ISSN 1691-5402
ISBN 978-9984-44-027-9
Environment. Technology. Resources
Proceedings of the 7th International Scientific and Practical Conference. Volume 1

BIOMASS MIXTURES AND ITS HOMOGENEITY
BIOMASAS MAISĪJUMI UN TO VIENDABĪGUMS

Aivars Kaķītis, Imants Nulle
Institute of Mechanics, Faculty of Engineering,
Latvia University of Agriculture
J. Čakstes bulv. 5, Jelgava, LV 3001, Latvia
E-mail: Aivars.Kaķītis@llu.lv; Imants.Nulle@llu.lv

Abstract. *Components of mixtures have to be in required proportion and homogeneous mixed to provide good quality of briquettes or pellets. Analyzing the mixing processes several advantages for mixing biomass with an in-flow or continuous mixer was discovered.*
To provide better quality of in-flow mixing process an electrical charge can be applied to the particles using corona discharge. When a sharply pointed electrode is raised to a high potential, the intense electrical field at its tip ionizes the air in its immediate vicinity. To mix particles of different bulk materials, it is necessary to give a negative electrical charge to one material, and a positive electrical charge to other material particles. The electrical charge provides mixing on a small scale, and electrostatic forces drive the process towards a perfect mixture.
In this article experiments of in-flow mixer equipped with electrodes of corona discharge is described. Three different rotation frequencies (20, 35 and 50 rpm) of conveyer shaft and five different voltages (0, 5, 10, 15, 20 kV) of corona electrodes were used to evaluate impact on flow direction of balk material.

Abstract. *Biomass mixtures, homogeneity, image analyze, electrostatic field.*

Introduction

Peat can be used as additive for manufacturing of solid biofuel, because it improves density and durability of stalk material briquettes (pellets). The burning performance of biomass fuel if we use peat additive is improved also. If only wood chips or herbaceous biomass are burned, the sulphur content is low and chlorides are formed [1]. The chlorides then tend to condense on heat transfer surfaces of the steam boiler, slowing down the heat transfer and causing the risk of high temperature corrosion. If the sulphur content of the fuel is increased, e.g. by blending peat with chips or herbaceous biomass, sulphates are formed instead of chlorides and high temperature corrosion is avoided. For these reason compositions with peat for solid biofuel production is recommended.

Components of mixtures have to be in required proportion and homogeneous mixed to provide good quality (density, durability, and burning properties) of briquettes or pellets. Analyzing the mixing processes several advantages for mixing biomass with an in-flow or continuous mixer was discovered. The machine costs of the in-flow mixing process are by 38 % lower than for the discontinuous mixing. The total operation costs for the briquetting process using an in-flow mixer are approximately 6% less than using a cyclic mixer.

To provide better quality of in-flow mixing process an electrical charge can be applied to the particles using corona discharge. When a sharply pointed electrode is raised to a high potential, the intense electrical field at its tip ionizes [2] the air in its immediate vicinity. The ions produced move away from the electrode along the electric field lines, and this corona discharge can be used to “spray” ions (and, thus, charge) onto particles.

The uncharged particle will attract field lines. Free ions will begin to be captured by the particle. The particle continues absorption until it has the same potential as the incoming ions. Degree of charge absorbed depends on particle size, field strength, and time in charge area (Fig.1 a).

When the particle has reached its saturation point of captured ions it develops its own electric field. This new field will then cause lines of force to be pushed away from the particle. Ions can no longer reach the particle due to repulsion (Fig.1 b).

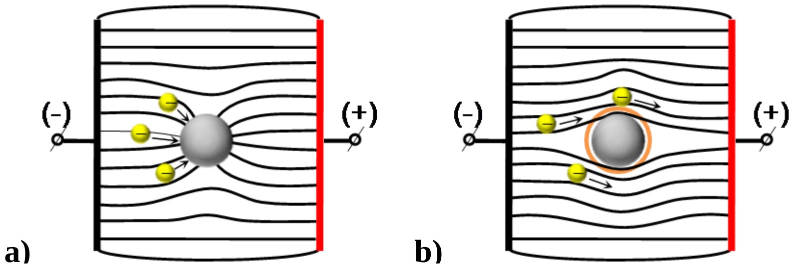

Fig. 1. **Particle in an electric field**

The basic idea of this mixing device is a simple one. For example, to mix black particles with white particles, give the black particles a negative electrical charge, the white particles a positive electrical charge, and allow them to combine. Two processes will now take place concurrently: groups of like particles will repel each other and tend to spread, while unlike particles will attract each other. Once an unlike pair is combined it will remain combined as long as the particles retain their individual charges.

Theoretically, if each particle were given the same charge and enough time was allowed, every black particle would be combined with one white particle (assuming that blacks and whites are being mixed in equal proportions), and the resulting pairs would be electrically neutral. Since the particles under consideration in this case are biomass materials which are electrical insulators, the combined pairs should not separate until the charges are depleted (i.e., relaxed). The net result would be a perfect mixture. Of course, a real device will deviate from such ideal behavior to some degree depending on the design of the device. The electrical charge provides mixing on a small scale, and electrostatic forces drive the process towards a perfect mixture.

Materials and methods

Estimation of the volumetric throughput of a rotor feeder of in-flow mixer was carried out in experimental equipment (Fig.2). Experimental equipment consists of containers 1, rotor of feeder 2 coated with a special rubber coating with knobs (highness of the knobs is 6mm), conveyer 3 and two electrodes 4 and 5. Rotation frequency of rotor and conveyer was changed by electromotor.

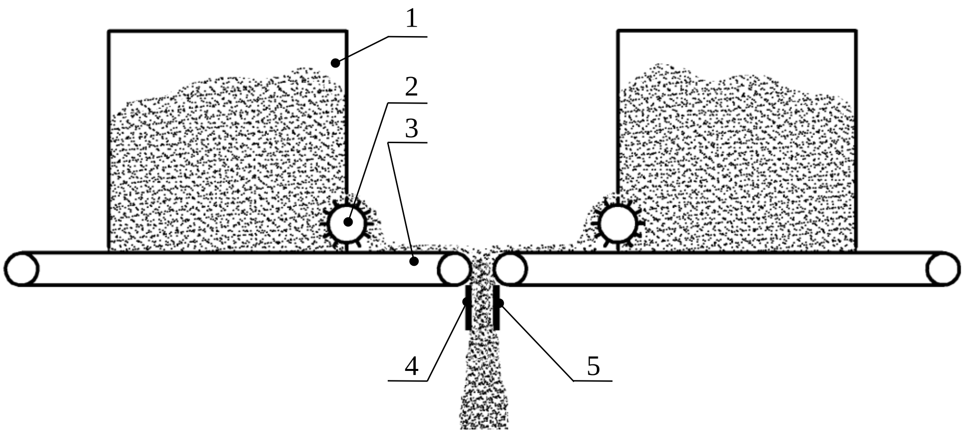

Fig. 2. **In-flow mixer**

1 – container; 2 – rotor of feeder; 3 – conveyer; 4 – positive electrode; 5 – negative electrode

The frequency of conveyer shaft (∅24 mm) was stated using AC tachogenerator. To process impulses coming from tachogenerator PicoScope 3423 oscilloscope was used. The frequency of rotor feeder (∅35 mm) is 1.46 times lower than frequency of conveyer shaft.

For understanding corona discharge impact on flow direction following experiment was carried out. Three different rotation frequencies (20, 35 and 50 rpm) of conveyer shaft and five different voltages (0, 5, 10, 15, 20 kV) of corona electrodes were used to evaluate impact on flow direction of bulk material. Beneath of a bulk material flow measuring box with 40 mm wide sections was placed (Fig.3). The weight of bulk material from every section was stated. Distance between electrodes 30 mm. Every electrode consists of two parallel wires charged with that same voltage. Distance between wires 27 mm.

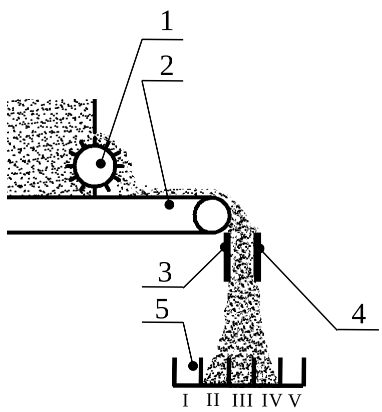

Fig. 3. **Impact of corona discharge on flow directions**

1 – rotor of feeder; 2 – conveyer; 3 – positive electrode; 4 – negative electrode; 6 – measuring box

To obtain parameters of in-flow mixer equipped with electrodes of corona discharge experiments with sawdust and peat were carried out. Particle size of sawdust and peat was less than 5 mm. The distribution of the particle size is shown in Fig.4 and Fig. 5. Moisture content of bulk material was ~12%. Density of sawdust was ~108 kg m^{-3} but for peat ~112 kg m^{-3}.

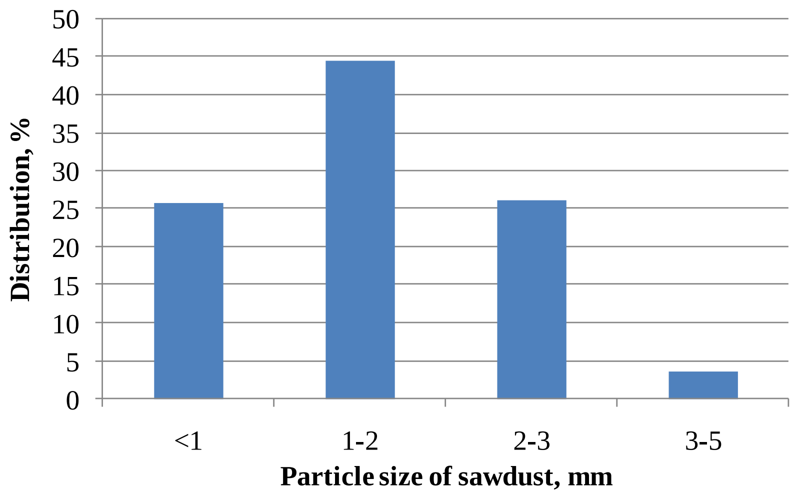

Fig. 4. **Distribution of particles size of sawdust**

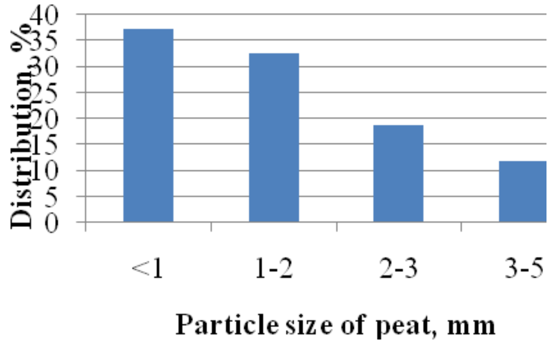

Fig. 5. **Distribution of particles size of peat**

Corona inception voltage CIV

Peek's law is a description of the conditions necessary for corona discharge between two wires [3; 4]:

$$e_v = m_v g_v \delta r \ln\left(\frac{S}{r}\right), \tag{1}$$

where e_v – the "visual critical corona voltage" or "corona inception voltage" (CIV), the voltage required to initiate a visible corona discharge between the wires, kV;

m_v – an irregularity factor to account for the condition of the wires. For smooth, polished wires, $m_v = 1$. For roughened, dirty or weathered wires, 0.98 to 0.93, and for cables, 0.87 to 0.83;

r – the radius of the wires, cm;

S – the distance between the wires, cm;

δ – the air density factor.

It is calculated by the equation [4]:

$$\delta = \frac{3.92b}{273 + t} \tag{2}$$

where b – pressure in centimeters of mercury;

t – temperature in degrees Celsius.

At standard conditions for temperature and pressure (25°C and 76 cmHg) [4]:

$$\delta = \frac{3.92 \cdot 76}{273 + 25} \tag{3}$$

where g_v – is the "visual critical" potential gradient, and is calculated by the equation [4]:

$$g_v = g_0 \delta \left(1 + \frac{0.301}{\sqrt{\delta r}}\right) \tag{4}$$

where g_0 – is the "disruptive critical" potential gradient, about 30 kV cm^{-1} for air.

Results and discussion

The specific throughput of rotor feeder doesn't depend on frequency and at frequency from 10 to 60 rpm (conveyer shaft frequency) is 0.005 kg rev^{-1} for both sawdust and peat.

The throughput of the rotor feeder is increasing linearly at rotation frequency from 10 to 60 rpm. The throughput of the sawdust and peat (< 5 mm) in this frequency range grows from 0.05 to 0.3 kg min^{-1}.

The calculated CIV (corona inception voltage) according equation (1) for discussed corona electrodes construction is 15 kV. Obtained result (15 kV) match with experimentally noticed voltage required to initiate a visible corona discharge between the wires.

In Fig.7 it is shown that the angle of mass flow through electrodes depends on voltage. If the voltage is higher ion’s flow from the electrodes move the bulk material stream away from positive electrode 3 (Fig.3). As we can see in Fig.8 the corona charge doesn’t have impact on bulk material (sawdust) stream direction if voltage doesn’t exceed 5 kV. The center of bulk material (sawdust) stream moves about 20% if the voltage increases from 0 to 15 kV. Increasing voltage from 15 to 20 kV doesn’t move anymore the center of stream.

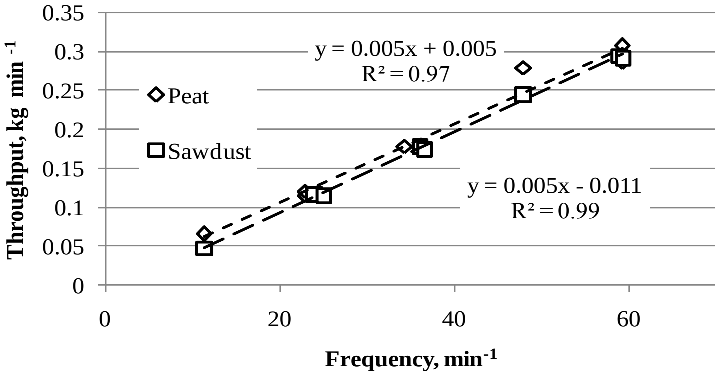

Fig. 6. **Throughput of the rotor feeder**

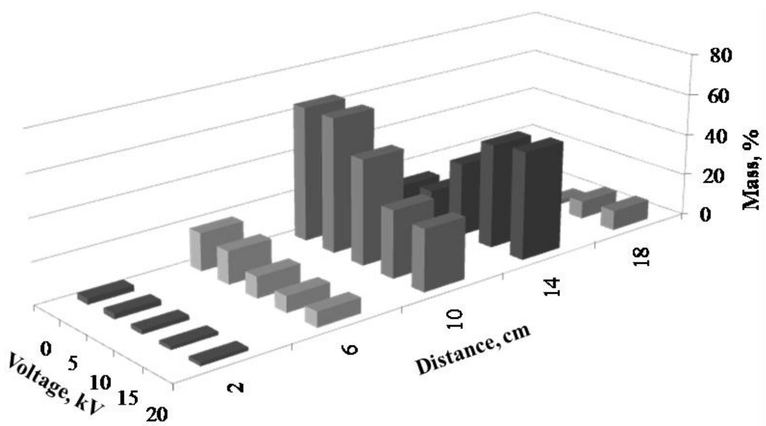

Fig. 7. **Distribution of the bulk material**

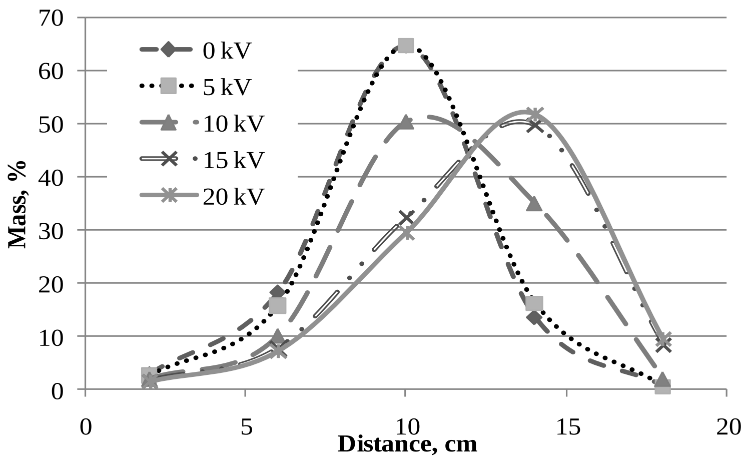

Fig.8. **Displacement of flow centre in dependence on voltage**

Conclusions

1. The specific throughput of rotor feeder doesn't depend on frequency and at frequency from 10 to 60 rpm is 0.005 kg rev^{-1} for both sawdust and peat.
2. The throughput of the rotor feeder is increasing linearly at rotation frequency from 10 to 60 rpm. The throughput of the sawdust and peat (< 5 mm) in this frequency range grows from 0.05 to 0.3 kg min^{-1}.
3. The corona charge doesn't have impact on bulk material stream direction if voltage doesn't exceed 5 kV
4. The center of bulk material (sawdust) stream moves about 20% if the voltage increases from 0 to 15 kV.

Acknowledgements

The authors gratefully acknowledge the funding from Latvia Board of Science this work under grand 05.1598.

References

1. Terhi Lensu. Quality guidelines for fuel peat preparation started [Online]: Newsletter 2 on standards for bioenergy in the Baltic Sea Area. March 2005. Nordisk Innovation Centre. [viewed: 2008-02-28] Available at: http://www.nordicinnovation.net/_img/newsletter2_final.pdf
2. Corona discharge [Online]: Sci-Tech Encyclopedia [viewed: 2008-02-28] Available at: http://www.answers.com/topic/corona-discharge#Positive_coronas
3. Blaze Labs EHD Thrusters Research [Online]: Blaze Labs Research [viewed: 2008-02-28] Available at: http://blazelabs.com/l-intro.asp
4. Peek's law [Online]: Wikipedia, the free encyclopaedia [viewed: 2008-02-28] Available at: http://en.wikipedia.org/wiki/Peek%27s_law