ROTARY SPOOL FEEDER FOR BIOMASS DOSAGE

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Abstract. Relevant resources for renewable biomass fuel production are wood, cereal straw residues, and emergent vegetation from wetlands. Peat 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. For in-flow mixing, 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 rotary spool feeder is stated for peat. The specific computerised 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 control in automatic regulation systems. The throughput of a spools' feeder is dependent on rotation frequency and rotation direction of spools. The throughput difference between rotation directions 1 and 2 is approximately 3 times at frequency 8 s^{-1}.

Key words: spool feeder, dosage, peat.

Introduction

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 austral-lis). Straw more than 340 000 t annually can be used for heat production. More than 230 million tons of peat are 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 favourable 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 is analyzed. Dependence of dosage accuracy on angular velocity of rotary spools' feeder is stated for peat. 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 spools' feeder was carried out in experimental equipment. A feeder with radial located spools 1 on rotary body 2 was built (Fig. 1, Patent pending: P-07-25 (26.02.2007.)). Feeder was equipped with spools' drive 3. Direction of spools 1 rotation was changed with location of spools' drive: on the top side or beneath of feeder body. Diameter of feeder body 2 was 140 mm. Three spools with efficient volume 37.5 cm^3 were located on radial rotary axes. Rotation frequency of feeder was adjustable.

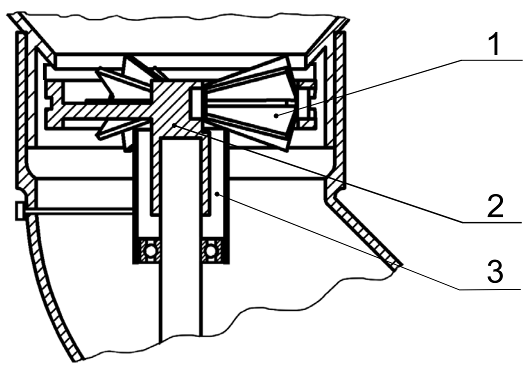

Fig. 1. **The feeder with radial located spools**:
1 – spool; 2 – feeder body; 3 – spools' drive

Rotation frequency of spools changed in accordance with rotation frequency of feeder body. Rotation frequency of feeder body was changed by hydraulic drive. The specific computerised data acquisition system for measuring dynamic mass flow and angular velocity of feeder was worked out. Peat with moisture content less than 10% was used for obtaining volumetric throughput of a spools' feeder. Density of peat was 160 kg m^{-3}.

The volumetric throughput of a spools' feeder is given by:

$$Q = Q_t \eta_v \ (\mathrm{m^3\ s^{-1}}), \tag{1}$$

$$Q_t = Vnk\omega , \tag{2}$$

where Q_t – maximum theoretical volumetric throughput with feeder running 100% full;
η_V – fullness efficiency;
V – spool efficient volume, m^3;
n – number of spools,
k – number of spool revolutions per one revolution of feeder body;
ω – angular velocity of feeder body, s^{-1};

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

$$S = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(m_i - \overline{m})^2} \tag{3}$$

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

Relative feed constancy [3]:

$$S_{rel} = \frac{|S|}{\overline{m}}100 \tag{4}$$

Results and discussion

The throughput of a spools' feeder (Fig. 2) is dependent on rotation frequency and rotation direction of spools (location of spools' drive: on the top side or beneath of feeder body). As the rotational speed of the feeder increases, the fullness efficiency decreases (Fig. 5) and difference from theoretical line significant increases (Fig. 2).

If spools' drive is located beneath of feeder body, rotation direction of spools is opposed to rotation direction of spools' body (rotation direction 1) – bulk material is griped by wall of spool sector. By change of spools' drive location from bottom to top, rotation direction of spools synchronizes with rotation direction of feeder body (rotation direction 2) – spools are rolling on the bulk material surface. Throughput of the feeder vs. revolution is higher in first case (Fig. 3), because bulk material lying on the feeder body and spools is creating additional pressure in direction of loading. If spools are rolling in direction 2, bulk material pressure influences loading in vertical direction but when spool continues rolling by influence of centrifugal forces bulk material is thrown away from spools' sectors.

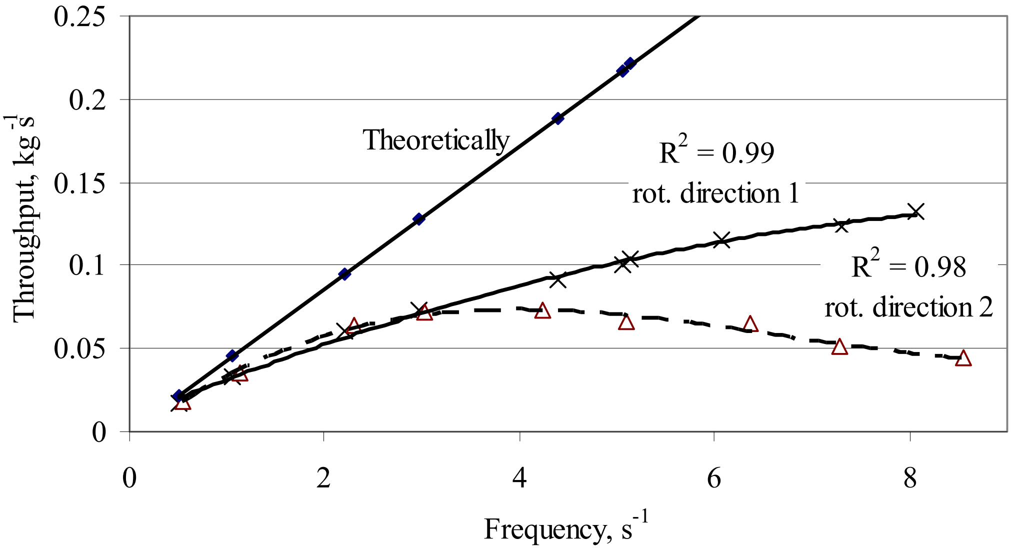

Fig. 2. **Throughput of rotary spools feeder in dependence on frequency**

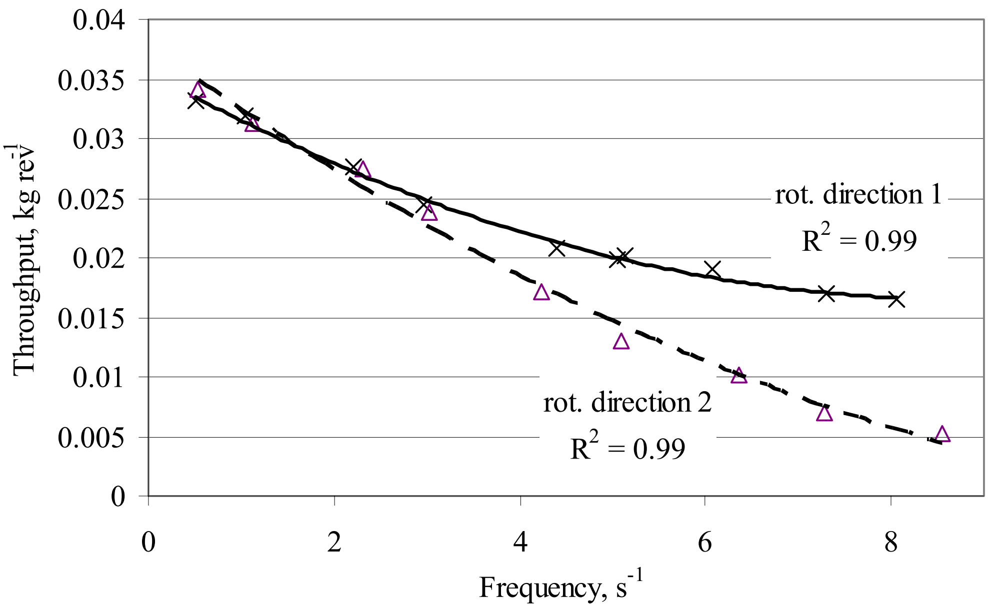

Fig. 3. **Throughput of the spools feeder vs. rotation frequency**

The throughput difference between rotation directions 1 and 2 is approximately 3 times at frequency 8 s^{-1} (Fig. 2). There is no difference in throughput from 0.5 to 3 s^{-1}. If it is sufficiently with feeding frequency 3 s^{-1} then more recommendable is second rotation direction because it takes less energy for dosage.

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. 4) therefore it could be used for flow control in automatic regulation systems.

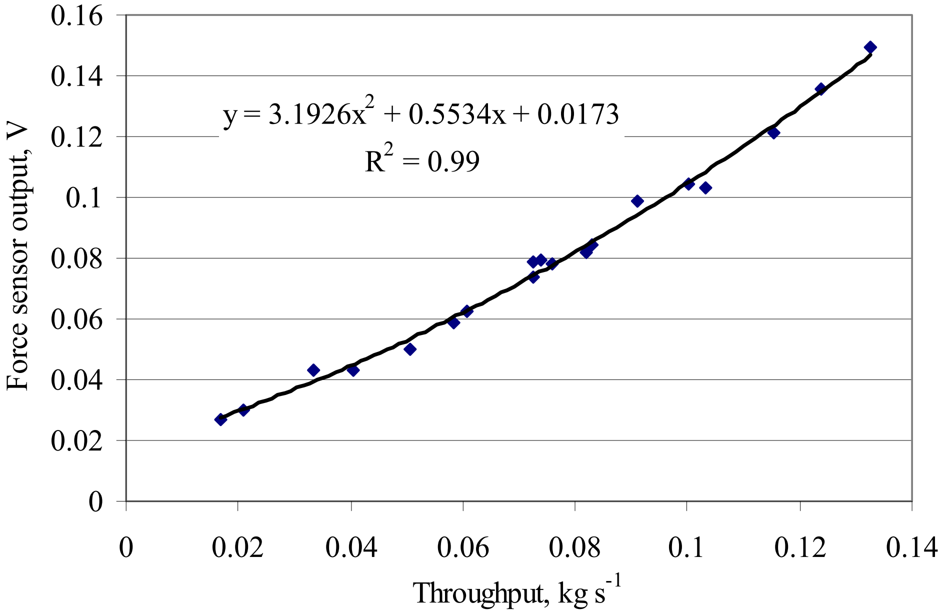

Fig. 4. **Force sensor output voltage vs. mass throughput**

Fullness efficiency decreases from 0.8 to 0.4 (rotation direction 1) and from 0.8 to 0.1 (rotation direction 2) if rotation frequency increases from 0.5 to 8 rev s^{-1} (Fig. 5). As we can see in Fig. 5 fullness efficiency is less than 0.5 at rotation frequency 4 s^{-1} therefore for higher feeding throughputs necessary to increase feeder dimensions.

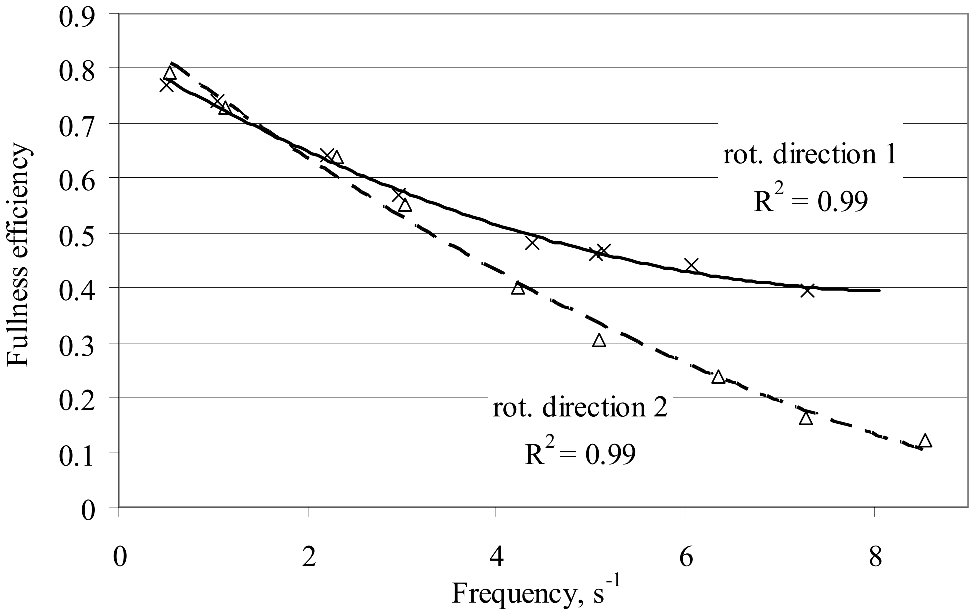

Fig. 5. **Fullness efficiency in dependence on frequency**

Relative feed constancy calculated by equation (4) is less then 5%. The feed accuracy influences the continuous mixer's design and size. A small, compact mixer with low residence time and limited axial mixing requires a high degree of feed accuracy even over long periods of time [3].

Conclusions

1. The throughput of a spools' feeder is dependent on rotation frequency and rotation direction of spools (location of spools' drive: on the top side or beneath of feeder body).
2. The throughput difference between rotation directions 1 and 2 is approximately 3 times at frequency 8 s^{-1}. There is no difference in throughput from 0.5 to 3 s^{-1}.
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.
4. Fullness efficiency decreases from 0.8 to 0.4 (rotation direction 1) and from 0.8 to 0.1 (rotation direction 2) if rotation frequency increases from 0.5 to 8 rev s^{-1}.
5. Fullness efficiency is less than 0.5 at rotation frequency 4 s^{-1} therefore for higher feeding throughputs necessary to increase feeder dimensions.

Acknowledgements. The authors gratefully acknowledge the funding from European Union (ESF Postgraduate Study grand PD15) and Latvia Board of Science (grand 05.1598).

References

1. Quality guidelines for fuel peat – preparation started. Newsletter 2 on standards for bioenergy in the Baltic Sea Area. http://www.cbss.st/basrec/documents/bioenergy/dbaFile8466.pdf. – 06.02.06.
2. A.W. Roberts. Design and application of feeders for the controlled loading of bulk solids onto conveyor belts. http://www.saimh.co.za/beltcon/Beltkon2paper27.html – 09.02.06.
3. R. Weinekötter, H. Gericke. Mixing of solids. Dordrecht: Kluwer Academic Publisher. 2000. 151 pp.