EVALUATION OF DRUM FEEDERS FOR BIOMASS DOSAGE

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Abstract. As the fossil fuel resources are decreasing, in future we will have to rely on renewable energy sources. The most significant part (74 %) of renewable energy sources has been planned for biomass energy in European Union. The main resources for solid biofuel in rural area of Latvia are wood, residues of cereal crops, peat and emergent vegetation in lakes as common reeds (Phragmites australis). Straw more than 340 000 t annually can be used for heat production. More than 230 million tons of peat is available for biofuel production which is also an important slowly renewable biomass fuel. For in-flow mixing of biomass components, accurate feeding is necessary. In this paper the problem of a steady and measured feeding of chopped biomass is analyzed. Dependence of dosage accuracy on angular velocity of drum feeder is stated for peat and chopped straw. The specific computerized data acquisition system for measuring dynamic mass flow and angular velocity of feeder was worked out. Load cell for flow measuring showed good repeatability in dependence on flow intensity therefore it could be used for flow measuring in automatic control systems.

Key words: drum feeder, dosage, biomass.

Introduction

As the fossil fuel resources are decreasing, in future we will have to rely on renewable energy sources. The main resources for solid biofuel in rural area of Latvia are wood, residues of cereal crops, peat and emergent vegetation in lakes as common reeds (Phragmites australis). Straw more than 340 000 t annually can be used for heat production. More than 230 million tons of peat is available for biofuel production which is also an important slowly renewable biomass fuel. Using blended peat and woody or herbaceous biomass, sulphur content of the fuel is increased and if the mixture is burned sulphates are formed instead of chlorides, and the risk of high temperature corrosion is avoided [1]. Peat also improves density and durability of stalk material briquettes (pellets).

Naturally herbaceous biomass is a material of low density (0.02–0.06 g cm^{-3}) and is not favorable for transportation over long distances. Those biomass properties cause necessity of biomass conditioning in shape of pellets or briquettes. Mobil briquetting equipment including dosage and mixing technique for trial version of stalk material and peat briquetting is recommendable. Therefore more applicable because of small dimensions by the side of discontinuous mixer is in-flow or continuous mixer.

For in-flow mixing, accurate feeding is necessary. Besides of this feeders for controlling the flow of bulk solids require certain criteria to be met:

- deliver the range of flow rates required;
- handle the range of particle or lump sizes and flow properties expected;
- deliver a stable flow rate for the given equipment setting. Permit the flow rate to be varied easily over the required range without affecting the performance of the bin or hopper from which it is feeding;
- feed material in the correct direction at the correct speed with the correct loading characteristics and under conditions which will produce minimum impact, wear and product degradation;
- fit into the available space [2].

It is important that the flow pattern be such that the whole outlet of the feed hopper is fully active. This is of fundamental importance in the case of mass-flow hoppers. To achieve this condition, special attention needs to be given to the design of the outlet as vertical skirts and control gates can often negate the effect of a tapered outlet. Gates should only be used as flow trimming devices and not as flow rate controllers. Flow rate control must be achieved by varying the speed of the feeder [2].

Mixing process is essentially influenced by quality of the continuous feed. The objective is to feed set quantities of material per unit of time in an uninterrupted product flow. Feeding can be performed volumetrically by feeder equipment which draws material by volume or gravimetrically by controlled feeding using weight or mass as the control value. Gravimetric feeding offers greater accuracy even over periods of hours or days (long term constancy) and is also suited to the feeding of materials with fluctuating bulk density or flow properties, such as cohesive powders and liquid additives with a variable viscosity.

Gravimetric feeding also enables the actual metered volume to be reported back for the purposes of recording, taking printouts and storing, as well as data transference to the process control, information management and alarm systems [3].

In this paper the problem of a steady and measured feeding of peat and straw is analyzed. Dependence of dosage accuracy on angular velocity of drum feeder is stated for peat and straw. The specific computerised data acquisition system for measuring dynamic mass flow and angular velocity of feeder was worked out.

Material and methods

Estimation of the volumetric throughput of a drum feeder was carried out in experimental equipment (Fig. 1). Experimental equipment consists of drum 1 coated with a special rubber coating 3 with knobs. Highness of the knobs is 6mm. Space between knobs defines throughput of feeder.

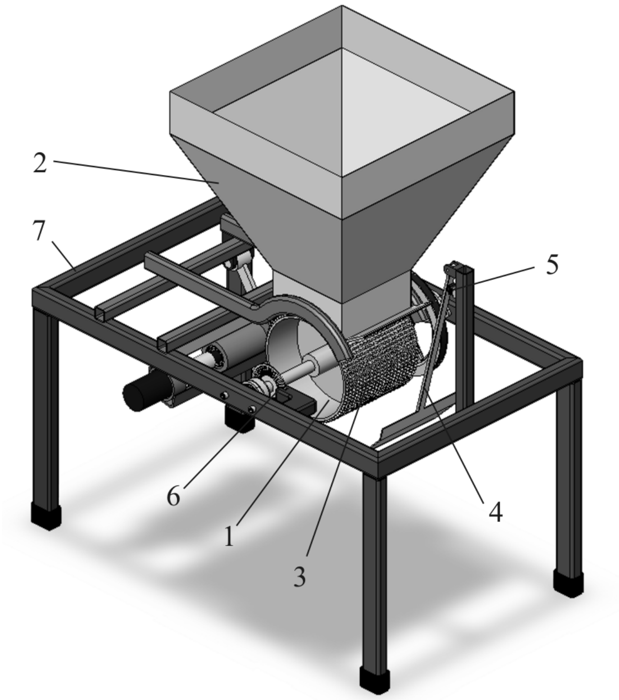

Fig. 1. **Experimental design of drum feeder:**
1 – drum, 2 – container, 3 – rubber coating, 4 – beam, 5 – force sensor,
6 – angular velocity sensor, 7 – frame

Rotation frequency of feeder drum was changed by hydraulic drive. The specific computerised data acquisition system for measuring dynamic mass flow and angular velocity of feeder was worked out. Mass flow measuring system consists of force sensor 5. Beam 4 equipped with plate acts to force sensor. Plate is located across mass flow in the certain angle. Such construction allows measuring mass flow as a function of reaction force.

The volumetric throughput of a drum feeder is given by:

$$Q = Q_t \eta_v \ (\text{m3} \cdot \text{s}^{-1}). \quad (1)$$

Theoretical volumetric throughput was calculated from geometrical proportions of the drum. Cylindrical surface of the drum was covered with rubber pins located according Fig. 2.

The theoretical volumetric throughput was calculated by equation (2):

$$Q_t = 0.3D \cdot b \cdot h \cdot \omega , \quad (2)$$

where: *Qt* –theoretical volumetric throughput, m3·s-1;
η_v – fullness efficiency;
D – diameter of the drum, m;
b – width of the drum, m;
h – thickness of mass layer, m;
ω – angular velocity of the drum, s^{-1}.

Thickness of the mass layer depends on the position of the plate, Fig. 2b.

The mass throughput of a drum feeder can be calculated from eq. (1) and (2):

$$Q_m = Q \cdot \rho = 0.3D \cdot b \cdot h \cdot \omega \cdot \eta_v \cdot \rho \, , \tag{3}$$

where *Qm* – mass throughput, kg·s-1;
ρ – mass density, kg·m3.

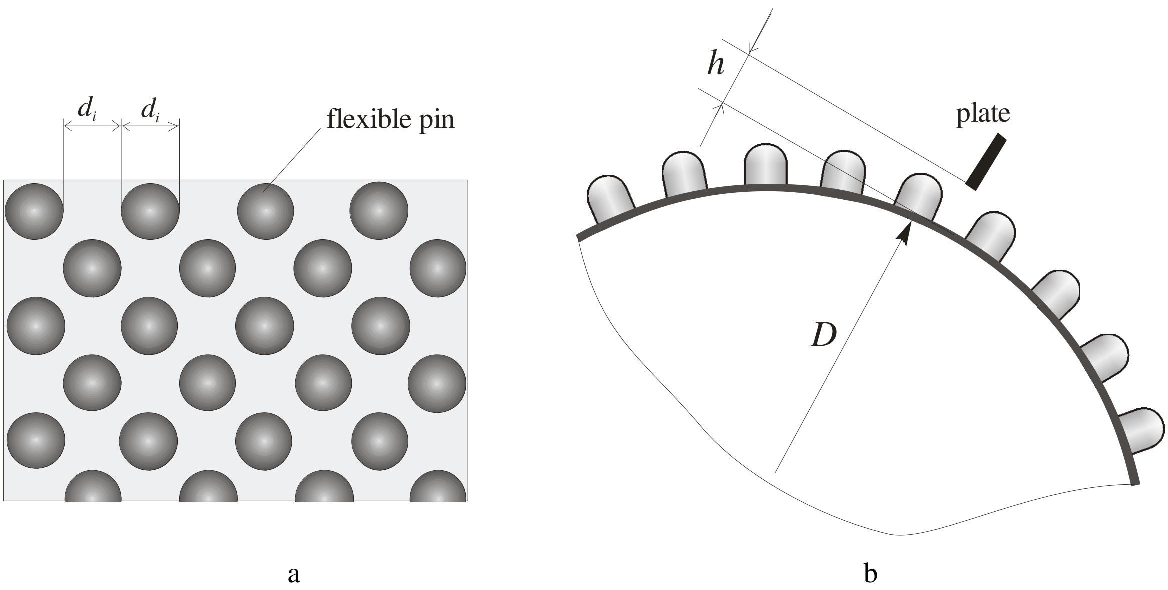

Fig. 2. **Position of the flexible pins on the drum:** a – top view, b – side view

The empirical standard deviation of the mass throughoutput can be used to define the feeding accuracy [2]:

$$S = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(m_i - \overline{m})^2} \, , \tag{4}$$

where S – standard deviation;
$\overline{m}$ – mass flow rate average value, kg s^{-1};
m_i – mass flow rate, kg s^{-1}.

Relative feed constancy [3]:

$$S_{rel} = \frac{|S|}{\overline{m}}100 \, . \tag{5}$$

To obtain parameters of drum feeder for chopped biomass experiments was carried out with two biomass – chopped straw and peat. Straw was grinded and separated by sieves in two groups depending on particles sizes. One group contains particles with size less than 3mm, another group contains particles with size from 3mm to 10mm. Moisture content of straw was ~12 %. Density of grinded straw groups was different. Density of straw group <3mm was ~100 kg m^{-3}, but density of straw group 3 – 10 mm was 70 kg m^{-3}.

Peat with moisture content less than 10 % was used for obtaining volumetric throughput of a drum feeder. Density of peat was 160 kg m^{-3}.

Results and discussion

Experiments were carried out to establish parameters of drum feeder for wheat straw and peat. The specific throughput per revolution of drum feeder depends on frequency and decreases by 0.01 kg rev^{-1} if rotation frequency increases from 0.25 to 3 s^{-1} (Fig. 3).

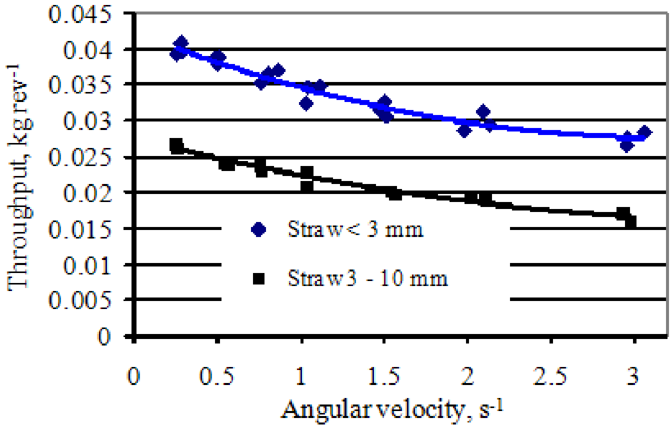

Fig. 3. **Specific throughput in dependence on frequency**

This tendency is similar for both groups of straw particles (< 3 mm and 3 to 10 mm). The specific throughput of larger straw particles by the same frequency is lower because of the densities of particles groups are different. The specific volumetric throughoutput for both fineness groups of straw is close by each another (Fig. 4).

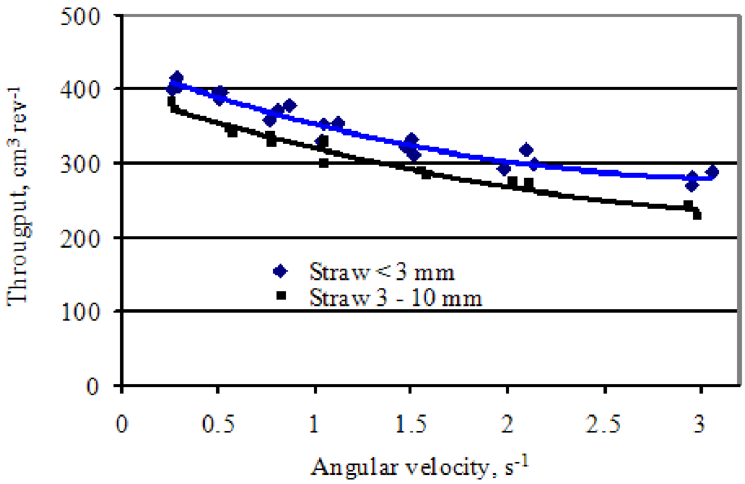

Fig. 4. **Specific throughput in dependence on frequency**

Difference between specific volumetric throughoutput at the same angular velocity for both straw groups differs only approx. 7 %. Volumetric throughoutput for straw with particle size 0 – 3 mm is greater than for straw with lager particles. The reason of this phenomena is filling degree of space between rubber knobs on the drum. Fine chopped straw particles fills drum rubberised space better than roughly chopped straw.

Increasing of rotational frequency occurs sharply emptying of bin and decreasing of vertical stress of mass on the feeder because the mass flow velocity is limited and it causes decreasing of specific throughput (Fig. 3 and 4).

The throughput of the drum feeder is increasing nearly linearly at rotation frequency from 0.25 to 3 s^{-1}. The throughput of the small particles (< 3 mm) in this frequency range grows from 0.01 to 0.08 kg s^{-1} but throughput for particles 3 to 10 mm grows from 0.01 to 0.05 kg s^{-1} (see Fig. 5).

Relative feed constancy calculated by equation (5) is in range from 3 to 11 %. The feed intensity is influenced by particles size, particles orientation and other bulk properties and also by changing vertical stress of the mass.

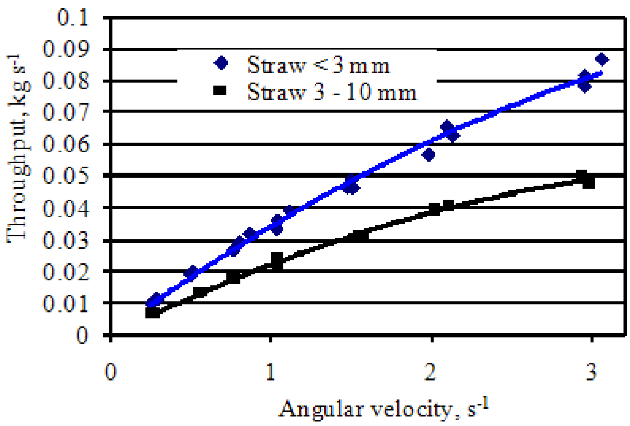

Fig.5. **Throughput of drum feeder**

The mass flow rate of feeder was measured using reflection plate equipped with the force sensor. Force sensor for flow measuring showed good repeatability in dependence on flow intensity (Fig. 6) therefore it could be used for flow control in automatic control systems.

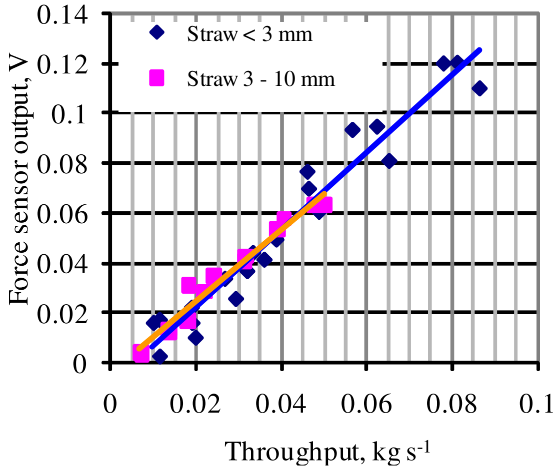

Fig.6. **Force sensor output voltage vs. mass throughput**

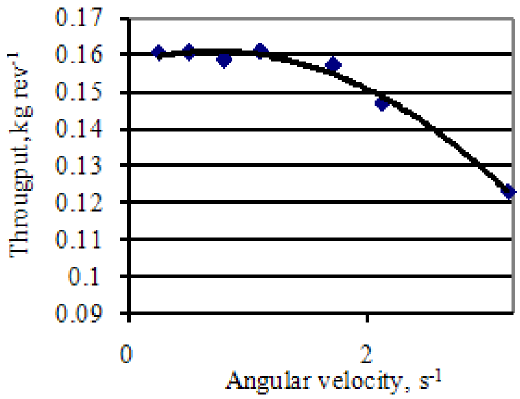

Fig.7. **Specific throughput of drum feeder for peat**

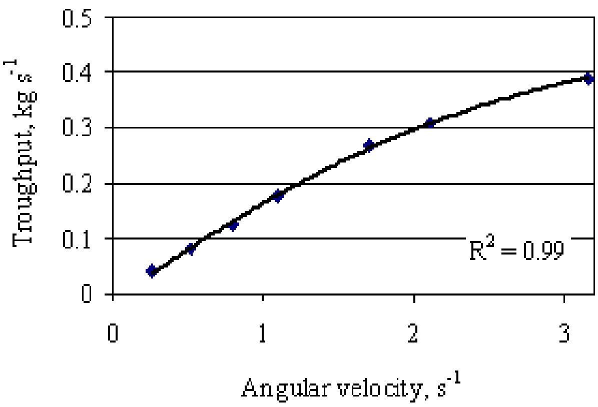

Fig. 8. **Mass throughput of drum feeder for peat**

The specific throughput of drum feeder for peat is greater than specific throughput for straw (Fig. 7). At low angular velocities of drum ~0.2 s^{-1} specific throughput for peat reaches value 0.16 kg rev^{-1} and it is 4 times lesser than for fine chopped straw. Increasing of angular velocity till 3 s^{-1} leads to decreasing of specific throughput till 0.125 kg rev^{-1}. The tendency of specific throughput is parabolic depending on angular velocity.

Mass throughput of drum feeder for peat increases depending on rotational frequency and reaches value 0.4 kg s^{-1} at the angular velocity 3.2 s^{-1}. It is 5 times greater than mass throughput for fine chopped straw (Fig. 8).

The difference of throughputs can be explained with greater mass density (for peat) and more suitable particle shape (peat) for filling of drum rubberised space.

Conclusions

1. The specific throughput of a drum feeder is dependent on rotation frequency and reaches value 0.04 kg rev^{-1} for fine chopped straw and 0.16 kg rev^{-1} for peat at the angular velocity 0.2 s^{-1}.
2. The specific volumetric throughput difference between fine chopped straw and roughly chopped straw is 7 %.
3. Force sensor for flow measuring showed good repeatability in dependence on flow intensity therefore it could be used for flow control in automatic regulation systems.

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