Investigation of inorganic element K release during combustion of biomass particles with different potassium concentration

1 Introduction

During last decade, the use of biomass for energy production became very important. With increase of biomass usage, the quality of the feedstock for energy production becomes worse. During thermal degradation of biomass various chemical transformation occurs and due to change of fuel properties it is hardly to forecast the whole combustion process. The biggest challenges occurring during combustion is related with an ash issues. Flame and combustion monitoring using chemiluminescence method has received a lot of attention for combustion sensing and diagnostic applications in various fields.

2 Experiment

2.1 Wood and Straw particle characterisation and particle preparation for single particle combustion

The original fuel used was wood and wheat straw milled pellets. Table 1 shows the properties of this biomass.

Table 1 Properties of wood and wheat straw

Proximate analysis, %	***Wood***	***Straw***
Moisture	2.94	4.04
Volatiles	78.56	73.13
Fixed carbon	15.50	18.8
Ash	3.50	4.15
HHV (MJ/kg)	19.12	17.53
LHV (MJ/kg)	18.05	16.52
Ultimate analysis, %		
Carbon	51.38	49.06
Hydrogen	5.58	5.41
Oxygen	39.48	40.72
Nitrogen	<0.01	0.42
Sulphur	<0.01	<0.01
Chlorine	0.042	0.226

The sewage sludge particles were prepared in two size groups; 200–250 µm and 400–450 µm. But in experiment were used only 200-250 µm size wood and wheat particles. Raw wood and wheat straw sample was dried at 105 ºC. Afterwards, the biomass was impregnated with different concentrations of K (using potassium oxalate monohydrate as reactant). The wet impregnation procedure consists of adding different amounts of K reactant to 50 ml of ion-exchange water and their subsequent mixture with 5 g of dried biomass. The resultant impregnated biomass samples were dried at 105 °C, and stored at ambient conditions. Three doped sample with different concentrations of potassium were used during experiment:

1) Wood sample with 0%, 3% and 6 wt.% of K ;
2) Wheat straw with 0%, 3% and 6 wt.% of K.

2.2 Experiment equipment

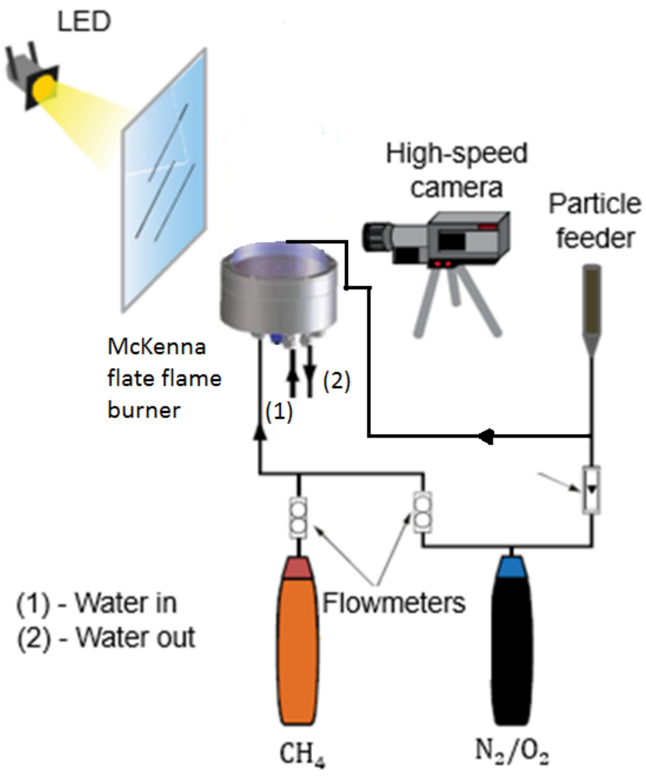

Figure 1 Principal scheme of laboratory stand

The image acquisition system includes a CMOS high-speed camera Optronis CamRecord CR600x2, equipped with a lens AF Micro-Nikkor 60 mm f/2.8D and a teleconverter Kenko TelePlus MC7 AF 2.0X DGX to increase the focal length of the lens used. Cartridge with filters is mounted between CMOS high-speed camera and teleconverter. Additionally, the image acquisition system includes a diffuse led backlight to enable the camera to record the shadow projection of the particles. In order to align the position of the camera, a target with millimetre marks was used for calibration before each experimental session. The axis of the camera was aligned perpendicularly with the axis of the burner so that the camera could record images of the particles since their injection. The particle were injected in the middle of the burner from metal probe tube. Table 2 lists the main camera settings used.

Table 2 Main camera settings

Frame format	840x672
Frame rate [FPS]	1000
Exposure time [sec.]	1/1000
Gain	1
Recording time	7391 frames = 7391 [ms]

Table 3 Burner operating parametres

Parameter	**T1**
Methane flow [dm^3/min]	1.6
Primary air flow [dm^3/min]	16.2
Transport air flow [dm^3/min]	0.092
Mean gas temperature [K]	1307

2.3 Post processing data

The images collected with the high-speed camera were analysed in order to calculate the intensity of signal. Capturing the visible light from the particles has been proved to be a good indicator of ignition despite soot and char emissions being included in the visible light captured. intensity defined by the ignition criterion. About 50 experiments with different doped samples were done. Plot diagrams and results rom pictures was obtained using Matlab program.

3 Results and discussion

Release of potassium at high temperature after complete dechlorination can be due to the thermal decomposition of carbonates, producing K or KOH depending on the partial pressure of water vapor in the ambient gas [1]. The release of potassium in the form of KOH was reported for low chlorine fuels and high H2O concentrations in the gas phase in other studies [2,3]. The following reaction paths are suggested in the literature [1,3,4] for the formation of KOH:

$$K_2CO_{3(s)} \rightarrow CO_{2(g)} + K_2O_{(s)};$$
$$K_2O_{(s)} + H_2O_{(g)} \rightarrow 2KOH_{(g)};$$
$$K_2CO_{3(s)} + H_2O_{(g)} \rightarrow KOH_{(g)} + CO_{2(g)};$$

By using the kinetic rates proposed in this study and the findings of previous works, a reaction mechanism is proposed for the release of potassium from low Cl content biomass. This model suggests that the inorganic potassium evaporates during the devolatilization stage mainly in the form of KCl. A parallel reaction produces carboxylic acid groups, char-K, that remain inside the char structure. During char reactions with O_2/CO_2/H_2O, these carboxylic acid groups decompose to carbonate, sulfate and silicate groups.

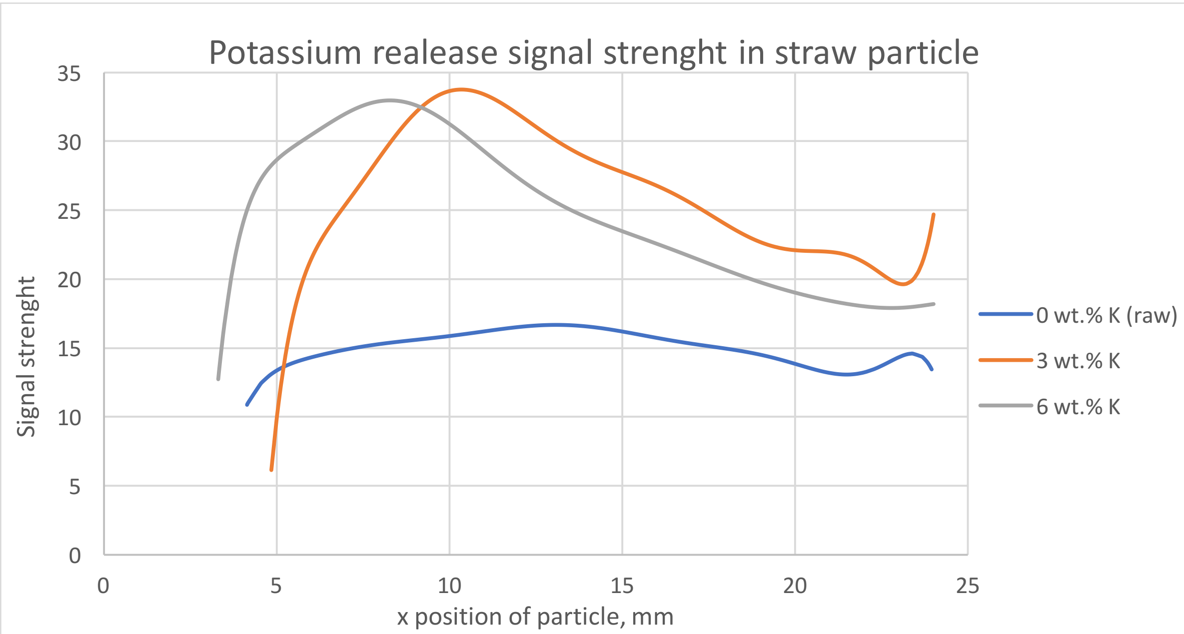

Figure 2 Potassium release signal strength during wheat straw particle combustion

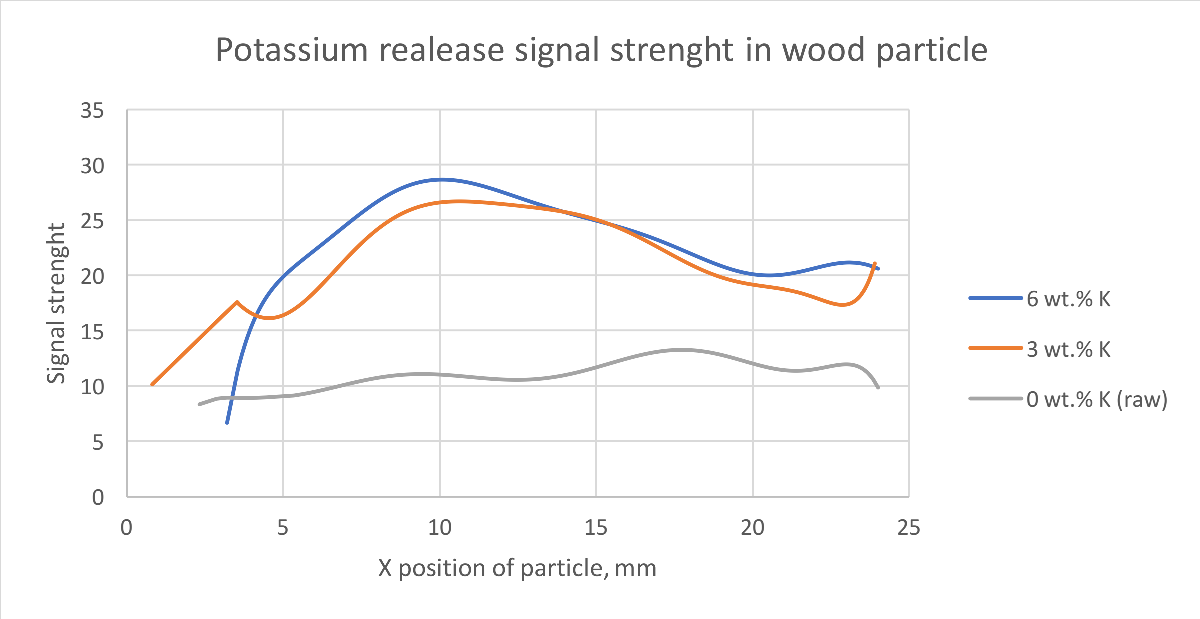

Figure 3 Potassium release signal strength during wood particle combustion

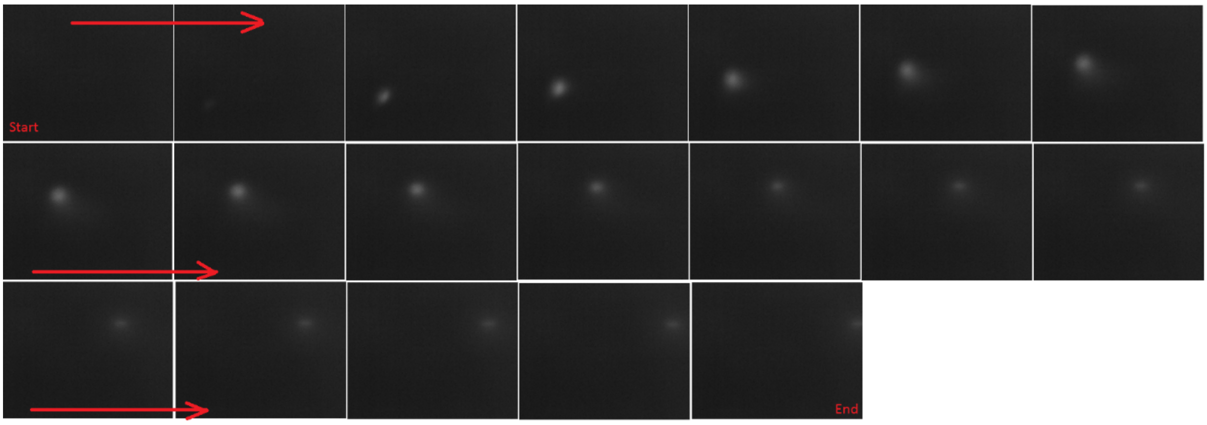

Figure 4 Releases of K during combustion of single wheat straw particle

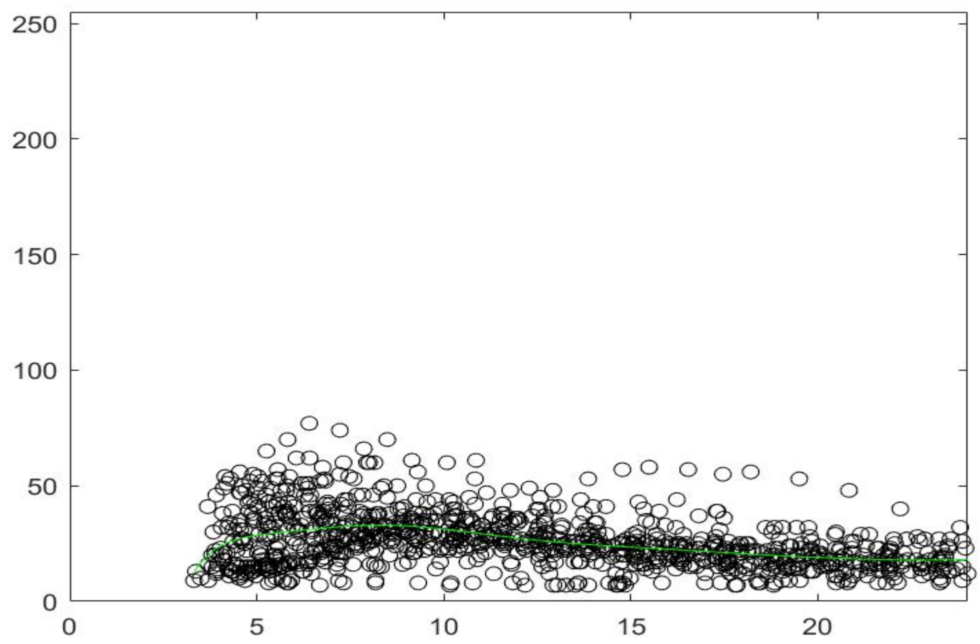

Figure 5 Data collected from 50 experiments with 200-250 µm wheat straw particle

In [Figure 2] and [Figure 3], the higher signal intensity is then particle already ignited and flied 10 mm from the injector. Later the signal of intensity is decreasing. It depends of concentration of K in doped sample. During combustion of 6 % wt. % K wood particle, signal intensity is higher than 3 % wt. % K wood particle. Using high speed camera with mounted K filter, signal strength is not very high [Figure 4] , but with data [Figure 5] calculated using Matlab program we can get important information about K release during combustion of biomass particles with different potassium concentration. This topic is important and in the future I will continue my experiments in this science field.

4 References

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4. S.C. van Lith, V. Alonso-Ramı´rez, P.A. Jensen,F.J. Frandsen, P. Glarborg, Energy Fuels 20 (3)
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