictional item. According to the [3] this parameter could be expressed without any consequences to exactness and usage of measured figures and express unique with pre-exponential multiplicator k or, as it is known, frequency factor [4]. Activation energy of real technical materials does not have that point as in the cases of ideal gases. According to this, the role of universal gas constant (R) is conected with the formalism of usual investigation process as occures in nowdays literature.

In shown figure, the equation (2) has dimension 1/s , so pre-exponential multiplicator has dimension $kg/\left(m^3 s\right)$. Velocity of heterogenic reaction is expressed per unit of surface of burned material.

Suggested investigation method belong to the category of multi-factored experiments [5]. Basic factor, whose influence should fortify by knowing the pre-exponential multiplicator (k) and fictive energy activation (E) according to given low, is the temperature of cirkulated fluid (T). Also, it is possible to investigate the influence of following variables, thanks to this project experiment:

- composition of cirkulated agens (excess air coefficient),
- moisture straw in bales,
- density of baled straw (compression).

3. DESCRIPTION OF EXPERIMENTAL FACILITY

This experimental facility consist of:

- mixing chamber and burner,
- combustor,
- fuel bunker which is plased on the carrying construction above the combustor,
- basic construction,
- air input and flue output system with regulation and measurement construction,
- flue gas cooler (surface heat exchanger),
- exhaust stack with flue gas fan.

Combustor of experimental facility with fuel bunker and additional canals for input fresh air and output flue gases as assemble for removing ash, which is placed in unique stabile steel construction.

Fuel is coming to the combustor following the velocity of burning bale, and ash transporting handy according to the need over the ash try. Air, gas agens is inputing from one side of the burning area, and flue gases, apropos volatils, are going out of the combustor from the other side.

Assemble for fuel addition in combustor is a part of vertical bunker with constant horizontal cross-cut 0.5x0.6m (dimension of bale cross-cut). Upper cap bunker is made of steel tin. Putting down bale is made by mechanical way with the velocity that is equal with the velocity of burning out bale. Over the straw bale is made conection which link to the mechanism for dropping the bale and scale for measuring mass change because of burning. On the sides of burning area is placed a pair of glass for observation the process of burning and valuation of burning velocity. From one side of the burning area the door is placed for all kinds of intervence.

By the bottom of the combustor in the basic construction is shaped the part for inputing the assemble for ash removing. It consists of fender for burning and ash collecting box. It carries out manualy. Agricultural waste approximately do not contain a lot of ash so, for purpose of smaller construction this part is in general redundant.

According to the conception investigation one of the most important parameters in process is air elapse. Part of construction which is made for input, measurement and regulation air amount in the burning process consists of:

- centrifugal fan,
- measured path with measured stifler,
- flow regulator ,
- valve and orifice plate,
- gas burner,
- mixing chamber.

Fresh air fan is mid-pressure and have to overcome the reactions of measured path from the fan to the combustor. Fan type is chosen understudying its work characteristic during the experimental construction work with that fan. Construction includes the flue gases fan to eliminate monometric presser in the combustor.

To reduce flue gases temperature it is provided heat exchanger in flue output channel. Cooling is done with water perforce circulation around the flue gases pipings. Cooled flue gases leave installation and go through exhaust stack into surroundings.

Most of measure equipment is joined to system for converting signals (outcome tension) into number values and send them to the computer to memorize them. On that way subjektive errors during the readin and writing are eliminated.

4. INSTRUMENTS AND GAUGE POINTS

Gauge points are located on experimental construction according to scheme on the Fig.1. Description of gauge points are given in Table 1.

Table 1. Plan of gauge points

1	2	3	4
NUM. SIGN	**Time**	**Sign**	**Dim.**
1	Mass	m	kg
2.1	Flow of fresh air	$\dot{V}_{fa}$	m³/h
2.2	Flow of natural gas	$\dot{V}_{ng}$	m³/h
3.1	Temperature of fresh air	t_{fa}	K, °C
3.2	Temperature of agens	t_a	K, °C
3.3	Temperature of natural gas	t_{ng}	K, °C
3.4	Temperature of flue gases	t_{fg}	K, °C
3.5	Temperature of flue gases	t_{fg}	K, °C
4.1	Pressure of natural gas	P_{ng}	Pa
4.2	Pressure in combustor	P_c	Pa
5.1	Composition of agens	CO_2, CO, NO_x, SO_2	%
5.2	Composition of flue gases	CO_2, CO, NO_x, SO_2	%
5.3	Composition of flue gases	CO_2, CO, NO_x, SO_2	%

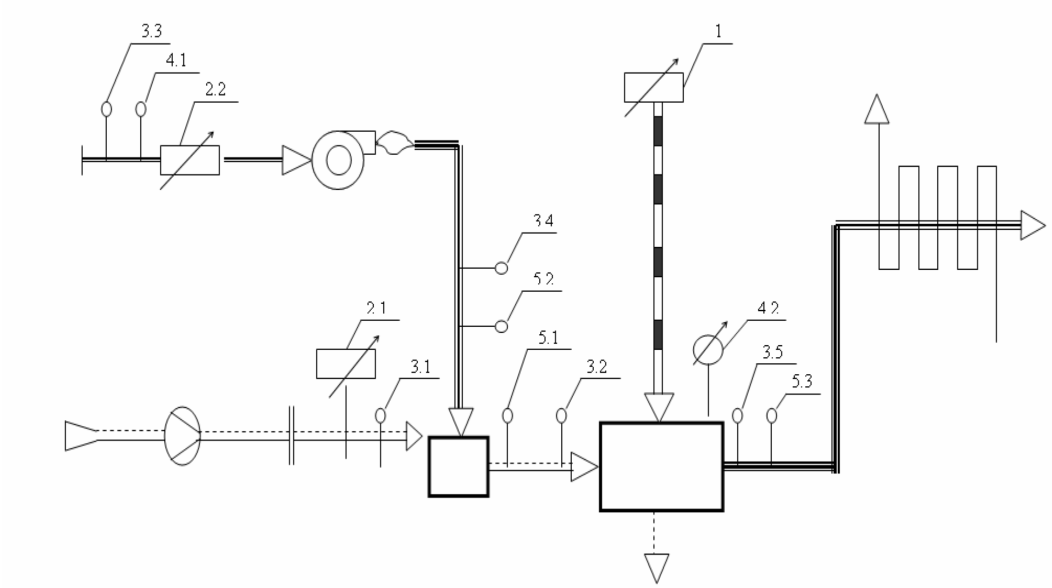

Fig.1. Schematic of gauge points

5. EXPERIMENTAL PROCESS

One cycle of measurement, i.e. examination from the ignition to the fire extinction is done with only one bale of straw. Mass and dimension of bale are measured before examination, and than bale is put into the bunker. Fire can be burned after preparation the burning regime, that include mass flow of water through the boiler and given excess air coefficient . Because the mass flow of fuel is discontinual, during the examination, it is very important to determine the level of fuel on the observation glasses, and exchange velocity of putting doun bale if it is necessary. Examination of one cycle last from the time of the ignition to the optionaly chosen momentum. During that time it is necessary to determine value of important measures in the proper time interval.

When the measurement is finished, construction should work until the fire is burning. After construction cooling, ash is colected from the combustor and measured its weight for purpose of accounting ash contents in the fuel.

Projected construction make possible to follow:

- mass reduction of straw bale during the burning,
- flue gases temperature in flue output system,
- capacity and mass flow of air for burning,
- excess air coefficient in gas,
- boiler water input and output temperature.

6. CONCLUDING REMARKS

In concrete cases there are many factors that influence on concrete kinetic of cereals bale combustion. Dominant process that determines this process is pyrolysis reaction that can be described by Arrhenijus monomoleculus equation of the first order. By variation of density and moisture of fuel and agents composition that activate pyrolysis reaction it is possible to follow kinetic change of the rest of the solid fuel mass. For the purpose of making experimental model of different cases it is made special facility.

Acknowledgments
The authors acknowledges the generous support given by Department of science, tehnology and environment.
This work is part of the projekt NPEE br.300037: ''Development of the construction for energetic conversion of baled biomass for the purpose of industry in the rural valley areas.''

Nomenclature
E - activation energy, k - frequency factor, m - the mass concentration, R - universal gas constant, kJ/(kgK), T - temperature, K, ρ - density, m^3/kg, τ - time, s

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