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Optimisation of Biomass Structured by Chopping for Energy Utilisation

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Abstract. The paper is focusing on presenting latest research results in the field of utilization of biomass for energy purposes. Analyses of the chopped bulk biomass material (energy plants, woods) is demonstrated with description if laser imaging technology for identification of surface metrics. Results can be used in process control for feeding furnaces. Biomass combustion dynamics has been investigated to identify basic properties of energy transfer during burning of biomass particles.

Keywords: Biomass, Energy, Image Analyses, Combustion Dynamics

1. Introduction

Fossil fuel resources are becoming depleted all over the world. Their abstraction is becoming increasingly expensive. At the same time, the growth dynamics of the volume of environment pollution generated during their utilisation, in "overpopulated" regions in particular, gives rise to an increasing threat. Escalation of the problem is further strengthened by multiplied energy consumption accompanying technical development. Under such circumstances it is quite natural that the researchers and users of energy are looking for complementary fuels everywhere, which are believed to decrease the deficiency and increase the environment and health retaining capacity of nature and humanity. Among these alternative energy bases we can find the voluminous biomass as well, which accumulates solar energy and can be produced in excess for human or animal nutrition locally or is unsuitable for that purpose right from the start, which, if converted into a fuel of sufficient efficiency and security, can decrease the hunger of the world for fossil fuels and improve the balance figures of environmental load.

Our research work whose results we are going to briefly present has been focused in the recent years on how to utilise the vegetable (plant) and woody biomass in a most economical way, that is, by the least possible labour input and by generating the largest possible energy output when it is used for the production of heat energy by combustion in a power plant, or for the production of biogas when semi-wet procedure is applied (mixed with organic manure).

What should be the level of preparation of the input biomass meeting the requirement of high energy demand but only of the necessary rate of preparation in order not to be excessively voluminous, but to be homogenous, suitable for manipulation, feeding, sufficiently explored for energy recovery and suitable for process control?

A prerequisite, however, to the above investigations is the continuous control of the composition of the biomass and the size of the related adequate surface by applying parametric approach, or if it is not possible, the use of reliable heuristic methods as it has to be suitable for application in continuous processes of identical power production output. Without this, stable, balanced, process controlled power production at operational capacity is unconceivable. For this reason, first we would like to present our findings of the structure identification research followed by the biogas output results, and finally we discuss the lessons

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offered by the combustion dynamics experiments. We emphasize, however, that although our findings have resulted in theses suitable for generalisation regarding the processes under review, they are significant only amidst the given laboratory circumstances. For their application in practice, validation by semi- or permanent operation is indispensable.

2. Investigations on biomass structure

Mobile machines, self-propelled forage harvesters equipped with a chopper drum or chopper disk of several hundred kW engine performance are used on a broad scale for producing chopped green biomass. Szendrő's size distribution model offering six parameters on the composition of the output bulk material of such machines' operation has been known and has been in use all over the world since the 1970s [1]. In essence it means that a large proportion of the chopped biomass produced by such modern, so-called exact forage harvesters is close to the adjusted chopped green mass length and is of normal distribution, a smaller proportion, about 5% in general, is broken mass of homogenous distribution due to finite and varied leaf length for biological reasons, and another, not more than 30% is of the so-called excessive size proportion caused by the disorderly arrangement of the leafs in the machine, of decreasing volume along the power function, but of increasing length. This parametric approach offers very precise definition, but requires the execution of empiric density function (Figure 1), which is of excessive labour and time demand. It is a discrete diagnosis, which is not suitable for analogy; therefore it is not suitable for process control input either [2].

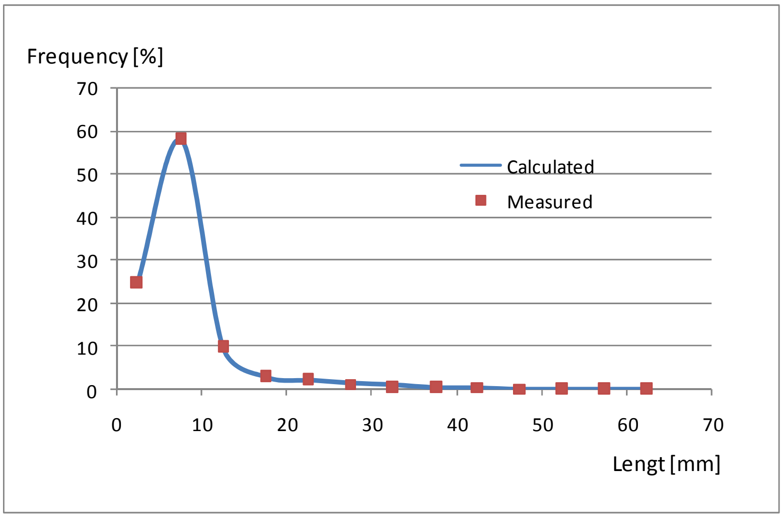

Fig. 1: Size composition of chopped green maize forage (adjusted length 5 mm)

Modern, computerised image processing technology allows us to apply the more precise 3 D scanning technology instead of chop length to define unique surfaces of the chopped forage and the total free surface that is of primary importance for combustion and gas generation. Related experiments have proved to be successful, but the effective arrangement of the chopped forage sample (to avoid covering the edges) and the difficulties with the appropriate lighting have loaded the input of the software already well managing the totality of the contours with a lot of room for errors (Figure 2).

Most effective structure diagnostics offering heuristic size, and within this, surface composition, suitable for the control of the combustion process or the biogas generation process of mixed organic manure and chopped green maize can be reached by the analysis of the plane section laser image of the fractions surface. With this method, the structure can be continuously surveyed and assessed by computer even during the material flow heading for production (see e.g. the feeding process of the combustion furnace). The penetration depth of laser, that is, the continuity of surface fractures proved to be significant for the total free surface of the chopped mass, which is decisive from the aspect of power generation capacity (combustion dynamics, biogas emission). Smaller size and the related total surface result in coherent, balanced fractures, while proceeding towards larger sizes, the picture becomes less balanced and more fragmented (Figure 3).

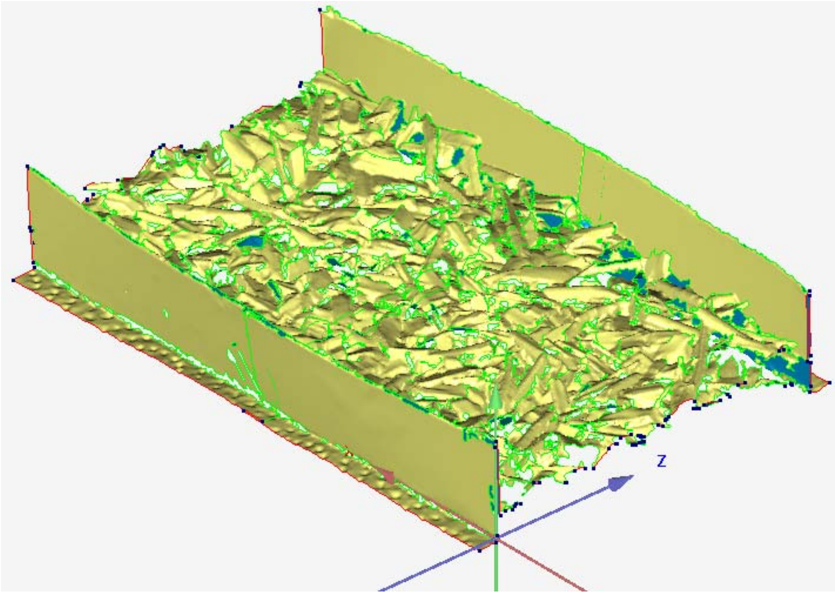

Fig. 2: 3D image of unsettled woodchips

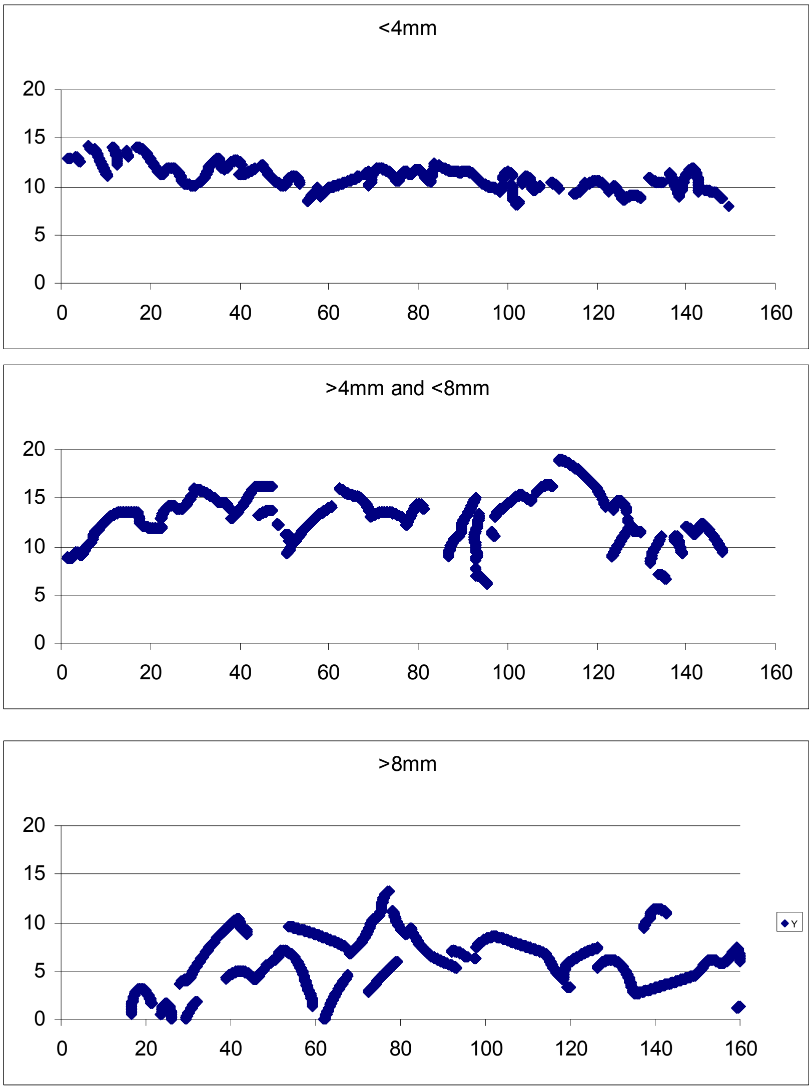

Fig. 3: Changes in surface fractures in case of increasing fraction length (x and y axes scale are [mm]

These surface fractures can be well managed by practical routine software and the parameter defined thereby can be reproduced in an identical situation with minor errors, therefore it can be efficiently used for fraction rating and as process control input signal.

3. Analyses of Combustion Dynamics

The combustion process, its equilibrium state of continuous operation, and the speed of the combustion have been examined by the change in mass during small volume sample combustion in a model combustion oven [5, 6].

The experimental measuring equipment is shown in Figure 4. Measurements have been adjusted to ensure the burning of the sample of identical mass at a constant and continuous temperature, therefore the only independent variable in the process is the structure of the chopped mass and its arrangement.

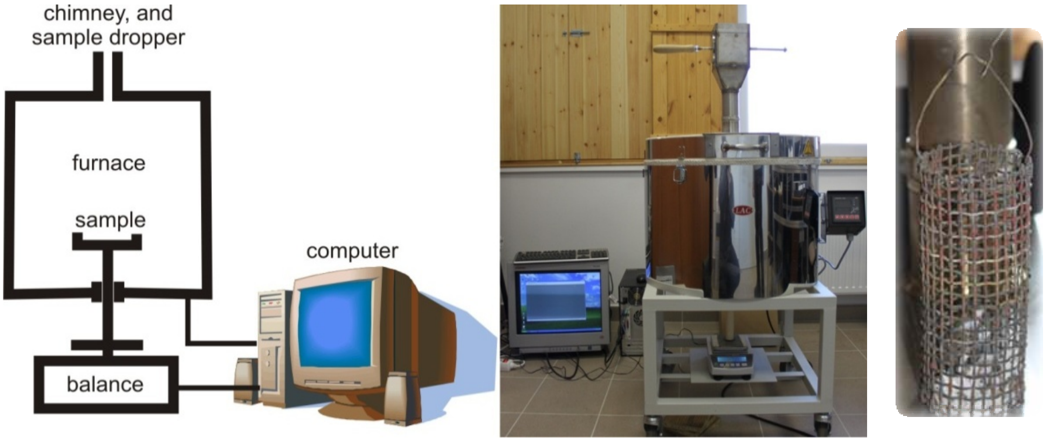

Fig. 4: The experimental assembly, the oven and the sample holding basket

We have obtained proof that in case of structures of identical size and form (homogenous, so-called artificial structures made of acacia wood were applied during the test) combustion runs of identical dynamics and duration were generated in repeated runs (Figure 5), that is, in case of feeding the oven with identical mass flow, balanced heat energy production can be presumed.

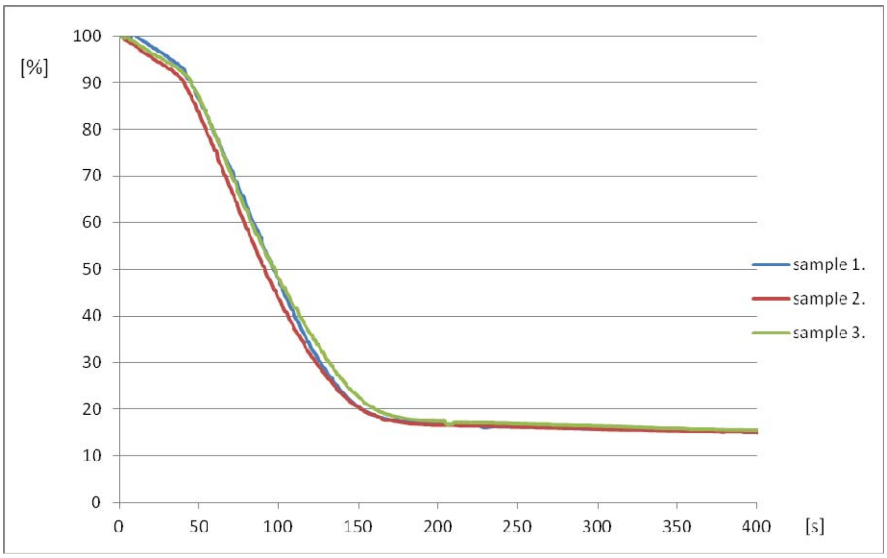

Fig. 5: Combustion dynamics image of repeated measurements overlapping and showing the balanced state of combustion

Proof has also been obtained of the fact - which in the present case is also evident - that combustion speed increase is in direct ratio to the total surface of the homogenous sample. The news, however, is that this phenomenon is independent of the rate of settlement of the chopped mass.

In case of inhomogeneous, real structures, however, e.g. woodchips, chopped biomass, the situation is different. The reason is that the speed of mass decrease during combustion depends not only on the total surface of the pile, but also on the size of the free surface brought about by the accidental arrangement of the particles, the channelling effect. Along the arranged flow routes generated in the pile the spreading speed of the flame front is increased. The unpredictable combustion behaviour of the fuel mix is caused by the ventilation glass system blocked by the collapse of the pile, randomly generating alternative routes, while in a homogenous fuel pile blocked and newly generated channel lengths show no significant difference. A frequent consequence of the phenomenon is that the combustion speed of chopped mass of different size composition is highly settlement dependant, therefore in order to attain balanced combustion of operation level it is advisable to apply e.g. a vibration feeder in order to reach homogenised settlement.

4. Results

Objective of the investigations described earlier was to identify optimal size distribution of mixed bulk input biomass in a semi-wet biogas production process when the mixture contains 70 % liquid manure and 30 % corn or sorghum silage. The results show that the volume of biogas production is increasing monotonously assuming that the general size of the input particles of both mixed biomass bulk is decreasing. (It must be noted that no significant changes were identified in the content and the dynamics of biogas production).

According to these findings there is no optimal size parameter regarding the raw material preparation process. At the same time chopping bulk raw biomass consisting of smaller and shorter particles requires significantly more energy. Therefore optimum setting is feasible in terms of economics where biogas volume surplus generated by smaller sized biomass is balanced with the increased energy input requirements during the preparation of chopped material.

5. Acknowledgement

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